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Isometric and Isokinetic Torque Curves at the Knee Joint

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Isometric and isokinetic torques of bilateral quadriceps and hamstrings were measured with Isokinetic Rehabilitation and Testing System (Model No. Cybex 340) on 40 normal untrained subjects, 20 males and 20 females, ranging between the ages of 23 and 35 years. The mean peak isometric and isokinetic torque values of both muscle groups showed no significant differences between dominant (right) and nondominant (left) limbs in both sexes; however there were significant differences between the male and the female. As the angular velocity increased, the peak torque significantly decreased, and the point of peak torque output occurred significantly later in the range of motion for quadriceps and hamstrings ($p<0.01$). There were no significant changes in the hamstrings to quadriceps (H/Q) ratios as the angular velocity increased. However, there were significant differences of mean H/Q ratio between male and female ($p<0.01$). Height had significant positive correlation with peak isometric and isokinetic torques for both quadriceps and hamstrings($p<0.01$). Weight was found to correlate significantly with peak isometic and isokinetic torques ($p<0.01$). The mean isometric torques were significantly higher than the mean isokinetic torques for any joint angles in both sexes ($p<.01$).

Key Words: Isometric and isokinetic torques, angle of peak torque, H/Q ratio

Human muscular strength refers to the ability of a muscle group to exert maximal force in a single voluntary efforts (Knapik and Ramos 1980). The 3 methods currently available for measuring strength have been termed isometric, isokinetic and isotonic (Hislop and Perrine 1967; Knapik *et al.* 1983). A measurement of isometric strength, although valuable to the clinician, supplies only partial information about the muscle function. The term 'isokinetics' is defined as the dynamic muscular contraction when the velocity of movement is controlled and maintained constant by a special device (Hislop and Perrine 1967; Thistle *et al.* 1967).

Many researchers have found the isokinetic test to be a reliable and valid method of objectively describing human muscle function (Moffroid *et al.* 1969; Alexander and Molnar 1973; Caiozzo *et al.* 1981). The clinical applications of isokinetics include documentation of patient progress, rehabilitation exercise regimens, the use of normative data, and analysis of force-velocity or power-velocity relationships (Pipes and Wilmore 1975; Thorstensson *et al.* 1976; Perrine and Edgertson 1978; Goslin and Charteris 1979; Gregor *et al.* 1979; Coyle *et al.* 1981).

A description of the relationship between the torque exerted by a muscle group and the joint angle is useful both in clinical settings and in human factors engineering. The relationship between the torque and the joint angle is determined by three major factors: the cross-sectional area of muscle, the length-tension relationship of the muscle, and the mechanical characteristics of the lever system (Knapik *et al.* 1983).

During isokinetic tests involving the vertical plane (e.g. knee extension-flexion), the torques acting on the limb-lever system are the actual muscular torque and the gravity effect torque generated by the mass of the limb and the lever arm.

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Fillyaw *et al.* (1986) reported that failure to consider the gravity effect torque greatly underestimated quadriceps femoris muscle torque and overestimated hamstring muscle torque. While the uncorrected hamstring to quadriceps femoris muscle peak torque ratio increased as speeds went from 60°/sec to 240°/sec, the gravity corrected ratio significantly decreased.

Thus, the interpretation of the reciprocal muscle group ratio, without considering the gravity effect, results in erroneous conclusions about muscle function. So, the gravity effect torque should be corrected for the evaluation of muscle function.

However, many researchers reported the values for maximum isokinetic torque by using their unique method.

The objectives of this study are to: (1) find the peak torque with gravity correction for quadriceps and hamstrings at isometric and isokinetic testings; (2) measure the knee angle at which peak torque was generated at selected angular velocity; (3) calculate the hamstrings to quadriceps ratio at different angular velocity; and (4) determine the relationship between peak isometric torque and peak isokinetic torques at various joint angle.

SUBJECTS AND METHODS

Forty normal untrained volunteer subjects, 20 males and 20 females, ranging between the ages of 23 and 35 years were studied. None of the subjects had any history of neuromuscular or skeletal disorder, and none were participating in any regular exercise program. All of the subjects used their right foot to kick the ball. Height and weight measurements were obtained on each subject.

Bilateral strength of quadriceps and hamstrings were measured with Isokinetic Rehabilitation and Testing System (Model No. Cybex 340). Cybex 340 printer and dynamomrter were interfaced with the Cybex 340 Computer for analysis of test results. Right knees were tested first 50% of the time for each sex. Each subject was seated on the Cybex Chair with the back supported and the hip in approximately 90° to 100° of flexion. Stabilization of the subject was provided by a three-point safety belt, thigh strap, and contralateral limb stabilization bar.

