Normal isometric and isokinetic peak torques of hamstring and quadriceps muscles in young adult Saudi males

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ABSTRACT

Objectives: To provide reference data for peak isometric and isokinetic muscle strength of hamstring and quadriceps muscles in young adult Saudi males.

Methods: The strength of left and right quadriceps and hamstrings leg muscles was assessed in 132 college-male students in the campus of King Saud University, Riyadh, Kingdom of Saudi Arabia in the year 2002 using a Cybex machine and a standardized protocol at the following velocities: 0, 60, 180, and 300°/sec. Isometric strength (0°/sec) was assessed at 65° angle of knee flexion.

Results: Isometric flexion strength was 9.3% higher in the right leg compared to the left ($p < 0.01$), while there was no significant difference between the 2 legs in extension. In isokinetic strength, there was a decrease in both extension and flexion strength with increasing velocity. However, only in flexion strength a significant right-left difference was observed. Flexion/extension peak concentric torque ratio relative to angular velocity varied from 59.9-63.3% in the right leg and from 55.8-59.9% in the left leg, with significant difference ($p < 0.02$) between the 2 legs. In addition, the angle of peak torque decreased with increasing velocity at knee extension but increased at knee flexion.

Conclusion: Young Saudi males appeared to have similar isometric peak strength in the knee extensors but not in the flexors when compared to previously published research. Isokinetic extension strength at 60°/sec in the Saudi males is lower than values reported for untrained males elsewhere. Furthermore, the hamstrings/quadriceps ratio in Saudi males seems to be within the recommended range of appropriate muscle function.

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Strength is operationally defined as the maximal force a muscle or a group of muscles can generate at a specified velocity.[1] The importance of muscle strength in everyday life can not be overemphasized. As an example, its relation to even the simple movement of walking has been investigated.[2,3] With the advancement of age, muscle strength plays an even more noticeable role in walking disability.[4] In addition, high muscular imbalance between hamstring and quadriceps is associated with knee and low-back injuries.[5] In recent years, the use of isokinetic testing (measurement of muscular force under constant-velocity condition) as a mean of measuring dynamic muscle strength has increased considerably.[6-9] Part of this popularity may be due to the ability of isokinetic testing to provide accurate information about the dynamic quality of muscular contraction. Results of isokinetic measurement were also shown to be highly reproducible.[10,11] Nowadays, isokinetic devices have been extensively used for the assessment and evaluation of muscle function and pathology,[12] rehabilitation,[13] training of muscles,[9,14,15] and assessments of muscle strength and injury.[11,16]

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In the clinical setting, it has been used for the evaluation of populations with anterior cruciate ligament deficiency,[17-20] after reconstruction of anterior cruciate ligament,[21-23] chronic knee ligament deficiency[24] and partial meniscectomy.[25] Currently, the availability of combined isometric, concentric and eccentric isokinetic devices has made it possible for physical therapists and sport medicine physicians to employ combined tests for the evaluation and rehabilitation of patients.[8] As a result of the wide range of isokinetic measurement and the role isokinetic strength plays in different life settings, the availability of age-related reference values of muscle strength is important not only for patients with impaired locomotor system but also for training programs of healthy individuals.[26] However, in Saudi Arabia there exists a need for normative data on isokinetic muscle strength for all age categories. Therefore, the aim of this study was to provide a reference data for peak isometric and isokinetic muscle strength of hamstring and quadriceps muscles in young adult Saudi males.

Methods. ***Subjects.*** One hundred and thirty-two college-male students gave their informed consent and served as subjects in this study. They were randomly selected from Riyadh campus of King Saud University in the year 2002, using a stratified sampling technique based on the student's undergraduate levels (Freshmen to Senior). The subjects were all healthy Saudi, and free from any musculoskeletal injuries or deformities.

Anthropometrics and body composition measurement. Body mass (kg) and height were measured using a Seca digital scale. Mid-thigh (from greater trochanter to lateral epicondyle) circumference was measured using a measuring tape. Thigh skinfold thickness was measured by Harpenden caliper. In addition, lean body mass was assessed by bioelectric impedance analysis (Body Stat 1500, Body Stat Ltd, United Kingdom). Fat content (%) was then calculated by subtracting lean body mass from total body mass.

