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Eccentric and concentric isokinetic knee flexion and extension: a reliability study using the Cybex 6000 dynamometer

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Abstract

***Objective*—To determine the reliability of the Cybex 6000 isokinetic dynamometer in measuring the knee muscle performance concentrically and eccentrically.**

***Methods*—18 male and 12 female subjects with no previous knee injuries, who had not previously undergone any isokinetic testing, were studied. The flexor and extensor muscles groups of both knees were tested at 60° s^{-1} and 120° s^{-1} with the continuous concentric-eccentric cycle testing protocol. Variables studied included peak torque, total work, and average power. The interclass correlation coefficient (ICC 2,1) was used to determine the reliability with $P < 0{\cdot}05$.**

***Results*—Peak torque showed significantly greater ICC than the total work and average power, with test-retest reliability ranging from 0·82 to 0·91 for peak torque, from 0·76 to 0·89 for total work, and 0·71 to 0·88 for average power. Average variability for the three variables studied ranged from 9% to 14%. The ICCs for the three variables studied were significantly greater at 120° s^{-1}. The knee extensor muscle group showed greater test-retest reliability, and the results of isokinetic testing in the concentric contraction mode were more reproducible.**

***Conclusions*—The Cybex 6000 isokinetic dynamometer shows high reliability in measuring isokinetic concentric and eccentric variables. Some fluctuation should be allowed when evaluating variations of muscle performance between tests.**

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Key terms: reliability; isokinetic testing; concentric contraction; eccentric contraction

Isokinetic assessment of muscle performance is widely used for epidemiological studies, for performance prediction, and for rehabilitation purposes.[1-9] Several such dynamometers are now commercially available, the existing dynamometers are constantly upgraded, and new brands are coming on the market.

Several investigators studied the reliability of various isokinetic muscular variables.[1 2 10-29] Harding *et al* studied test-retest reliability of concentric peak and average torques of the knee extensor and flexor muscles using the Kin-Com.[13] Feiring *el at* measured peak torque and total work output of knee extensor and flexor muscles using the Biodex dynamometer.[30] In both studies, high test-retest reliability interclass correlation coefficients (ICCs) were shown (ICCs 0·936 and 0·952, respectively).

Using the Kin-Com, eccentric peak torque values of the knee extensor muscle group showed excellent reliability (ICC 0·94),[14] while Tredinnick and Duncan[10] reported moderate to good reliability (ICCs 0·47 to 0·86) for eccentric peak torque of the knee extensor muscle group. Using the Lido Active dynamometer, McCrory *et al*[12] reported that the reliability of eccentric contractions of the knee extensor muscle group was less good than concentric reliability, and Steiner *et al*,[1] in subjects both with and without tibio-femoral pathology, reported moderate to excellent reliability in average peak torque (ICCs 0·58 to 0·96), total work (ICCs 0·63 to 0·93), and power (ICCs 0·67 to 0·93) for knee eccentric muscle performance.

Recently, Frontera *et al* studied test-retest reliability of the knee extensor and flexor muscles in 178 45 to 78 year old subjects of both sexes using the Cybex II+ dynamometer.[19] They concluded that at least two tests should be performed to determine average peak torque accurately in older subjects.

Bandy and McLaughlin[17] studied the intra- and interdynamometer reliability of concentric muscle contraction using the Cybex II+ and the Cybex 6000, concluding that the two dynamometers were comparable when measuring concentric muscle contraction.

In this study we determined the reliability of the Cybex 6000 isokinetic dynamometer by measuring knee flexor and extensor muscle performance both concentrically and eccentrically.

Methods

The knee flexor and extensor muscle groups of the dominant and non-dominant knee were tested in 18 males (age 27, SD 6·9 years) and 12 females (age 26, SD 5·8 years) (table 1) with no previous knee injury. Dominance was determined by asking the subjects to kick a ball placed in front of them. None of the subjects had previously undergone isokinetic testing.

Table 1 Demographic data

Subjects	*n*	*Age (years)*		*Height (cm)*		*Weight (kg)*	
		Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Male	18	27	6·9	174	4·19	67	6·67
Female	12	26	5·8	163	3·65	54	4·72

DYNAMOMETER

All tests were performed using the Cybex 6000 isokinetic dynamometer calibrated before and after each test according to the manufacturer's instructions.[31] RCTL performed all the calibrations and tests, which were always supervised by at least one of the other authors.

TESTING PROTOCOL

Several protocols have been used to test knee flexor and extensor muscles performance concentrically and eccentrically.[2 11 13 18 32 33] Some examples are isolated concentric knee extension,[18 32] concentric knee extension-flexion cycles with[13] and without[11] pause, continuous passive movement mode,[12] and concentric-eccentric knee extension cycle with[10] and without[1 2 32 34–38] a pause between cycles. The continuous concentric-eccentric contraction cycle,[1 2 33 35–38] originally described by Bennett *et al*[33] and subsequently used by Kramer,[2] was applied in this study.