The tested leg was strapped to the input adapter

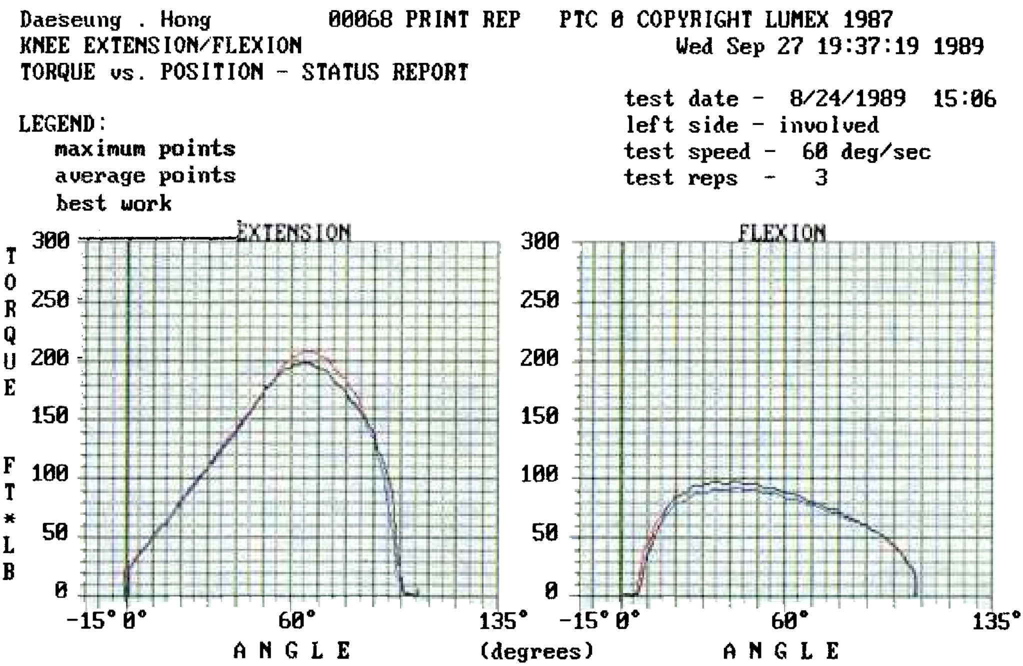

Fig. 1. Torque curves of quadriceps and hamstrings at 60°/sec.

with the shin pad just above the malleoli, and the axis of rotation of the dynamometer was aligned with the anatomical axis of the subject's knee. To provide correction of the gravity effect during testing, the gravity effect torques at every point in the range of motion were determined by the 340 Computer automatically.

The isokinetic testing session consisted of four submaximal efforts followed by three maximal efforts at 30°, 60°, 90°, 120°, and 180°/sec of angular velocity. Subjects kept the trunk in contact with the back rest and did not grasp the hand stabilization handles of the seat during testing. Subjects were instructed to kick and bend their leg as hard and as fast as possible through a full range of motion. The isometric testing session consisted of two submaximal efforts followed by three maximal effort during 3 to 5 seconds at the knee angles 15°, 30°, 45°, 60°, 75°, and 90°. Verbal encouragement was given during every trial. A three minutes rest was allowed between the maximal efforts.

Peak isokinetic torques and knee angles were obtained from the highest output of test at each angular velocity (Fig. 1). Highest isometric and isokinetic torques at the knee angles 15°, 30°, 45°, 60°, 75°, and 90° were obtained from the highest output of tests.

The ratio between the hamstrings and quadriceps was calulated for each test speed.

For statistical analyses of these data, independent Student's t-test, correlation coefficients, and multiple comparison test(Scheffe test) were used.

RESULTS

1) Physical characteristics of subjects are presented in Table 1. There was no significant difference in age between male and female, but there was significant difference in height and weight.

2) There was no significant difference in the mean peak isometric and isokinetic torque values of both muscle groups between right and left knees in each sex (Table 2, 3).