Measurement of muscle strength. Subjects were tested for isometric and isokinetic knee extension and flexion strength in both right and left legs. Testing was performed using Cybex isokinetic dynamometer (Cybex, New York, United States of America). The isokinetic dynamometer permits isokinetic contraction to be at various predetermined velocities. Isokinetic dynamometer provides resistance by matching the force applied against it, then preventing acceleration beyond the preset velocity movement.[27] Maximal isometric torque was measured with a velocity of zero degrees^{-1}, while the lever arm is locked in a position of 65^{o} flexion of the knee joint. The selection of this position was based on previous research which indicated that the recommended isometric strength ratio of .60 between hamstring to quadriceps ratio (H/Q) occurs at this angle of knee flexion.[28] Isokinetic concentric torque was assessed at 3 angular velocities; 60, 180 and 300$^{o}s^{-1}$. The order of tests (dominant versus non-dominant leg and isokinetic velocity) was randomized through a counter-balanced design. All measurements were preceded by a warm-up period consisting of riding a bicycle ergometer for 3 minutes at 60 rpm with a resistance of 1.5 kg. At the end of the warm-up period, the subject performed 2 brief (5 second) all out sprints. A resting period for 3 minutes preceded leg strength testing. Following a warm-up period, the subject was introduced to the isokinetic apparatus and the procedures were fully explained. They were then seated on the machine chair without shoes, while the thighs and trunk were firmly strapped to the chair at 90^{o} position and with both hands grabbing the handles. The axis of rotation of the dynamometer was aligned with the anatomical axis of rotation of the knee joint (lateral femoral condyle). The ankle cuff was then attached proximal to the lateral malleolus. The other leg was restrained with a padded cushion. Each subject's functional range of motion was set electronically between 0-90^{o} of knee flexion to prevent hyperextension and hyperflexion. Gravity correction was made for limb weight on torque measurement. The subject was instructed to grab stabilization handles during the test, and fully extend the leg and then flex it as hard and fast as possible (one maximal extension followed immediately by a reciprocal maximal flexion). Each subject was given 2 familiarization trials followed by 20 seconds of rest. Four repetitions were then performed at each velocity, and the highest torque was recorded. A one-minute rest was given before advancing to the next angular velocity.

Statistical analysis. Data calculation and analysis were performed using the Statistical Package for Social Sciences for PC, version 10. Descriptive statistics were obtained for peak torque during extension and flexion in both legs. Differences between right and left leg strength were tested using t-test. The level of significance was set at 0.05.

Results. Descriptive characteristics of the subjects are shown in **Table 1**. The age ranged from 18-27 years. Body mass and height averaged 71.3 kg and 170.3 cm. Body fat content ranged from about 4-42% with a mean of 20.8%. The results of the hamstring and quadriceps peak torque for both legs are presented in **Table 2**. In the isometric test, the maximum strength of the knee extensors exhibited much higher values (49.4% for the right leg and 44.6% for the left leg) than knee flexors. During flexion, right leg strength was stronger than the left ($p < 0.01$), while there was no significant differences in isometric extension strength between

Table 1 - Physical characteristics of subjects (n=132).

Variable	Range
Age (years)	18 - 27
Body mass (kg)	45.3 - 115
Body height (cm)	157 - 186
Fat content (%)	3.9 - 42
Lean body mass (kg)	38.5 - 72.7

Table 2 - Mean (SD) values of hamstring and quadriceps peak torque (Nm).

Variable	Flexion		Extension	
	Right leg	Left leg	Right leg	Left leg
Isometric (0°.s-1)	107.7 (24.8)	97.7† (24.7)	217.8 (46.2)	218.9 (49.1)
Concentric (60°.s-1)	100.9 (22.3)	96.3† (20.5)	172.2 (32.9)	173.1 (32.8)
Concentric (180°.s-1)	74.1 (17.9)	69.6† (15.3)	118.2 (20.7)	117.6 (21.3)
Concentric (300°.s-1)	52.3 (15.6)	49.8* (13.5)	84.5 (16.8)	84.5 (17.5)

Nm - Newton meter
* significantly different from right leg at 0.05 level
† significantly different from right leg at 0.01 level

Table 3 - Percentile values of isometric peak torque (Nm).