The knee extensor and flexor muscle groups were bilaterally tested at the angular velocities of 60° s^{-1} and 120° s^{-1} with five cycles at each velocity. The muscle contraction variables measured were average peak torque, average peak torque, total work output, and average power.

POSITIONING

Each subject was positioned on the knee testing table of the Cybex 6000 isokinetic dynamometer with the stabilisation straps across the chest, and a horizontal pad over the middle third and proximal half of the distal third of the thighs.[31] The trunk was leaning against the back rest of the testing table. This was inclined so that the hips were at an angle of 110° with the trunk. The knee joint axis was aligned with the mechanical axis of the dynamometer. The shin pad was placed just superior to the medial malleolus, and the two stoppers were anchored to allow 85° of movement from 5° to 90° of knee flexion.[31]

TEST SEQUENCE

Each subject was tested on two separate occasions at the same time of the day (± 2 h) 4 to 10 d apart, using the same warm up routine and the same testing protocol. On the first visit, demographic data were obtained, and leg dominance was determined. Before starting the actual test, a standard adaptation session included a detailed explanation of the difference between concentric and eccentric contractions, and gave the opportunity for the subject to experience how these muscle actions were going to be tested. Before the test, each subject performed a 3 min general warm up including stretching exercises to the lower limb muscles. Immediately after the warm up, each subject was positioned on the knee testing table. Each test consisted of a trial phase of three continuous concentric-eccentric cycles, a 1 min rest, and an actual test phase of five continuous concentric-eccentric cycles. Of the three trial cycles, the first two were submaximal, and the final one was maximal. Subjects received verbal encouragement to produce maximal efforts throughout the five cycles of the actual test phase.

The knee extensor muscle group of the dominant limb was tested first at 60° s^{-1}, and then at 120° s^{-1}, with a 2 min rest between the two speeds. Each subject was instructed to extend the knee from 90° to 5° of flexion against the shin pad of the dynamometer arm during the concentric phase, and then to resist the dynamometer as it pushed in the opposite direction from 5° to 90° of knee flexion during the eccentric phase.

After a 3 min rest, the dominant knee flexor muscle group was tested. Each subject was instructed to flex the knee from 5° to 90° during the concentric phase, and then to resist the dynamometer from 90° to 5° of knee flexion during the eccentric phase. The non-dominant knee was then tested in exactly the same manner as the dominant one after a 5 min rest.

DATA ANALYSIS

Although it is acknowledged that there can be significant interactions between dominant and non-dominant sides, the results for each limb were considered separately. Data were entered in the Microsoft Excel V.4.0 database.[39] Descriptive statistics was calculated. A paired t test was used to compare the averages of all the individual variances between the two tests.

The interclass correlation coefficient (ICC 2,1) was used to determine the reliability of peak torque, average torque, total work and average power obtained from each test.

The percentage difference for all the variables between the two tests were calculated using the formula:

$$\frac{\text{Result of the 1st test} - \text{result of the retest}}{\text{Result of the 1st test}} \times 100$$

Significance was set at $P = 0{\cdot}05$.

Results

Descriptive statistics concerning peak torque, total work, and average power for all the muscles tested in males and females in both tests, and the percentage difference between the two tests, are given in tables 2, 3, and 4.

Males were significantly stronger than females, and were able to produce a higher total work and to express a significantly higher average power during the tests (Student's t test, $0{\cdot}05 < P < 0{\cdot}001$) (tables 2, 3 and 4).

No significant dominance or gender differences were found in the ICC values for peak torque, average torque, total work, and average power between the two tests ($P > 0{\cdot}05$, paired t test).

All the variables studied (peak torque, total work and average power) showed high reliability between the two tests with a significance of less than 5% (tables 5 and 6). The averages of the percentage differences for peak torque were 9·5(SD 2·07)% for the knee extensor muscle group and 9·02(3·18)% for the knee flexor muscle group; for total work the values were 11·9(3·95)% for the knee extensor muscle group and 13·7(2·58)% for the knee

Table 2 Peak torque (in Nm) and percent difference (% Diff) values during eccentric and concentric contractions of knee extensor and knee flexor muscles in session 1 and 2. Values are mean(SD) (P < 0·01).