3) The peak isometric torques for quadriceps and hamstrings were 177.4 and 105.5 ft-lbs in male, 102.1 and 58.2 ft-lbs in female. The peak isokinetic torques of quadriceps and hamstrings at 30°/sec were 154.3 and 92.1 ft-lbs in male, 89 and 50.3 ft-lbs in female, and at 180°/sec, 107.8 and 67.9 ft-lbs in male, 56.6 and 33.6 ft-lbs in female (Table 4). The peak isometric torques were greater than any peak isokinetic torques for both quadriceps and hamstrings of each sex ($p<0.01$). The peak torque significantly decreased as the angluar velocity increased for both quadricpes and hamstrings of each sex with negative correlation coefficients($p<0.01$).

4) The angle at which peak isokinetic torque was produced in the range of motion was determined for each angular velocity. The mean angle of peak torque production during extension and flexion changed as the angular velocity increased. At the

Table 1. Physical characteristics of subjeces

Sex	n	Age(years)	Weight(lbs)	Height (cm)
Male	20	28.0± 3.6	157.5±24.7	172.2±5.1
		(22-33)	(111-220)	(165-187)
Female	20	27.5± 3.8	114.7±10.2*	159.6±5.6*
		(21-35)	(100-134)	(152-170)
Total	40	27.7± 3.7	136.1±28.6	165.9±8.1

Values are means±SD with ranges in parentheses.
* $p<0.01$

Table 2. Results of peak torque in male

Test	Quadriceps		Hamstrings	
	Right	Left	Right	Left
Isometric	175.7±34.8	179.1±32.4	105.9±13.7	105.1±12.0
30° /sec	153.5±32.5	155.2±30.4	92.6±14.4	91.6±13.0
60° /sec	145.9±27.1	147.5±27.8	86.5±14.9	86.0±11.3
90° /sec	133.0±22.7	135.5±22.0	81.7±12.8	82.8±10.8
120° /sec	123.3±21.6	125.1±19.8	75.7±11.6	76.4±10.3
180° /sec	108.0±19.0	107.6±19.0	67.9±10.4	67.9±10.3

Values are given as mean and standard deviation (ft-lbs).
* $p<0.01$

Table 3. Results of peak torque in female

Test	Quadriceps		Hamstrings	
	Right	Left	Right	Left
Isometric	100.8±16.6	103.5±17.2	58.1± 8.4	58.3± 8.4
30° /sec	89.1±14.8	89.0±18.6	51.1±11.0	49.5± 9.6
60° /sec	82.4±12.9	85.3±15.0	44.2±10.2	45.2±10.2
90° /sec	73.4±12.2	75.3±13.3	44.2± 7.4	42.7± 9.0
120° /sec	67.1±11.2	67.5±12.7	39.8± 8.7	41.1± 8.6
180° /sec	57.7±10.5	55.4±11.1	33.1± 9.0	34.0± 7.7

Values are given as mean and standard deviation (ft-lbs).
* p<0.01

Table 4. Results of peak isometric and isokinetic torques

Test	Quadriceps		Hamstrings	
	Male	Female	Male	Female
Isometric	177.4±33.2	102.1±16.7*	105.5±12.7	58.2± 8.3*
30° /sec	154.3±31.1	89.0±16.6*	92.1±13.6	50.3±10.2*
60° /sec	146.7±27.1	83.8±13.9*	86.2±13.1	44.7±10.1*
90° /sec	134.3±22.1	74.3±12.6*	82.8±11.7	42.4± 8.2*
120° /sec	124.2±20.5	67.3±11.9*	76.0±10.8	40.4± 8.6*
180° /sec	107.8±18.8	56.6±10.7*	67.9±10.2	33.6± 8.3*
Correlation	-0.6473*	-0.7301*	-0.6951*	-0.6422*

Values are given as mean and standard deviation (ft-lbs).
*p<0.01

Table 5. Angles of peak isokinetic torque

Test	Male		Female	
	Quadriceps	Hamstrings	Quadriceps	Hamstrings
30° /sec	69.1±8.2	22.2±6.7	65.7±6.6	19.5±7.3
60° /sec	65.7±6.7	28.5±6.8	58.1±6.7	26.8±5.7
90° /sec	60.7±5.7	34.0±6.8	56.7±5.4	31.8±6.0
120° /sec	56.4±5.5	40.6±8.3	52.7±5.9	35.3±5.2
180° /sec	50.9±5.8	49.8±8.7	48.3±5.5	44.8±7.5
Correlation	-0.7073*	0.7884*	-0.6743*	0.7962*

Values are given as mean and standard deviation (degree).
*p<0.01

lowest velocity, 30°/sec, the peak torque of quadriceps and hamstrings were generated in the male at 69.1° and 22.2°, in the female at 65.7° and 19.5°. At the highest velocity, 180°/sec, the peak torque of quadriceps and hamstrings were generated in the male at 50.9° and 49.8°, in the female at 48.3° and 44.8° (Table 5). As the angular velocity increased, the point of peak torque output occurred significantly later in the range of motion(p<0.01).

