Isokinetics and Exercise Science 19 (2011) 23–32
DOI 10.3233/IES-2011-0392
IOS Press

Isokinetic norms for ankle, knee, shoulder and forearm muscles in young South African men

Leon Lategan
Department of Sport and Movement Studies, Faculty of Health Sciences, University of Johannesburg, PO Box 524, Auckland Park, Johannesburg 2006, South Africa
Tel.: +27 11 5592748; Fax: +27 11 559 2671; E-mail: leonl@uj.ac.za

Abstract. *Background and objectives*: Isokinetic test results are often evaluated against a norm or normal value. Previous research on isokinetics is prolific however, different populations present with different "normal" values. Thus, the aim of the present study was to establish isokinetic norms for the ankle, knee, shoulder, elbow and forearm joints in young, South African men.

Methods: Four hundred and thirty eight (N = 438) young male participants (19.06 ± 1.86 yrs) were evaluated in terms of isokinetic peak torque of the ankle, knee, shoulder and forearm. A Cybex 340 isokinetic dynamometer was used to evaluate their concentric peak torque at a low velocity (30 or 60°/s); gravity was not corrected for. The data was tested for normality and the descriptive statistics were calculated. Percentile scores were subsequently constructed.

Results: Normative values for peak torque, peak torque per body mass and agonist-antagonist ratios were constructed for the ankle, knee, shoulder and forearm.

Conclusions: Results from this study might provide useful norms for the clinical evaluation of low-velocity, concentric peak torque in young males, when gravity correction is not performed.

Keywords: Isokinetic, norms, peak torque, muscle strength, ankle, knee, shoulder, forearm

1. Introduction

Isokinetic testing is currently widely used in sports performance and orthopaedic rehabilitation. Accurate feedback by practitioners is dependent on adequate academic and practical training as well as on the availability of applicable norms. Isokinetic test results are often evaluated against a norm or "normal" value [7,14,37]. Earlier work done by Perrin and co-workers [38] has indicated that the assumption of bilateral equivalency as a goal of therapeutic exercise may be inappropriate for some muscle groups and in some populations and this opinion is supported by other researchers [20]. Practitioners continue to utilise the uninvolved side for comparison to the involved side when making clinical decisions, however, normative comparison may be useful especially in the weight-bearing joints or in bilateral involvement, and for screening purposes in athletes or manual workers [40,45].

Several researchers have investigated the isokinetic strength in specific joints in a number of different populations, but few have generated normative values for several joints or movement patterns in the same population.

Another complicating factor in establishing norms is the wide variety of movement velocities (0–500°/s) available to clinicians [12] and the fact that most modern isokinetic dynamometers allow for both concentric and eccentric muscle testing and thus necessitate specific norms for each of these muscle actions [11, 29]. Age, gender, activity level and even nationality may play a significant role in interpreting an isokinetic evaluation, with older participants, women and sedentary individuals demonstrating significantly lower values compared to athletes [10,12,28]. In addition, isokinetic results are affected by the correction or not for the effects of gravity. Currently, gravity correction is being widely used in clinical practice however, espe-

ISSN 0959-3020/11/$27.50

cially when bilateral comparisons are done it is advised that gravity correction should not be done to rule out methodological errors as well as avoiding errors due to the inability of subjects to completely relax [5]. Lastly, several studies have highlighted the significant effect of the specific dynamometer used for analysis, since different dynamometers will often give inconsistent results [20,31,43].

Norms or reference values refers the word "normal" [23,38], however, what is normal for one population may not necessarily be normal for another. Several authors have in the past investigated normal values for different joints [15,16,23,35,42]. In the context of physical properties like isokinetic torque, a norm denotes the average or mean value of a large group of individuals (usually > 200) tested under similar and controlled circumstances [11,16,25]. Normative isokinetic data relating to the knee joint is by far the most prolific, while some data on the other joints are also available [7,12,16,38,39]. However, very few studies have focussed on establishing isokinetic norms for several joints in one specific group of people and thus, the aim of the present study was to address this aspect in a specific cohort.

Values for concentric knee flexion and extension have been reported by various researchers on a variety of populations. Using a testing velocity of 60°/s, mean relative peak torque values for knee flexion ranged between 1.29 and 1.9 Nm/kg and between 2.28 and 3.38 Nm/kg for knee extension. The hamstrings-quadriceps (H/Q) or knee flexion-extension ratio was reported to range between 54% and 71% [16,33,48]. Freedson and co-workers [16] who conducted isokinetic testing on more than 1 500 men (between 21 and 30 yrs), reported a non-gravity corrected (NGC) H/Q ratio of 65% at 30°/s. They also reported a mean weight-adjusted value of 1.63 Nm/kg for knee flexion and 2.55 Nm/kg for knee extension in the same sample. Wyatt and Edwards [48] also investigated isokinetic strength in men (average age: 29 yrs) and reported a concentric knee flexion value of 130 Nm (1.68 Nm/kg), a knee extension value of 183 Nm (2.36 Nm/kg) and an H/Q ratio of 71% (NGC). Some of the lowest values were reported by Neder and co-workers [33] whose sample included a randomised group of 45 men between the ages of 20 and 80 years (49.8 ± 18.1 yrs). They reported gravity corrected (GC) mean values of 172.1 Nm (2.28 Nm/kg) for knee extension and 97.1 Nm (1.29 Nm/kg) for flexion, with an H/Q ratio of 57.4%, using an angular velocity of 60°/s. The lower values by Neder and co-workers could be attributed to the fact that their sample was considerably older than the others.