	Knee extensor muscle			*Knee flexor muscle*		
	Session 1	*Session 2*	*% Diff*	*Session 1*	*Session 2*	*% Diff*
Male (n = 36)						
Concentric						
60° s^{-1}	176·2 (37·0)	173·5 (34·8)	7·0 (4·3)	93·5 (15·6)	96·1 (17)	11·5 (6·9)
120° s^{-1}	148·8 (34·1)	152·4 (28·6)	8·3 (7·2)	90·4 (17·4)	93·7 (18·1)	9·3 (7·5)
Eccentric						
60° s^{-1}	195·0 (46·7)	193·1 (53·5)	10·6 (7·5)	105·2 (17·8)	103·0 (22·3)	6·5 (4·7)
120° s^{-1}	196·9 (57·0)	197·0 (54·4)	11·6 (15·0)	111·7 (22·4)	105·6 (25·1)	9·9 (6·5)
Female (n = 24)						
Concentric						
60° s–1	99·5 (16·6)	100·5 (17·9)	6·6 (5·1)	55·7 (7·7)	54·8 (9·0)	6·3 (5·7)
120°	82·0 (13·7)	84·0 (12·3)	11·0 (9·2)	52·4 (10·4)	51·7 (9·3)	4·5 (3·0)
Eccentric						
60° s^{-1}	122·2 (30·7)	124·6 (30·4)	11·9 (8·4)	64·8 (13·8)	62·3 (13·2)	9·8 (9·7)
120° s^{-1}	125·9 (30·1)	121·2 (31·7)	8·9 (7·9)	66·9 (15·8)	65·9 (10·9)	14·4 (10·9)

Table 3 Total work (in J) and percent difference (% Diff) values during eccentric and concentric contractions of knee extensor and knee flexor muscles in session 1 and session 2. Values are mean(SD) (P < 0·01).

	Knee extensor muscle			*Knee flexor muscle*		
	Session 1	*Session 2*	*% Diff*	*Session 1*	*Session 2*	*% Diff*
Male (n = 36)						
Concentric						
60° s^{-1}	160·9 (31·6)	161·3 (32·3)	5·4 (4·1)	90·1 (18·9)	90·1 (18·4)	11·9 (9·9)
120° s^{-1}	144·9 (34·8)	150·5 (28·1)	9·9 (7·6)	80·7 (18·4)	87·0 (16·8)	12·8 (13·5)
Eccentric						
60° s^{-1}	167·3 (37·1)	173·9 (44·9)	12·7 (8·7)	97·7 (23·2)	99·0 (23·8)	14·8 (11·8)
120° s^{-1}	168·0 (49·5)	178·6 (46·0)	13·5 (16·9)	101·2 (29·3)	98·7 (22·9)	13·0 (8·8)
Female (n = 24)						
Concentric						
60° s–1	98·6 (15·3)	101·3 (16·3)	10·0 (8·5)	51·1 (10·6)	53·9 (7·5)	15·3 (11·5)
120°	85·6 (13·1)	86·9 (13·8)	10·0 (7·9)	45·7 (8·9)	45·4 (8·8)	9·1 (8·0)
Eccentric						
60° s^{-1}	105·0 (29·9)	113·9 (30·4)	18·5 (20·8)	60·1 (15·4)	61·8 (16·2)	17·7 (13·4)
120° s^{-1}	112·8 (31·5)	119·7 (31·5)	14·9 (18·7)	60·0 (14·5)	63·3 (16·0)	14·7 (9·2)

Table 4 Average power (in W) and percent difference (% Diff) values during eccentric and concentric contractions of knee extensor and knee flexor muscles in session 1 and session 2. Values are mean(SD) (P < 0·01).

	Knee extensor muscle			*Knee flexor muscle*		
	Session 1	*Session 2*	*% Diff*	*Session 1*	*Session 2*	*% Diff*
Male (n = 36)						
Concentric						
60° s^{-1}	110·4 (22·9)	111·7 (22·7)	6·1 (4·5)	61·8 (12·2)	62·4 (126)	12·1 (9·1)
120° s^{-1}	195·3 (51·5)	201·2 (38·1)	10·9 (7·9)	110·5 (25·4)	117·6 (24·8)	15·1 (13·5)
Eccentric						
60° s^{-1}	112·0 (24·8)	117·1 (29·6)	6·0 (11·8)	14·64 (15·4)	65·3 (16·7)	14·8 (12·8)
120° s^{-1}	213·7 (61·3)	229·7 (58·4)	13·5 (17·9)	126·0 (36·8)	122·3 (28·3)	12·0 (10·3)
Female (n = 24)						
Concentric						
60° s–1	66·9 (12·8)	70·1 (11·9)	11·2 (11·1)	37·1 (8·5)	37·7 (8·1)	16·4 (11·2)
120°	113·9 (18·9)	115·2 (19·8)	12·3 (9·8)	62·9 (12·2)	61·2 (13·5)	11·7 (8·7)
Eccentric						
60° s^{-1}	72·9 (18·9)	79·6 (18·1)	16·9 (16·9)	40·5 (10·2)	42·1 (10·7)	16·3 (13·9)
120° s^{-1}	137·7 (39·4)	153·6 (40·5)	16·3 (19·2)	74·1 (18·3)	79·7 (20·4)	14·6 (9·2)