5) The peak torque to body weight ratios of quadriceps and hamstrings were 113.3% and 67.8

Table 6. Results of peak torque to body weight ratio

Test	Male		Female	
	Quadriceps	Hamstrings	Quadriceps	Hamstrings
Isometric	113.3±17.8	67.8±8.3	89.2±13.5	51.0±7.5
30° /sec	98.5±15.5	59.0±8.0	77.8±13.6	44.0±9.0
60° /sec	93.5±12.7	55.4±8.7	73.3±12.1	39.1±8.7
90° /sec	85.8±11.6	52.8±7.9	65.0±10.9	37.2±7.4
120° /sec	79.5±11.6	48.9±7.4	58.9±10.5	35.4±7.7
180° /sec	68.9±10.3	43.7±7.3	49.6± 9.6	29.4±7.6

Values are given as mean and standard deviation (%).

Table 7. Peak torque of hamstrings to quadriceps ratio

Test	Male	Female
Isometric	60.6± 8.3	57.7± 7.6
30° /sec	60.7± 8.4	57.2± 9.9
60° /sec	59.6± 8.6	53.4± 8.9
90° /sec	62.1± 9.2	57.3± 7.9
120° /sec	62.0± 9.0	60.3± 9.5
180° /sec	64.1±11.1	59.7±12.2
Total	61.5± 9.2	57.6± 9.6*

Values are given mean and standard deviation(%).
* $p<0.01$

% in male, 89.2% and 51% in female at isometric testing. Its ratios of quadriceps and hamstrings were 98.5% and 59% in male, 77.8% and 44% in female at 30°/sec, and 68.9% and 43.7% in male, 49.6% and 29.4% in female at 180°/sec (Table 6).

6) The hamstrings to quadriceps ratios of male and female were 60.6% and 57.7% at isometric testing, 60.7% and 57.2% at 30°/sec, 64.1% and 59.7% at 180°/sec (Table 7). There were no significant differences in ratios as the angular velocity increased, but significant differences in mean ratio between male and female ($p<0.01$).

Table 8. Correlation coefficients in peak isometric and isokinetic torques to body weight and height

Correlations	Weight		Height	
	Quadriceps	Hamstrings	Quadriceps	Hamstrings
Isometric	0.8285 *	0.8346 *	0.7852 *	0.7688 *
30° /sec	0.8169 *	0.8408 *	0.7805 *	0.7543 *
60° /sec	0.7907 *	0.8663 *	0.7697 *	0.7930 *
90° /sec	0.7873 *	0.8502 *	0.8012 *	0.7981 *
120° /sec	0.7683 *	0.8312 *	0.7921 *	0.7731 *
180° /sec	0.7493 *	0.8343 *	0.7837 *	0.7741 *

* $P<0.01$

Table 9. Isometric and isokinetic torques of qudariceps in male

Test \ Joint angle	15°	30°	45°	60°	75°	90°
Isometric	72.6±12.0	107.2±16.7	139.3±23.6	171.1±31.2	172.3±33.7	145.9±28.0
30° /sec	59.5±11.4	86.2±17.2	118.2±21.7	144.1±28.3	146.1±30.9	124.2±25.6
60° /sec	61.6±11.8	90.6±17.7	116.3±20.4	139.1±25.7	136.3±27.3	106.6±25.3
90° /sec	59.4±12.0	88.4±14.9	114.3±18.4	130.4±21.7	121.2±21.7	85.2±18.7
120° /sec	59.2±12.2	89.9±15.5	111.9±17.9	121.8±20.7	106.1±19.5	71.1±18.1
180° /sec	60.2±12.7	87.0±16.4	102.7±18.7	102.9±18.3	83.6±17.0	49.6±17.2

All values are mean and standard deviation (ft-lbs).