Athletic populations have also been investigated. Schlinkman [41] utilised 342 male high school football players, between the ages of 15 and 17, to construct norms (GC) for knee flexion and extension at 60, 240 and 300°/s. He reported a knee flexion value of 128 Nm (1.8 Nm/kg), a knee extension value of 235 Nm (3.38 Nm/kg), and an H/Q ratio of 54% at 60°/s. Previously, the present author reported a GC H/Q ratio of 63% in 46 South African (SA) provincial male rugby players, at a velocity of 60°/s [28]. The same study yielded values of 187 Nm (1.9 Nm/kg) and 298 Nm (3.04 Nm/kg) for knee flexion and extension respectively. A GC H/Q ratio of 54% (at 60°/s) was also previously reported in young SA males [26,29]. In terms of weight-adjusted torque, the present author previously reported GC values of 1.64 Nm/kg for knee flexion and 3.03 Nm/kg for knee extension [29], while Kruger and co-workers [25] reported GC values of 1.83 and 3.38 Nm/kg for knee flexion and extension, respectively. Thus, NGC isokinetic norms in SA men are still largely lacking.

Relatively little research have been conducted on large numbers of participants for the different shoulder joint movements, thus norms for the shoulder at 60°/s is limited. Ivey and co-workers [23] reported a shoulder flexion/extension ratio of 78%, at 60°/s, an abduction/adduction ratio of 63%, and an external/internal shoulder rotation ratio of 65%, in 18 men (average age: 27 yrs) (NGC). Connelly Maddux and co-workers [9] found an external/internal shoulder rotation ratio of 63% (using the 90°-abducted position) and a value of 66% for shoulder abduction/adduction at 60°/s, in the dominant arm of males aged on average 34 years (NGC). Shoulder flexion and extension peak torque was investigated by Freedson and co-workers [16] using a velocity of 60°/s. They tested 1 647 men between the ages of 21 and 30 years and reported values of 62 Nm (0.77 Nm/kg) and 99 Nm (1.22 Nm/kg) for flexion and extension, respectively and a flexion/extension ratio of 63% (NGC). In terms of athletes, several researchers have investigated shoulder function. Brown and co-workers [4] tested 41 professional baseball players and when the dominant shoulder's data for pitchers and position players were grouped, the following results were found. Shoulder flexion and extension values were 77 and 164 Nm, respectively, while horizontal abduction was 54 Nm and horizontal adduction, 128 Nm. Internal and external shoulder rotation (at 90° of abduction) were 137 and 84 Nm, respectively, with an external/internal ratio of 61% for the dominant arm and 74% for the non-dominant arm. Their findings are largely similar to those of Huang and co-workers [22] who reported an external/internal ratio of between 71 and 77% in 80 baseball pitchers aged between 10 and 23 years. Thus, normative studies on the shoulder joint have been conducted, but not in SA.

Reference values for forearm pronation and supination in men, is largely absent from literature, especially for the non-athletic population, at 60°/s. Forthomme and co-workers [15] tested 20 young men (23y; 75 kg) and reported a forearm pronation/supination ratio of 133% in the non-dominant side, at an angular velocity of 30°/s.

The ankle joint is normally evaluated for plantar and dorsiflexion in one of two ways: either with the knee fully extended or with the knee flexed to approximately 90°. The fully extended position allows for both the gastrocnemius and soleus muscle groups to contribute to plantar flexion, while the bent knee position, reduces the contribution of the gastrocnemius muscle to plantar flexion [24]. Previous values for ankle dorsiflexion torque at 30°/s, have varied between 30 and 35 Nm (0.34–0.47 Nm/kg) and between 70 and 184 Nm (1.02–2.45 Nm/kg) for plantar flexion [18, 27]. Kruger and co-workers [27] evaluated the dominant leg's ankle plantar and dorsiflexion torque in 306 SA men (avg. age: 26 yrs) at 30°/s, using the flexed knee position. They reported values of 30 Nm (0.34 Nm/kg) and 70 Nm (1.02 Nm) for dorsiflexion and plantar flexion, respectively and a dorsiflexion/plantar flexion ratio of 43% was reported. Fugl-Meyer [18], using the straight knee position and a testing velocity of 30°/s, reported on 15 athletes and 15 sedentary controls and found dorsiflexion values of 35 Nm (0.47 Nm/kg) and 33 Nm (0.44 Nm/kg), respectively for these two groups. Their plantar flexion values varied between 184 Nm (2.45 Nm/kg) for the athletes and 126 Nm (1.8 Nm/kg) for the sedentary participants, while the respective dorsiflexion/plantar flexion ratios, were 19% (athletes) and 26% (sedentary controls). Fugl-Meyer and co-workers [17] also tested three groups of 15 participants each (40–44, 50–54 and 60–64 yrs) at three different movement velocities (30, 60 and 180°/s). At 30°/s, plantar flexion strength varied between 171 Nm for the younger group and 139 Nm for the oldest group. Poulmedis [39] investigated isokinetic strength at 30°/s in elite male Greek soccer players and found values of 32 Nm and 120 Nm for ankle dorsiflexion and plantar flexion, respectively.

Previous research on isokinetics is prolific however, different populations present with different "normal" values. The dilemma with using norms is the transferability of data from one population to the other; data obtained for Japanese people may not be valid for Germans and vice versa. The limited amount of published data on isokinetic norms for the South African population, prompted the author to investigate the isokinetic peak torque values for five different joints in this population. Thus, the aim of the present study was to establish isokinetic norms for the ankle, knee, shoulder and forearm joints in young, South African men.

2. Methods

An empirical, investigative and reductive research design that utilised quantitative data was adopted. The present study was carried out over a period of three years and the same researcher conducted all the tests.

2.1. Participants

Four hundred and thirty eight (438) participants were recruited from men between the ages of 16 and 29 years (19.06 ± 1.86 yrs), who applied to become pilots in the South African National Defence Force. Three hundred and ninety seven (90.6%) were of European descent, while 41 participants (9.4%) were of African descent.