Percentile	Flexion		Extension	
	Right leg	Left leg	Right leg	Left leg
5	66	65	149	144
10	75	71	158	162
20	82	76	172	176
30	91	84	192	190
40	96	91	207	205
50	102	97	226	215
60	106	101	230	228
70	119	107	240	243
80	126	114	253	258
90	138	132	273	280
95	155	148	293	315

Nm - Newton meter

Table 4 - Percentile values of isokinetic concentric peak torque.

	Velocity (degree.s-1)					
	60°		180°		300°	
Percentile	R	L	R	L	R	L
Flexion						
5	71	63	42	46	26	27
10	75	74	54	53	35	34
20	84	79	61	58	40	38
30	90	83	66	61	44	42
40	94	89	71	64	48	45
50	99	95	74	69	51	50
60	104	100	77	72	55	55
70	111	105	82	76	60	57
80	118	115	88	82	64	61
90	132	125	97	88	72	66
95	142	135	106	93	82	72
Extension						
5	125	119	86	82	60	56
10	134	132	89	91	64	62
20	145	145	100	98	69	68
30	155	155	106	107	74	75
40	164	165	112	113	78	79
50	169	172	116	117	83	83
60	176	179	122	122	123	90
70	187	190	131	128	95	93
80	199	200	139	135	100	101
90	218	221	149	146	107	12
95	235	231	154	156	111	115

R - Right leg, L - Left leg

Table 5 - Knee angle at isokinetic concentric maximal torque development (mean ± SD).

Velocity (Degrees.s-1)	Flexion		Extension	
	Right leg	Left leg	Right leg	Left leg
60	34.6 ± 8.7	34.1 ± 8.1	71.5 ± 8.5	70.7 ± 8.1
180	41.9 ± 9	42.2 ± 8.5	67.4 ± 8.2	66.3 ± 7.1
300	45.9 ± 7.7	45.4 ± 7.7	67.4 ± 7.4	65.9 ± 7.3

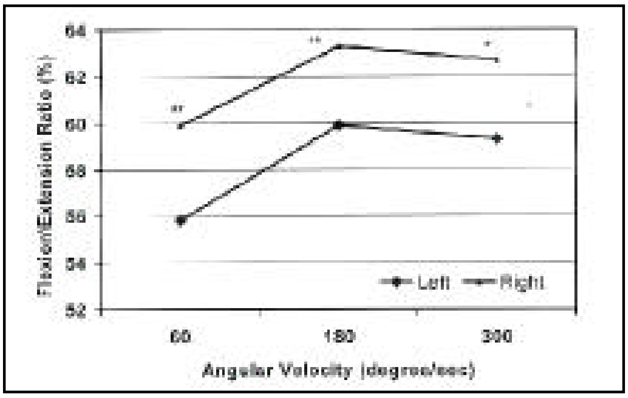

Figure 1 - Flexion/extension peak torque ratio (%) of right and left leg relative to angular velocity (** significant difference from left at p<0.001; * p<0.02).

Table 6 - Comparison of isometric and isokinetic right leg peak torque in the present study with findings from selected studies of similar age group.

Population	Age (years)	Mass (kg)	Type	Velocity (Degrees.s^{-1})			
				0	60	180	300
Untrained [6] (n=11)	30.6 ± 6.3	71.9	Ext	210	185	130	--
			Flex*	115	105	80	--
Untrained [8] (n=28)	30.2 ± 601	73.2 ± 15	Ext*	250	215	135	85
			Flex	130	105	80	60
Moderately active [30] (n=143)	30 ± 4	76 ± 8	Ext	--	193	117	--
			Flex	--	121	88	--
Inactive [29] (n=19)	24 ± 1.8	72 ± 8.5	Ext	206	216	141	113
			Flex	133	123	95	95
Present study (n=132)	21.6 ± 1.7	71 ± 14	Ext	218	172	118	85
			Flex	108	101	74	52

Ext - Extension, Flex - Flexion
*peak torque estimated from graphs

right and left leg. Regarding isokinetic test results, peak torque during both flexion and extension decreased with increasing angular velocity. The right-left differences in peak torque were only significant ($p < 0.05$) at flexion but not at extension. As shown in **Figure 1**, flexion/extension peak concentric torque ratio relative to angular velocity varied from 59.9-63.3% in the right leg and from 55.8-59.9% in the left leg, with significant difference ($p < 0.02$) between the 2 legs. **Tables 3 and 4** present selected percentiles for isometric and isokinetic peak torques for the young Saudi males. They are shown in rank from the 5th centile to the 95th centile. **Table 5** shows the knee angles at peak isokinetic torque. The knee angles at peak isokinetic torque at 60°/sec showed that the mean peak for the hamstrings occurred at 34.6 for the right and 34.1 degrees for the left leg. At higher angular velocity, peak torques occurred at increasingly higher knee angles. The corresponding peak torque for the quadriceps, however, occurred at higher angles compared to flexion, with decreasing knee angles as velocity increased from 60-300°/sec.