Table 10. Isometric and isokinetic torques of hamstrings in male

Test \ Joint angle	15°	30°	45°	60°	75°	90°
Isometric	102.6±15.0	101.9±11.6	93.7±10.8	85.5±11.1	77.1±11.4	65.7±11.1
30° /sec	83.6±12.3	87.9±13.8	81.9±12.7	73.6±12.3	62.7±10.5	54.3± 9.4
60° /sec	65.2±10.6	83.3±12.7	79.8±13.1	73.1±13.4	64.9±12.8	56.0±11.1
90° /sec	50.3± 8.4	78.2±10.7	76.6±12.0	69.8±12.1	61.1±11.3	50.6±10.3
120° /sec	42.4± 7.6	69.2±10.8	72.7±10.8	68.4±10.9	60.6±11.2	49.6±11.3
180° /sec	27.4±10.9	52.2± 8.9	63.7± 9.7	63.1±10.4	57.9±10.8	47.4±11.6

All values are mean and standard deviation (ft-lbs).

Table 11. Isometric and isokinetic torques of quadriceps in female

Test \ Joint angle	15°	30°	45°	60°	75°	90°
Isometric	42.0±6.5	63.0± 9.2	82.1±13.4	99.0±15.7	97.1±18.7	79.4±15.3
30° /sec	34.7±6.8	51.0± 8.7	69.6±14.3	84.3±16.3	80.3±17.7	66.6±12.9
60° /sec	34.2±7.4	52.7±10.1	69.8±12.9	80.9±14.4	73.7±14.4	52.1±12.6
90° /sec	32.8±7.2	51.5± 8.6	66.3±11.7	72.3±13.0	63.9±13.0	44.6±12.2
120° /sec	32.6±7.0	50.4± 8.4	62.4±11.3	64.9±12.1	55.1±12.6	36.4±12.2
180° /sec	30.8±6.9	45.6± 8.7	53.8±10.3	53.1±11.3	42.4±11.0	24.1±11.7

All values are mean and standard deviation(ft-lbs).

Table 12. Isometric and isokinetic torques of hamstrings in female

Test \ Joint angle	15°	30°	45°	60°	75°	90°
Isometric	56.5±7.9	55.9± 9.2	51.2±8.4	46.1±7.2	40.6±6.5	34.3±6.7
30° /sec	45.8±9.7	45.9±10.6	42.4±9.2	38.3±7.7	32.7±7.0	28.4±6.9
60° /sec	34.6±9.3	43.3±10.0	40.4±9.1	36.5±8.2	32.0±7.5	27.2±7.3
90° /sec	28.6±7.2	41.0± 8.0	38.7±7.8	34.4±7.6	29.8±7.4	25.4±7.3
120° /sec	24.5±6.7	37.9± 8.7	37.5±8.5	33.6±8.4	28.5±8.8	23.1±8.3
180° /sec	16.9±8.1	28.2± 7.6	31.9±8.0	30.7±8.5	26.3±9.2	20.1±8.6

All values are mean and standard deviation (ft-lbs).

Table 13. Difference of peak isometric and isokinetic torques

Joint angle	Male		Female	
	Quadriceps	Hamstrings	Quadriceps	Hamstrings
15°	7.6± 5.8	19.1±10.3	5.8±3.3	10.5±5.4
30°	11.9± 8.0	12.6± 7.5	7.7±4.5	8.9±4.8
45°	15.9±10.2	10.5± 6.2	9.3±6.8	8.1±4.5
60°	22.7±14.2	8.8± 6.9	13.2±7.6	7.3±4.2
75°	24.9±15.7	9.2± 6.4	16.4±7.7	6.5±3.3
90°	22.5±14.0	7.8± 4.2	12.7±6.3	4.7±3.0

All values are mean and standard deviation (ft-lbs).