Participants were medically screened by a medical doctor before participating in any tests and they all provided the researcher with written informed consent. The project was approved by the Ethics Review Committee of 1 Military Hospital (SA Medical Services) and the SA Air Force's Institute for Aviation Medicine. Standard anthropometrical measures were obtained and six skinfolds were measured using the Hapenden skinfold calliper. Percentage body fat was calculated from the six skinfolds by utilising the MOGAP method [6].

2.2. Isokinetic testing protocol

Participants warmed up prior to the isokinetic testing by jogging slowly for five minutes on a grass surface and performing gentle stretches (2×30 seconds) of the major muscle groups (hamstrings, quadriceps, calves, and shoulder muscles). Five familiarization contractions were also performed prior to each movement pattern tested.

Isokinetic testing was performed using a Cybex 340 isokinetic dynamometer (Cybex, A division of Lumex, Inc., 2100 Smithtown Avenue, Ronkonkoma, New York). The reliability of isokinetic dynamometry has previously been established by different authors [21, 30,35,44] Calibration was performed before each day

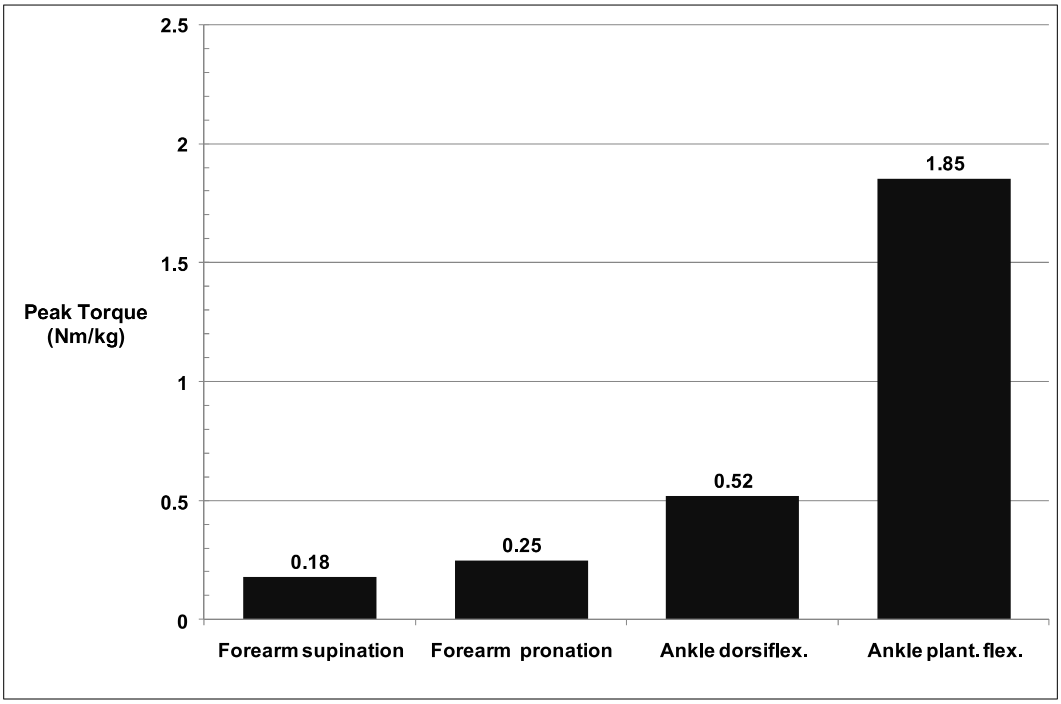

Fig. 1. Peak torque (Nm/kg) values at 30°/s for the forearm and ankle.

Table 1
Participants' anthropometric characteristics

	Mean	Min	Max	STD	N
Age (yrs)	19.1	17	24	1.86	438
Body mass (kg)	71.5	46	95	8.72	438
Height (m)	1.786	1.6	1.92	5.55	438
Body fat (%)	9.90	5.6	22.3	3.04	438
Fat mass (kg)	7.23	3.0	19.8	2.91	438
Lean mass (kg)	64.3	42.9	85.8	6.86	438

of testing. The following movement patterns were performed: prone ankle plantar and dorsiflexion (hip and knee extended), seated knee flexion and extension, supine shoulder flexion and extension, supine shoulder horizontal abduction and adduction (90°-pronated grip), supine shoulder medial and lateral rotation (in 90° of shoulder abduction) and seated forearm pronation and supination (at an elbow flexion angle of 90°). The movement velocity was set at 60°/s for the knee and shoulder, but at 30°/s for the ankle and forearm. Participants were positioned according to the standardized procedure described by Perrin [37]. Low isokinetic velocities were selected as higher velocities may introduce the problem of very short isokinetic sectors [3, 12].

Five familiarization repetitions (reps) at increasing effort levels (2 reps at 50% of effort, 2 reps at 75% and one maximal repetition) preceded the five maximal concentric contractions performed for each movement pattern. The non-dominant side was used and each test was followed by at least a 5-minute rest period before the next movement pattern was tested. No correction was made for the effects of gravity (NGC) to exclude any calculation errors (some participants may find it difficult to relax completely during the weighing of their limbs). Participants were verbally encouraged during each test to perform at their best and participants were also allowed visual feedback during the testing [7, 12].

Peak torque in Newton-metres (Nm) was recorded as the highest of the five repetitions. The peak torque relative to body mass (Nm/kg) and the agonist-antagonist ratio (%) were calculated for each movement pattern.