Discussion. The present study has reported, for the first time in Saudi Arabia, comprehensive normative data for isometric and isokinetic peak torques of the knee extensors and flexors. Indeed, the absence of such data attests to the importance of the present study's findings in a variety of applications, including sports medicine, exercise training, physical therapy and rehabilitation. The main objective of the present study was to establish referenced values for peak strength in young Saudi males. Therefore, it is important to compare such norms with reference data from similar studies worldwide. **Table 6** presents a comparison of peak torques in the young Saudi males with those reported in the literature. We must understand, however, that differences in the assessment procedures and types of devices used in testing all make the comparison more difficult. Differences in body mass must also be taken into consideration when muscular strength comparison was made. Thus, relative to body mass, isometric torque of the knee extensors in young Saudi males appears similar to those reported for untrained males elsewhere.[6,8,29] However, flexor's peak torque of Saudi males is lower than values reported for untrained males elsewhere.[6,8,29] Furthermore, isokinetic extensors muscle's strength in Saudi males at 60° s^{-1} is lower than values reported for untrained males elsewhere.[6,8,29,30] The hamstring strength in the Saudi males appears either similar to[6,8] or lower than[29,30] those values previously reported for untrained males. As we move from lower to higher velocity, isokinetic peak torques in the present study exhibited similar trends to that reported in previous studies.[30,31] Peak extension and flexion torques decreased with increasing velocity. The magnitude of reduction ranged from 48% in the flexion of the right leg to 51.1% in the extension of the left leg. The decrement in the quadriceps is more noticeable than in the hamstrings.

It has been stated that evaluation of peak torque irrespective of joint angle could lead to erroneous conclusions regarding muscle function. That is caused by high acceleration at higher speeds, which could lead to the limb passing the optimum angle before the activation of the resistive mechanism.[13] The angle at peak torque of the present study showed similar trend to that of other studies.[5,7,9,19,26,31,32] At knee extension, as the speed of movement increased, the angle at peak torque decreased. However, at knee flexion, there was an opposite trend; as the speed of movement increased, the peak torque angle occurred later in the range of movement.

Even though peak torque has been used as a golden standard and a reference point in all isokinetic studies,[33] it has been suggested that H\Q is more important in muscle function assessment.[34] The H/Q has been used as a measure of knee muscle balance and hence linked to increased stress and injury susceptibility.[35,36] The H/Q of the present study showed similar values compared to other studies with comparable speeds.[5,7,9,19,26] The values of H/Q in our Saudi subjects appear within the recommended range values (55-80%) for appropriate muscle function of untrained individuals.[22,37-39] It was previously found that H/Q increases with increasing velocity.[40,41] In the present study, H/Q steadily increased from zero to 180°/sec with no further increase at 300°/s.

The present findings showed that there were significant differences between the right and the left leg in the flexion movement but not in the extension one. It is also shown that the right leg flexors, but not extensors were stronger than the left. However, this right-left strength imbalance is lower than 15%. It has been found that athletes with flexion right-left imbalance of more than 15% are 2.6 times more likely to suffer lower extremity sprain and strain injuries in the weaker side than subjects without this imbalance.[38] Furthermore, previous studies have found no significant difference between right and left leg in the measured variables, and hence recommended testing either leg as a representative of the other.[7,24,26] Octavia[26] reported a small but significant extension peak torque difference but no significant flexion peak torque difference. Based on the results of the present study, it is fair to say that using the results of either leg as representative of the other can be carried out for the extension part of the movement but not for the flexion.

In summary, the present study provided for the first time normative data for isometric and isokinetic peak strength of the knee extensors and flexors muscles in young Saudi males. Such normal data are extremely useful as reference values when testing weak or injured hamstrings and quadriceps muscles.

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