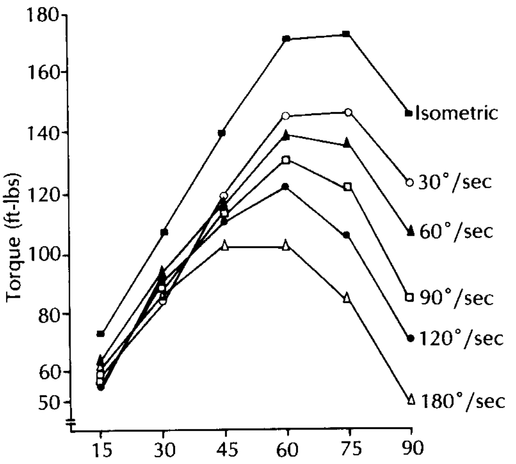

Fig. 2. *Torque-joint angle curves for quadriceps of male.*

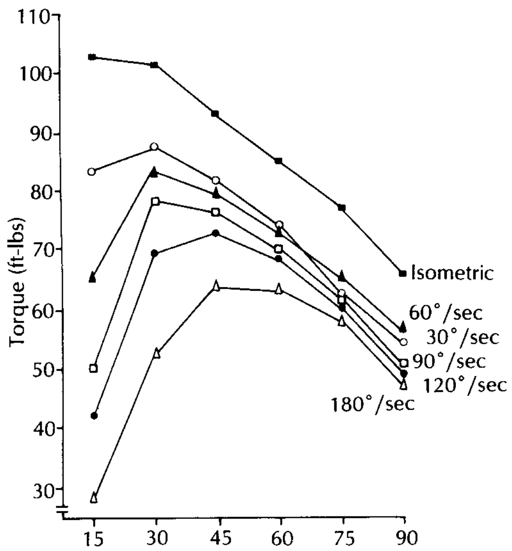

Fig. 3. *Torque-joint angle curves for hamstrings of male.*

7) Height had significantly positive correlation with peak isometric and isokinetic torques for both quadriceps and hamstrings ($p<0.01$). Weight was found to correlate signigicantly with peak isometic and isokinetic torques (Table 8).

8) The mean isometric torques were significantly higher than the mean isokinetic torques for any joint angles for both sexes (Table 9,10,11,12). The magnitude of this difference varied with joint angle; larger differences between peak isometric and

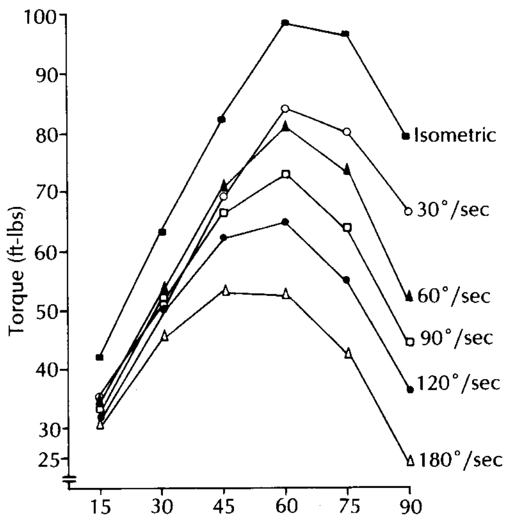

Fig. 4. *Torque-joint angle curves for quadriceps of female.*

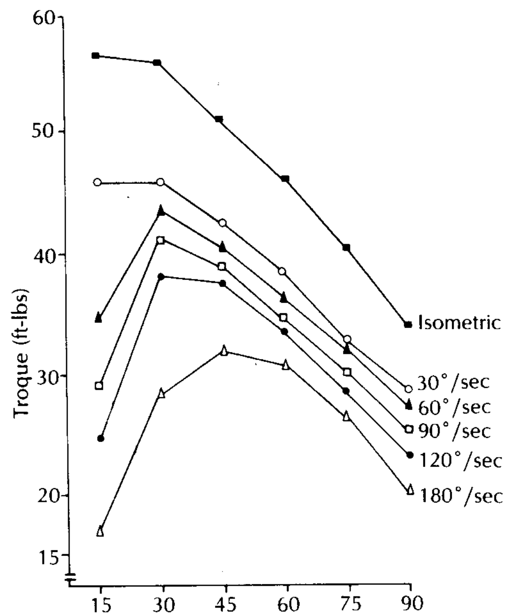

Fig. 5. *Torque-joint angle curves for hamstrings of female.*

isokinetic torque occurred at the more flexed angle (60°,75°,90°) for quadriceps and at the more extended angle (15°, 30°, 45°) for hamstrings (Table 13). Among isometric torques, there was no significant difference between 60° and 75° knee angles for both sexes in quadriceps, or between 15° and 30° knee angles for both sexes in hamstrings. The differences among isokinetic torques were greatest at the beginning of range tested when the muscle was near its normal resting length. And there was no significant difference among isokinetic torques at 15° and 30° knee angles for both sexes in quadriceps, and at 75° and 90° knee angles for male in hamstrings (Fig. 2-5).

DISCUSSION

The peak isokinetic torque is a measurement of the muscular force applied in dynamic condition. The peak isokinetic torque is affected by many factors, age, sex, test position, angular velocity, and gravity effect torque (Goslin and Charteris 1979; Murray *et al.* 1980; Fillyaw *et al.* 1986; Miyashita and Kanehisa 1979). Failure to consider gravity effect torque greatly underestimates quaderceps muscle torque and overestimates hamstring muscle torque in the vertical plane (Winter *et al.* 1981; Nelson and Duncan, 1983; Fillyaw *et al.* 1986). Specific comparison of datas from many previous studies to data from this study is not feasible due to differences in subjects, methods, and equipment. The peak isokinetic torque is affected by the angular velocity of movement. The muscular torque exerted during isokinetic testing decreased with increasing angular velocity with and without gravity correction (Moffroid *et al.* 1969; Thorstensson *et al.* 1976; Osternig 1975; Gilliam *et al.* 1979; Wyatt and Edwards 1981). Our results are consistent with previous reports. This decline in torque output has been attributed to different neurological activation patterns of motor units at different velocities (Milner-Brown *et al.* 1975; Barnes 1980).