2.3. *Data analysis*

Statistics were performed on the data by a qualified statistician using Statistical Package for Social Sciences (SPSS) software. Firstly, the data was tested for normality, kurtosis and skewness, but a discussion of these aspects will not form part of the present study. Secondly, the descriptive statistics were calculated (e.g. mean, minimum, maximum and standard deviation). Percentile scores were subsequently con-

Table 2
Peak torques and ratios for the ankle and forearm (30°/s and NGC)

Movement pattern	Mean	Min	Max	STD	Percentiles			N
					P25	P50	P75	
Ankle dorsiflexion (Nm)	36.2	17.0	55.0	6.39	32.0	36.0	40.0	214
Ankle dorsiflexion (Nm/kg)	0.52	0.22	0.75	0.085	0.46	0.50	0.58	214
Ankle plantar flexion (Nm)	130.0	57.0	197.0	26.32	111.0	129.0	148.0	214
Ankle plantar flexion (Nm/kg)	1.85	0.61	2.80	0.34	1.63	1.87	2.03	214
Ankle dorsiflexion/plantar flexion (%)	28.9	14.8	80.7	8.23	23.4	28.2	32.5	214
Forearm supination (Nm)	13.0	8	23	2.6	12.0	13.0	14.0	199
Forearm supination (Nm/kg)	0.18	0.11	0.26	0.03	0.16	0.18	0.20	199
Forearm pronation (Nm)	18.0	9	31	3.7	16.0	17.0	20.0	199
Forearm pronation (Nm/kg)	0.25	0.11	0.47	0.05	0.21	0.25	0.28	199
Forearm supination/pronation (%)	73.8	47.6	121.4	2.24	62.5	71.4	83.3	199

Table 3
Peak torques and ratios for the knee and shoulder (60°/s and NGC)

Movement pattern	Mean	Min	Max	STD	Percentiles			N
					P25	P50	P75	
Knee flexion (Nm)	158.5	91	256	26.1	140.0	157.0	175.0	438
Knee flexion (Nm/kg)	2.23	1.44	3.21	0.29	2.02	2.22	2.42	438
Knee extension (Nm)	235.9	137	358	34.4	213.8	234.0	256.0	438
Knee extension (Nm/kg)	3.31	2.27	4.28	0.36	3.07	3.30	3.56	438
Knee flexion/extension (%)	67.6	44.6	103.7	8.80	61.2	67.2	72.6	438
Shoulder horizontal abduction (Nm)	93.4	50	210	27.1	77.0	88.0	108.0	103
Shoulder horizontal abduction (Nm/kg)	1.32	0.72	2.66	0.35	1.09	1.26	1.48	103
Shoulder horizontal adduction (Nm)	91.8	40	184	23.5	74.0	88.0	107.0	103
Shoulder horizontal adduction (Nm/kg)	1.30	0.73	2.61	0.28	1.11	1.26	1.46	103
Shoulder horizontal ab-/adduction (%)	101.3	53.4	186.0	21.9	88.5	100.0	111.0	103
Shoulder flexion (Nm)	80.5	44	137	19.0	65.0	77.5	92.8	116
Shoulder flexion (Nm/kg)	1.14	0.79	1.91	0.22	0.97	1.13	1.26	116
Shoulder extension (Nm)	87.2	40	138	19.8	72.3	85.0	100.0	116
Shoulder extension (Nm/kg)	1.23	0.53	1.82	0.21	1.09	1.20	1.36	116
Shoulder flexion/extension (%)	93.9	59.0	230.0	20.0	80.6	93.1	101.4	116
Shoulder lateral rotation (Nm)	39.3	20	80	9.3	33.0	39.0	44.0	239
Shoulder lateral rotation (Nm/kg)	0.56	0.34	0.85	0.11	0.49	0.55	0.62	239
Shoulder medial rotation (Nm)	50.6	27	88	12.7	40.0	50.0	59.0	239
Shoulder medial rotation (Nm/kg)	0.72	0.40	1.14	0.15	0.61	0.72	0.82	239
Shoulder lateral/medial rotation (%)	79.6	48.9	187.9	18.1	68.4	77.1	87.0	239

structed for peak torque values (Nm and Nm/kg). For the present study, the 25th, 50th and 75th percentiles will be presented for each movement pattern.

3. Results

The means, minimums, maximums and standard deviations for the participants' age, body mass, height, percentage body fat, fat mass and lean mass, are presented in Table 1. From their anthropometric values the present study's participants could be classified as young, physically active and lean (i.e. they had a percentage body fat of 9.9%). The mean percentage body fat for the general population varies between 12.5 and 16% [1,31,42], while swimmers and triathletes typically display body fat percentages that range between 7 and 10% [34].

Since the present study was carried out over a period of three years, not all participants completed all movement patterns that formed part of the study. Thus, the number of subjects that completed each movement pattern is given in Tables 2 and 3.

Table 2 contains the peak torque values (Nm and Nm/kg) for the ankle and forearm at a movement velocity of 30°/s, while the peak torque values for the knee and shoulder (at 60°/s) are presented in Table 3. In addition, both Tables 2 and 3 contain the agonist-antagonist ratio (%) and the 25th, 50th and 75th percentile scores (in Nm/kg) for each movement pattern.