Table 5 Interclass correlation coefficients (ICCs) for eccentric knee extensor and flexor muscle groups peak torque, total work, and average power (P < 0·05)

	Peak torque		*Total work*		*Average power*	
	60° s^{-1}	*120° s^{-1}*	*60° s^{-1}*	*120° s^{-1}*	*60° s^{-1}*	*120° s^{-1}*
Male (n = 36)						
Knee extensor	0·84	0·86	0·83	0·83	0·80	0·84
Knee flexor	0·83	0·83	0·78	0·88	0·77	0·86
Female (n = 24)						
Knee extensor	0·82	0·83	0·80	0·81	0·83	0·83
Knee flexor	0·83	0·84	0·78	0·82	0·76	0·84

Table 6 Interclass correlation coefficients (ICCs) for concentric knee extensor and flexor muscle groups peak torque, total work, and average power (P < 0·05)

	Peak torque		*Total work*		*Average power*	
	60° s^{-1}	*120° s^{-1}*	*60° s^{-1}*	*120° s^{-1}*	*60° s^{-1}*	*120° s^{-1}*
Male (n = 36)						
Knee extensor	0·90	0·91	0·82	0·89	0·85	0·88
Knee flexor	0·84	0·88	0·83	0·82	0·80	0·82
Female (n = 24)						
Knee extensor	0·83	0·85	0·81	0·84	0·80	0·82
Knee flexor	0·82	0·90	0·76	0·84	0·77	0·83

flexor muscle group; and for average power, they were 12·7(3·44)% for the knee extensor muscle group and 14·1(1·93)% for the knee flexor muscle group.

Discussion

In this study, we used a continuous concentric-eccentric test cycle[2], as it should reflect physiological activities during which different muscle actions are employed cyclically, rather than isolated concentric or eccentric actions. A slight modification of the original protocol[2 33] was to increase the number of repetitions from three to five to maximise the chances that maximum strength production would occur after the third contraction.[18 32 40]

In agreement with previous studies,[2 10 11 17 41 42] peak torques of both knee extensor and extensor muscle groups obtained from continuous concentric-eccentric cycles at the angular velocity of 60° s^{-1} and 120° s^{-1} were highly reliable (ICCs 0·82 to 0·92). Total work and average power reliability during knee extension and flexion was also high.[2 10]

In most instances, the ICCs of peak torque at 120° s^{-1} were greater than those at 60° s^{-1} (table 1),[2] in contrast with the report of Steiner *et al*.[1] A possible reason for this observation is that subjects found it more difficult to maintain maximum effort throughout the entire range of motion at the slower speed. This would also explain why the reliability of total work and average power were greater at the faster speed.

The majority of concentric peak torque and total work ICCs tended to be higher than those obtained with eccentric contraction modes,[11] while the average concentric and eccentric power ICCs were similar.[2] Although eccentric muscle action is physiologically part of normal activity, eccentric testing is unusual, possibly resulting in inhibition of maximum contraction in unaccustomed individuals. This may explain why eccentric muscle tests showed lower reliability than concentric tests.

When considering the different muscle groups, the ICCs associated with knee extension were greater than those produced by knee flexion. Also, ICCs tended to be slightly higher in males. The ICCs associated with total work and average power tended to be lower than those associated with peak torque.

Considerable inter-test variation has been reported when measuring muscle performance.[1 11 43] Thorstensson *et al*, testing isokinetic concentric knee extension in a test-retest design on separate days, found a 13·7% difference in peak torque.[43] Steiner *et al* reported a 14% difference in average peak torque, and a 20% difference in total work and average power between two tests,[1] while Montgomery *et al* found a 7% difference in concentric knee muscle actions between tests.[11] In the present study, we found differences ranging from 9·0% to 9·5% for average peak torque, from 11·9% to 13·7% for total work, and from 12·7% to 14·1% for average power. Some fluctuation should be allowed when evaluating changes of muscle performance between tests, as even a 15% change between two tests may not constitute a significant improvement or deterioration in muscular performance.[1]

In conclusion, the Cybex 6000 isokinetic dynamometer shows high reliability in measuring isokinetic concentric and eccentric peak torque, total work, and average power of knee extensor and flexor muscle groups at the angular velocities of 60° s^{-1} and 120° s^{-1} when using the continuous concentric and eccentric cycle. Isokinetic concentric strength measurements were more reliable than the measurements of eccentric strength. The ICCs for the three variable studies were greater at 120° s^{-1} than at 60° s^{-1}. The measurements of the knee extensor muscle group were slightly more reliable than those of the knee flexor muscle group. Although the continuous concentric-eccentric cycle testing protocol offers a clinically viable testing method, individual reliability should probably be established on selected patients.

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