The angular position is important in the assessment of muscle function because it provides information about mechanical properties of the contracting muscles. (Baltzopoulos and Brodie 1989). It can be used to evaluate the optimum joint angle for peak isokinetic torque at the preset angular velocity.

Many researchers (Moffroid *et al.* 1969; Osternig 1975; Thorstenson *et al.* 1976; Scudder 1980; Froese and Houston 1985) reported that, during knee extensions and as the preset angular velocity increased, the peak torque occurred later in the range of motion. Our results are consistent with previous reports.

During knee flexion, Knapik *et al.* (1983) reported the maximal torque occurred later in the range of motion as the angular velocity increased; Scudder (1980), however, reported no significant change. Our results are consistent with those of Knapik *et al.* (1983).

The point in the range of motion at which peak torque is generated is dependent on speed of motion. Moffroid *et al.* (1969) attributed this finding to a possible lag or delay in exciting the contractile elements of the muscle. A second possible explanation is based on the time required for momentum of the leg to overcome inertia (Osternig 1975). Another explanation may be the combination of the lag time as the limb accelerated to the preset velocity and the time required for the muscle group to develop additional torque(Knapik *et al.* 1983).

The reciprocal muscle group ratio is an indicator of muscular balance or imbalance around a joint (Gilliam *et al.* 1979; Goslin and Charteris 1979; Campbell and Glenn 1982). The hamstrings to quadriceps (H/Q) ratio of the knee joint is one of the more important parameters in isokinetic assessment because the knee is one of the largest and most complex joints in the human body and its normal function is important for injury prevention (Campbell and Glenn 1982; Gilliam *et al.* 1979; Baltzopoulos and Brodie, 1989).

Gilliam *et al.* (1979) reported that H/Q ratio was 60% at 30°/sec isokinetic test and 77% at 180°/sec isokinetic test of 151 high school football players. Scudder (1980) reported that the ratio remained quite constant at approximately 0.62 over the low speeds test (0° to 90°/sec) with 10 normal untrained male subjects. Davies *et al.*(1981) reported that the ratio was increased from 60.9% at 45°/sec to 80.4% at 180°/sec isokinetic test with 91 professional football players. Dibrezzo *et al.* (1985) reported that the ratio was 53.6% at 60°/sec with 241 normal untrained female. Wyatt and Edwards (1981) reported that the ratios were significantly increased between the test speeds(60°, 180°, 300°/sec) for both male and female groups. However, these are not considered gravity effect torque. The ratio is affected by age, sex, activity, different types of competitors, and gravity. As the gravity effect torque alters H/Q ratio, gravity effect torque should be corrected when measuring hamstring and quadriceps torque isokinetically in an antigravity position.

Appen and Duncan (1986) reported that the gravity corrected and uncorrected ratios were significantly different at all velocities and that the gravity corrected ratios remained constant with increasing angular velocity for both sprinters and endurance runners. With gravity correction, Fillyaw *et al*

(1986) reported that the ratio was significantly decreased from 0.54 at 60°/sec to 0.51 at 240°/sec in 27 female university soccer players. Our results were the same as Appen and Duncan(1986). The ratio was remained constant 61.5% in male and 57.6% in female with increasing angular velocity and significantly different between male and female with normal untrained subjects. The disparity between the results of Fillyaw *et al.* (1986) and the results of this study may be due to differences in test subjects and methods or isokinetic speed.

Lower extremity bilateral peak torque relationships for quadriceps and hamstrings have been previously reported in isokinetic testings. The resulting measured muscle torque of both the right and left extremities under ordinary circumstance is generally assumed to be equal, or "in balance" (Grace *et al.* 1984). Golslin and Charteris (1979) reported that there was a significant difference between dominant and nondominant limbs except in the difference between right and left limbs in a young adult. Wyatt and Edwards (1980) reported that there was a significant difference in the male population but not in the female group. Perrin *et al.* (1987) and Kim and Kim (1987) found no significant difference between dominant and nondominant limbs. Our findings did not show significant difference between dominant (right) and nondominant (left) limbs in isokinetic and isometric torques for both sexes. This discrepancy between reports on strength of bilateral lower extremities may be due in part to how dominance was defined by each of the authors.