At a velocity of 30°/s, forearm supination yielded the lowest relative peak torque value (0.18 Nm/kg), while

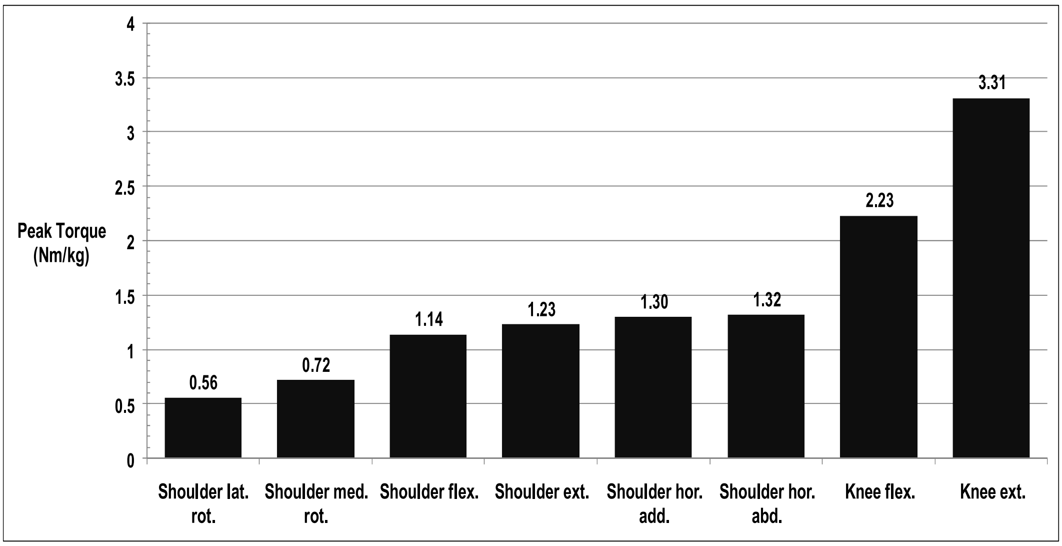

Fig. 2. Peak torque (Nm/kg) values at 60°/s for the knee and shoulder.

the highest value (1.87 Nm/kg) was observed for ankle plantar flexion (Fig. 1). The lowest relative peak torque value at 60°/s was reported for shoulder lateral rotation (0.56 Nm/kg) and the highest value obtained was for knee extension (3.31 Nm/kg) (Fig. 2).

The 30°/s velocity yielded an agonist-antagonist ratio of 28.9% for ankle dorsi-plantar flexion and 73.8% for forearm supination-pronation. Agonist-antagonist ratios at 60°/s ranged between 67.6% for knee flexion-extension and 101.3% for shoulder horizontal abduction/adduction (Fig. 3).

4. Discussion

In discussing the results of the present study, a conscious effort has been made to compare the data to that of other research studies that also aimed to establish norms for certain movement patters in healthy, non-athletic males. However, only a few studies that included a sufficient number of participants were found and thus the results of the present study were compared to those derived from smaller studies in a variety of populations. For the present discussion, only torque values at low angular velocities, ($\leqslant$ 90°/s), were considered and compared to that of the present study, since higher velocities may result in very short isokinetic sectors [3, 12].

Limitations of the present study included not randomising the population sample (representation), not being able to test every participant for all the movement patterns, not including females (gender) and all race groups (representation) in the study and not being able to spread the tests over more than one day (possibility of fatigue). Delimitations included not testing more joints or movement patterns, not including multiple angular velocities in the study and not performing eccentric testing. As a result of not performing eccentric testing, the author was unable to consider the dynamic control ratio (DCR) [10] or functional ratio (eccentric knee flexion vs. concentric knee extension) that has gained significant popularity in injury prevention and rehabilitation targets 12].

As far as ankle plantar and dorsiflexion is concerned, the results of the present study show slightly higher dorsiflexion values (0.52 Nm/kg) compared to previous studies (0.34–0.47 Nm/kg) [17,19,27,39]. The mean plantar flexion torque however, is similar to that reported by Fugl-Meyer in 1981 (1.87 vs. 1.8 Nm/kg) for sedentary participants [17], higher than the 1.02 Nm/kg reported by Kruger and co-workers [27], but lower than the 2.45 Nm/kg reported for athletes [18]. Both plantar and dorsiflexion values in the present study were slightly higher than those reported by Poulmedis for Greek soccer players [39]. The dorsiflexion-plantar flexion ratio of the present study (29%) is lower than the 43% reported by Kruger and co-workers [27], similar to the sedentary participants (26%) and higher than the athletes (19%) tested by Fugl-Meyer [18]. It also compares well with the value of 27% reported for Greek soccer players [39]. Thus, the present study's values are similar to previous findings, but the ankle dorsi-

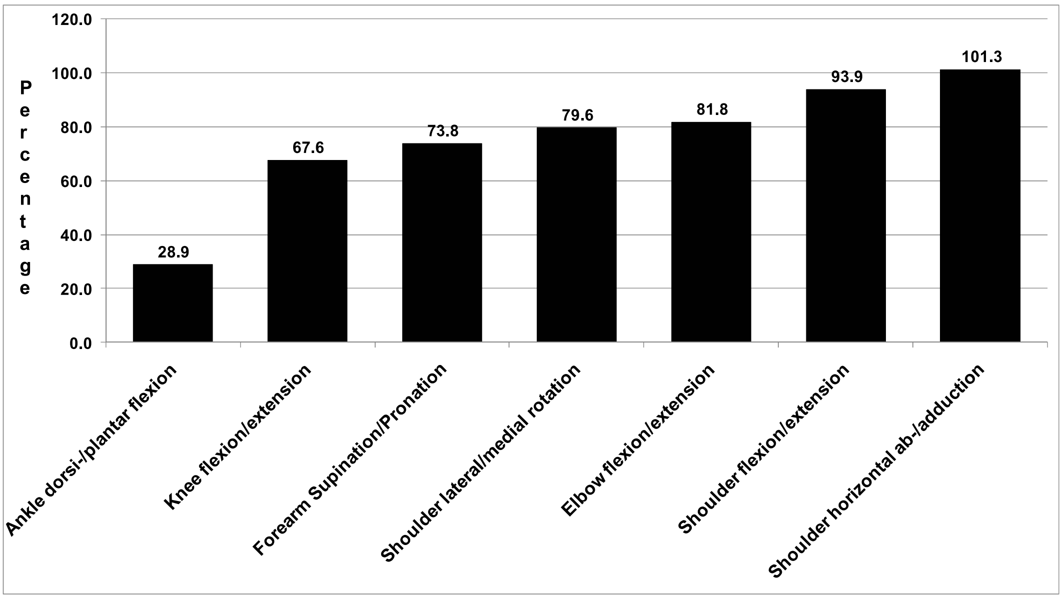

Fig. 3. Agonist-antagonist ratios (%) for the ankle and forearm (30°/s) and the knee and shoulder (60°/s).

flexion values were higher compared to previous data obtained from non-athletes.

The present study's mean torque values for knee flexion and extension are also high compared to previous research data. Mean knee flexion (158.5 Nm; 2.23 Nm/kg) is higher compared to previous studies, for both sedentary and athletic participants (1.63–1.9 Nm/kg), probably due to the fact that the present study did not correct for the effects of gravity. Notwithstanding this, the mean knee extension value (235.9 Nm; 3.31 Nm/kg) is similar to the upper range of values (2.36–3.38 Nm/kg) reported previously for both athletes and non-athletes [16,25,26,28,29,33,41,48]. Although there is general acceptance in the literature that 60% represents an average hamstrings quadriceps peak torque ratio (GC), there is also large individual variability [26,29,40]. The present study's H/Q ratio of 67.6% is higher than most previous research reports (54–63%) [26,29,33], with the exception of Wyatt and Edwards [48], who reported a ratio of 71%. Although the high H/Q ratio reported in the present study can also be attributed to not correcting for the effect of gravity on knee flexion torque, this finding supports the general trend of higher relative values for knee flexion and extension torques found in the present study, compared to previous research. Thus, it seems that young SA men have higher peak torque values for both knee flexion and extension, than their international counterparts.

In terms of peak torque values for the shoulder joint, the present study's values for shoulder horizontal abduction peak torque (93.4 Nm) is higher compared to the value reported for professional baseball players (54 Nm) by Brown and co-workers [4]. Compared to the same population, the present study's horizontal adduction torque value is lower (91.8 vs. 128 Nm). The horizontal abduction-adduction ratio reported for the present study (101.3%) is higher compared to the 42.2% reported for the baseball players. The differences between the two studies could be attributed to the unique adaptations specific to professional baseball, i.e. stronger horizontal adductors as a result of repetitive throwing, characteristic of this sport.

Shoulder flexion values in the present study (80.5 Nm and 1.14 Nm/kg) are similar to the values reported for baseball players (77 Nm) [4], but higher than those reported by Freedson and co-workers [16] for non-athletes (62 Nm and 0.77 Nm/kg). The present study's values for shoulder extension of 87.2 Nm (1.23 Nm/kg) is lower compared to the 99 Nm (1.22 Nm/kg) and 164 Nm, reported previously, but the shoulder flexion-extension ratio is higher (93.9% vs. 63–78%) [4,16]. This indicates that SA men exhibit stronger shoulder flexors compared to previous research, but weaker shoulder extensors.

The rotator cuff muscles of the shoulder play an important role in stabilizing the head of the humerus in the glenoid fossa and are thus important for normal, pain-free shoulder actions, especially when performed above shoulder level and at high velocities. In the present study a value of 39.3 Nm (0.56 Nm/kg) was reported for shoulder lateral rotation, compared to 84 Nm in professional baseball players [4]. The present study's shoulder medial rotation value of 50.6 Nm (0.72 Nm/kg) is lower than the 134 Nm reported by Brown and co-workers [4] for baseball players. The shoulder medial-lateral rotation value of 79.6% for the present study is higher than the 61% reported for baseball players' dominant arms, but similar compared to their non-dominant arm's strength ratio (74%) [4]. The above findings indicate that playing baseball will lead to a selective strengthening in the dominant or throwing arm of the shoulder lateral rotators as well as the medial rotators, compared to non-athletes. Whether this is an adaptation to protect the shoulder joint, or to achieve the high velocities required in throwing a baseball, or both, is unclear. According to previous research, the ratio between the medial and lateral rotators (at 60°/s) varied between 61 and 77% [4,9,16,22,23], thus the present study's ratio of 79.6% found in young SA males, is higher than previously reported. A possible explanation for this finding is the 90° shoulder abducted position that was used for the present study, since this position may have a favourable length-tension relationship for the external rotators of the shoulder, compared to that of a more adducted and/or flexed position of the shoulder [21].

The present study's values for forearm pronation (18 Nm; 0.25 Nm/kg) and supination (13 Nm; 0.18 Nm/kg), are higher than those reported earlier by Forthomme and co-workers [15] in young men for the non-dominant side (at 30°/s), for forearm pronation (11.8Nm; 0.16 Nm/kg) and supination (8.0 Nm; 0.12 Nm/kg). The present study's forearm supination value is lower than the isometric peak torque value (16.2 Nm) reported by O'Sullivan and Gallwey [35], but the pronation value of the present study is higher compared to their pronation value (13.5 Nm). The supination-pronation ratio of the present study (78.3%) is lower compared to the non-dominant arm's ratio reported for tennis players (98%) and baseball pitchers (98%), evaluated at 90°/s [13]. However, some researchers prefer to calculate the pronation-supination ratio. A value of 133.3% was reported by Forthomme and co-workers [15] for the non-dominant arm, which is comparable to the 138.5% found in the present study.

If norms are to be used the question arises "When is a value abnormal or not ideal?" The present author suggests using one of the following approaches in trying to answer the above question. Firstly, one may argue that a value that deviates more than 10% above or below the agonist-antagonist norm could be deemed as "not ideal." Thus, the range for normal knee flexion-extension ratio would be between 61% and 74%.