It is known that muscle strength is influenced by numerous anthropometric characteristics such as age, height, weight, and muscle cross-sectional area (Alexander and Molnar 1973; Watson and O' Donovan 1977; Schantz *et al.* 1983; Dibrezzo *et al.* 1985). Johnson (1982) reported that significant correlation was found between height and isometric and isokinetic strength. Weight was also found to correlate significantly with isometric strength. Froese and Houston (1985) reported that correlation analyses between corrected peak torque at the angluar velocities studied and body weight (Kg) did not reveal a significant linear relationship for either subject group. This result was that height had significant positive correlation with peak isometric and isokinetic torques for both quadriceps and hamstrings, and, also, that weight was found to correlate significantly with peak isometic and isokinetic torques.

The peak isometric torque has been recorded from 50° to 85° for quadriceps (Lindahl *et al.* 1969; Haffajee *et al.* 1972; Osternig 1975; Knapik *et al.* 1983), and from 20° to 30° for hamstrings (Scudder 1980; Knapik *et al.* 1983).

This studies showed 75° in male and 60° in female for quadriceps, and 15° in both sexes for hamstrings. This disparity between the previous results and our result may be due to differences in test position, test angle, and subjects. Knapik *et al.* (1983) reported no significant differences between 80° to 50° of men and between 60° to 75° of women for isometric torque of quadriceps.

Similarly, we found no significant differences between 60° and 75° for both sexes in this study. For isometric torque of hamstrings, Campney and Wehr (1965) reported that no significant differences appeared within the joint angle range segment 0°-60°, and Knapik *et al.* (1983) reported no significant differences between 20° to 40° for men and between 15° and 30° for both sexes.

Our findings are consistent with those of other investigators who found higher isometric than isokinetic torque for quadriceps and hamstrings (Thorstensson *et al.* 1976; Murrary *et al.* 1980; Scudder 1980). For this finding, Murray *et al.* (1980) reported that, according to muscle physiology, the amount of muscle tension developed is determined by the number of bridges formed between the actin and myosin filaments as they slide past each other during a contraction. Theoretically, in an isometric contraction, in which a relatively small amount of fiber shortening occurs, there is sufficient time for the maximum number of corss-bridges to be formed, thus allowing maximum tension to develop. In a shortening contraction, the speed of contraction limits the number of cross-bridges that have to be formed and thus decreases the tension that can be developed within the muscle.

Scudder (1980) reported that the differences between isometric and isokinetic torque became greater as the muscle shortened during flexion or extension (knee angle 30° to 60°). Murray *et al.* (1980) tested joint angles at 30°, 45°, and 60° and reported that differences occurred at the more flexed angle(60°) for quadriceps and at the more extended angle (30°) for hamstrings. Our results were the same as Murray *et al.*(1980); the differences occurred at the more flexed angles (60° to 90°) for quadriceps and at the more extended angle(15°) for hamstrings. This disparity between Scudder's results and ours may be because the gravity effect torques were not considered in Scudder's report. Murray *et al.* (1980) reported that the concept of an initial internal transfer of force might explain the lower ratios of isokinetic to isometric torque at the beginning of the range of motion compared to the ratios nearer toward end of the range of motion. Another explanation may be that the antagonists exerted nearly constant opposing torque throughout the joint range of motion in isokinetic test (Baratta et al. 1988).

In this study we found no significant differences in the isokinetic torques of quadriceps and hamstrings at the end of range of motion. This may be because the antagonists exerted nearly constant opposing torque throughout the joint range of motion in isokinetic test (Baratta et al. 1988). Also, at lowest speeds, the increased duration of effort are needed to provide higher muscle tension; many subjects could not tolerate the discomfort of effort at 30°/sec.

According to our findings, the gravity effect torque during an isokinetic test in antigravity position should be considerd. The clinical use of isokinetic exercises for the purpose of strengthening or improving endurance needs to be evaluated on a comparative basis and bilateral comparison. We hoped that the outcome of this study provides useful guidelines for normal untrained young adults and helps to establish the maximum rehabilitative goals the physician can use to return the patients to a productive life style. Further studies are needed for isometric and isokinetic testings of adolescents and the elderly and for the evaluation on power-velocity relationships.

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