Secondly, one could argue that a "normal" value should lie within one standard deviation from the mean (i.e. Mean $\pm$ 1STD or 67.6 $\pm$ 8.8%) thus, between 59% and 76%. The third approach would be to consider a value as "normal" if it falls between the 25th and 75th percentile of the group. This approach would then consider the middle 50% of participants as "normal." Using the knee flexion-extension again, this would translate into a value between 61% and 73%. Thus, whichever method one chooses to use, it is important not to be too rigid in interpreting an isokinetic evaluation and to allow for individual variability.

5. Conclusions

Seven of the twelve torque values investigated, were higher and one value was similar compared to the values reported earlier. Of the three values that were lower, two stemmed from comparisons with athletic populations. Thus, young SA men seem to have higher peak torque values compared to other populations and this should be taken into consideration when their results are compared to international norms. This study highlights the fact that norms are population-specific and that caution should be observed when using normative data in interpreting an isokinetic test. However, because most of the present study's participants were of European descent, there is a need for future research into the torque values of our country's people from African descent. There is also a need for the establishment of isokinetic norms in female populations.

Results from this study provide useful "norms" or reference values for clinical isokinetic evaluation when gravity correction is not performed. The present study is unique, because it established normative data for four different joints and six different movement patterns in a single group of participants. The present study provides clinicians with a comprehensive reference framework against which to evaluate concentric peak torque values for the ankle, knee, shoulder and forearm, in young men. Finally, the present author cautions clinicians not to be too rigid when interpreting "normality."

References

[1] American College of Sports Medicine (ACSM), *ACSM'S Guidelines for Exercise Testing and Prescription*, (7th ed.), Baltimore, Maryland: Lippincott Williams and Wilkins, 2006.

[2] V. Baltzopoulos and D.A. Brodie, Isokinetics dynamometry: Applications and limitations, *Sp Med* **8**(2) (1989), 101–116.

[3] L.E. Brown, and M. Whitehurst, Load Range, in: *Isokinetics in Human Performance,* L.E. Brown, ed., Champaign, IL: Human Kinetics, 2000.

[4] L.P. Brown, S.L. Niehues, A. Harrah, P. Yavorsky and H.P. Hirshman, Upper extremity range of motion and isokinetic strength of the internal and external rotators in major league baseball players, *Am J Sports Med* **16** (1988), 577–585.

[5] I.L. Bygott, J. McMeeken and S. Carroll, Gravity correction in trunk dynamometry: is it reliable? *Isokin Exerc Sci* **9** (2001), 1–9.

[6] J.E.L. Carter, ed., *Physical structure of Olympic athletes, Part II. Kinanthropometry of Olympic athlestes,* Basel: Karger, 1982.

[7] K.M. Chan and N. Maffulli, eds, *Principles and Practice of Isokinetics in Sports Medicine and Rehabilitation,* Hong Kong: Williams and Wilkins, 1996.

[8] T.J. Chandler, Testing and training the upper extremity, in: *Isokinetics in Human Performance,* L.E. Brown, ed., Champaign, IL: Human Kinetics, 2000.

[9] R.E. Connelly Maddux, W.B. Kibler and T. Uhl, Isokinetic peak torque and work values for the shoulder, *JOSPT* **11** (1989), 264–269.

[10] Z. Dvir, G. Eger, N. Halperin and A. Shklar, Thigh muscles activity and ACL insufficiency, *Clin Biomech,* **l4** (1989), 87–91.

[11] G.J. Davies, B. Heiderscheit and K. Brinks, Test interpretation, in: *Isokinetics in Human Performance,* L.E. Brown, ed., Champaign, IL: Human Kinetics, 2000.

[12] Z. Dvir, *Isokinetics: Muscle Testing, Interpretation and Clinical Applications,* Edinburg, UK: Churchill Livingstone, 2004.

[13] T.S. Ellenbecker and A.J. Mattalino, Concentric Isokinetic Shoulder Internal and External Rotation Strength in Professional Baseball Pitchers, *JOSPT* **25**(5) (1997), 323–328.

[14] T.S. Ellenbecker and A.J. Mattalino, *The Elbow in Sport,* Champaign, IL: Human Kinetics, 1997.

[15] B. Forthomme, J.L. Croisier, M. Foidart-Dessalle and J.M. Crielaard, Isokinetic assessment of the forearm and wrist muscles, *Isokin Exerc Sci* **10** (2002), 121–128.

[16] P.S. Freedson, T.B. Gilliam, T. Mahoney, A.F. Maliszewski and K. Kastango, Industrial torque levels by age group and gender, *Isokin Exerc Sci* **3**(1) (1993), 34–42.

[17] A.R. Fugl-Meyer, L. Gustafson and Y. Burstedt, Isokinetic and static plantar flexion characteristics, *Eur J Appl Phys* **45** (1980), 221–234.

[18] A.R. Fugl-Meyer, Maximum isokinetic ankle plantar and dorsiflexion torque in trained subjects, *Eur J Appl Phys* **47** (1981), 393–404.

[19] A.R. Fugl-Meyer, B. Gerdle, B.E. Eriksson and B. Jonsson, Isokinetic plantar flexion endurance, *Scand J Rehab Med* **17** (1985), 47–52.

[20] M.T. Gross, G.M. Huffman, C.N. Phillips and J.A. Wray, Intramachine and intermachine reliability of the Biodex and Cybex II for knee flexion and extension peak torque and angular work, *JOSPT* **13** (1991), 329–335.

[21] P.A. Hageman, D.K. Mason, K.W. Rydlund and S.A. Humpal, Effects of positioning and speed on eccentric and concentric isokinetic testing of the shoulder rotators, *JOSPT* **11**(**2**) (1989), 64–69.

[22] T.F. Huang, S.H. Wei, C.J. Chi, M.J. Hsu and H.Y. Chang, Isokinetic evaluation of shoulder internal and external rotators' concentric strength and endurance in baseball players: variations from pre-pubescence to adulthood, *Isokin Exerc Sci* **13**(**4**) (2005), 237–241.

[23] F.M. Ivey, J.H. Calhoun, K. Rusche and J. Bierschenk, Isokinetic testing of shoulder strength: Normal values, *Arch Phys Med Rehabil* **66** (1985), 384–386.

[24] F.P. Kendall, E.K. McCreary, P.G. Provance, M.M. Rodgers and W.A. Romani, *Muscles Testing and Function with Posture and Pain* (5th ed.), Baltimore, Maryland: Lippincott Williams and Wilkins.

[25] D.T. Kirkendall, *Comparison of Isokinetic Power-Velocity Profiles in Various Classes of American Athletes,* PhD dissertation, Ohio State University. Michigan: University Microfilms, 1979.

[26] P.E. Kruger, G.J. Van Wyk and H.O. Daehne, Prestasieskaal vir knie-evaluering op die Cybex II isokinetiese dynamometer, *Suid-Afrikaanse Tydskrif vir Navorsing in Sport, Liggaamlike Opvoeding en Ontspanning* **15**(2) (1992), 17–25.

[27] P.E. Kruger, G.J. Van Wyk and A. Du Toit, 'n Prestasieskaal vir enkelevaluaering op die Cybex II isokinetiese dynamometer, *SA Tydskrif vir Navorsing in Sport, Liggaamlike Opvoedkunde en Ontspanning* **18**(2) (1995), 61–74.

[28] L. Lategan, Normative concentric and eccentric knee torque ratios of South African male rugby union players in the Gauteng region, *AJPHERD* **June Special Edition** (2007), 8–18.

[29] L. Lategan, *Isokinetic Knee Torque Values in Female and Male Students at the University of Johannesburg,* Paper delivered at the South African Sports Medicine Association, Durban, RSA (2009).

[30] J.A. Levene, B.A. Hart, R.H. Seeds and G.A. Fuhrman, Reliability of reciprocal isokinetic testing of the knee extensors and flexors, *JOSPT* **14** (1991), 121–127.

[31] H. Lund, K. Søndergaard, T. Zachariassen, R. Christensen, P. Bülow, M. Henriksen, E.M. Bartels, B. Danneskiold-Samsøe and H. Bliddal, Learning effect of isokinetic measurements in healthy subjects, and reliability and comparability of Biodex and Lido dynamometers, *Clin Physiol Funct Imaging* **25**(2) (2005), 75–82.

[32] J.R. Morrow, A.W. Jackson, J.G. Dish and D.P. Mood, *Measurement and Evaluation in Human Performance,* (3rd ed.), Champaign, IL: Human Kinetics, 2005.

[33] A. Neder, L.E. Nery, G.T. Shinzato, M.S. Andrade, C. Peres and A.C. Silva, Reference Values for Concentric Knee Isokinetic Strength and Power in Nonathletic Men and Women from 20 to 80 Years Old, JOSPT **29**(**2**) (l999), 116–126.

[34] K. Norton and T. Olds, *Anthropometrica: A Textbook of Body Measurement for Sport and Health Courses*, Sydney, Australia: University of New South Wales Press, 1996.

[35] L.W. O'Sullivan and T.J. Gallway, Upper-limb surface electromyography at maximum supination and pronation torques: the effectof elbow and forearm angle, *Journal of Electromyography and Kinesiology* **12** (2002), 275–285.

[36] D.H. Perrin, Reliability of isokinetic measures, *Athl Train* **21** (1986), 319–321.

[37] D.H. Perrin, *Isokinetic Exercise and Assessment,* Champaign, IL: Human Kinetics, 1993.

[38] D.H. Perrin, R.J. Robertson and R.L. Ray, Bilateral isokinetic peak torque, torque acceleration energy, power, and work relationships in athletes and non-athletes, *JOSPT* **9** (1987), 184–189.

[39] P. Poulmedis, Isokinetic maximal torque power of Greek elite soccer players, *JOSPT* **6** (1985), 293–295.

[40] K.W. Russel, H.A. Quinney, C.B. Hazlett and D. Hillis, Knee Muscle Strength in Elite Male Gymnasts, *JOSPT* **22**(1) (1995), 10–17.

[41] B. Schlinkman, Norms of high school football players derived from Cybex data reduction, *JOSPT* **5**(5) (1984), 243–245.
[42] B.J. Sharkey, *Fitness and Health*, (5th ed.), Champaign, IL: Human Kinetics, 2002.
[43] M.C. Thompson, L.G. Shingleton and S.T. Kegerreis, Comparison of values generated during testing of the knee using the Cybex II Plus and Biodex Model B-2000 isokinetic dynamometers, *JOSPT* **11**(3) (1989), 108–115.
[44] K.E. Timm, P. Genrich, R. Burns and D. Fyke, The mechanical and physiological reliability of selected isokinetic dynamometers, *Isokin Exerc Sci* **2** (1992), 182–190.
[45] J. Van Meeteren, M.E. Roebroeck, R.W. Selles, T. Stijnen and H.J. Stam, Concentric isokinetic dynamometry of the shoulder: Which parameters discriminate between healthy subjects and patients with shoulder disorders? *Isokin Exerc Sci* **12**(4) (2004), 239–247.
[46] R.P. Walmsley and C. Szybbo, A comparative study of the torque generated by the shoulder internal and external rotator muscles in different positions and at varying speeds, *JOSPT* **9**(6) (1987), 217–222.
[47] T. Wrigley and G. Straus, Strength assessment by isokinetic dynamometry, in: *Physiological Tests for Elite Athletes: Australian Sports Commission*, Champaign, IL: Human Kinetics, 2000.
[48] M.P. Wyatt and A.M. Edwards, Comparison of quadriceps and hamstring torque values during isokinetic exercise, *JOSPT* **3** (1981), 48–56.