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MEASUREMENT OF TORQUE OF TRUNK FLEXORS AT DIFFERENT VELOCITIES

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ABSTRACT. The purpose of this study was to determine the test-retest reliability of recording isometric and isokinetic torque of the trunk flexors and to examine the effect of velocity on the torque curves. Thirty healthy subjects were tested on two occasions for isometric torque of trunk flexion at four angles and eccentric and concentric torque at three velocities. Two subjects repeated these tests in the passive mode to determine the torque produced by the trunk when there was no active flexion effort. Intraclass correlation coefficients were above 0.85 for all isometric and isokinetic measures. Standard errors of measurement ranged from 6.9 to 19.5 Nm. Student *t*-tests indicated no significant differences between occasions for all outcome measures. Examination of passive and active torque curves indicated that the torque produced by the mass of the trunk increased with increasing velocity. It is concluded that both isometric and isokinetic testing of the trunk flexors are reliable, but that testing at higher velocities may not provide a valid measure of muscle performance.

Key words: abdominal wall, isometric contraction, isotonic contraction, exercise test.

Several investigators have used quantitative strength assessment of the trunk muscles to gain more information on low back pain (2). However, differences in test protocols and equipment have contributed to the variability of study findings (2). Protocol variations include the test velocities, the test range of motion and the type of muscle contraction. Only a limited number of investigators (5, 18) have reported on the reliability and validity of their test procedures.

The velocities used in the isokinetic testing of the trunk muscles have ranged from 15° to 180°/s (4, 7, 22). Thorstensson & Nilsson (22) limited test velocities to 30°/s. They stated that, at high velocities, the large mass of the trunk prolongs the acceleration phase and increases the 'overshoot' that occurs at the end of this phase. Langrana et al (10) found that torque characteristics were similar at 30°/s and 60°/s, and therefore tested at the lower velocity only. However, others (4, 20) reported that velocity affects flexor/extensor torque ratios and the difference in torque between patients and normal subjects. The validity of testing at different velocities has not been established.

The test range of motion used in the isokinetic testing of the trunk muscles has also varied considerably. Smidt et al (15–19) tested through a range from 15–20° extension to 30–40° flexion. Other investigators (4) have reported flexion movements up to 90°. As the average total flexion-extension range of motion of the lumbar spine is reported as approximately 50°–70° (3, 8, 25) larger test ranges must include movement at other joints. From the figures of test setups (20), it would appear that this extra motion is occurring at the hip joint. Some authors (20, 21) even refer to the role of hip muscles such as the glutei and hamstrings in the performance of the trunk motion.

Most of the early studies (11, 23) included only isometric contractions because of the need to develop special equipment. With the introduction of isokinetic dynamometers, concentric torque of trunk muscles was also tested (19). Smidt et al. (15–18), however, are the only investigators who have reported on the eccentric torque of trunk muscles.

Only a few authors have reported the reliability of their measures (5, 12, 19, 20). Smidt et al. (19) reported good reliability (0.92–0.99) between trials of concentric contractions, and an average of 13% error when 4 subjects were tested on two separate days. Smith et al. (20) tested reliability on 4 females and 11 males and reported high Pearson Correlations. However, there were no reliability coefficients, no estimates of error, and no analyses of differences. Smidt et al. (18) reported good reliability of concentric and eccentric trunk strength measures, but in a small number ($n=7$) of subjects. Delitto et al (5) reported intraclass correlations and standard error of measurement for a larger number of subjects, but only for concentric torque.

It was the purpose of this study to examine the test-retest reliability of measuring isometric and isokinetic trunk flexion torque. Both concentric and eccentric contractions were tested, the movement was isolated to the lumbodorsal spine, and the sample was heterogeneous. A second objective was to describe the effect of velocity on the torque produced by the trunk.

SUBJECTS AND METHODS

Subjects were 15 healthy men and 15 healthy women between the ages of 18 and 56. They were not undergoing any special training for the abdominal muscles. Informed consent was obtained from all subjects, and the study was approved by the Faculty Ethics Committee.

The subjects were tested on a KinCom (Med-Ex Diagnostics, Coquitlam, BC, Canada) dynamometer on two occasions five to eight days apart for torque of isometric flexion at four angles and isokinetic flexion at three velocities. The order of testing isometric and isokinetic contractions was randomly assigned to the subjects, but remained the same for each subject over the two test sessions.

For all tests, the subjects were seated on the KinCom table with the pelvis stabilized in the trunk testing unit (Fig. 1). The posterior pad fit firmly against the sacrum, while the anterior arms fit firmly against the anterior superior iliac spines. The thighs were fully supported on the table with the knees bent over the front edge and the lower legs stabilized with pads against the shins. Gravity compensation was not used.

The special KinCom lever arm for trunk testing was used. Its centre of rotation was aligned with the level of the highest point on the crest of the ilium in the mid coronal plane of the trunk (Fig. 1). With the lever arm vertical and the trunk in neutral position, the resistance pad was adjusted in the vertical and anterior/posterior positions until it rested comfortably against the sternum and ribs at the level of the sternal angle. The vertical and horizontal distances of the resistance pad were recorded, and exactly the same set-up was used for the second test session. Subjects were instructed to keep their arms by their sides and push the trunk maximally against the lever arm. Verbal encouragement was used for all tests. Each test was preceded by a submaximal warm-up of the test contractions.

Three-second isometric contractions were performed at trunk angles of 20° extension and 0°, 20° and 40° of flexion with a 10 second rest between each angle. This entire test was performed three times with a two minute rest between tests. Isokinetic tests were performed through a range from 20° extension to 40° flexion (range = 60°) with the subject completing three maximal concentric and eccentric contractions at each of the three velocities (30°, 60° and 90°/s). Testing was not performed at higher velocities because of the whiplash effect on the head and trunk. The pause between successive contractions was 0.25 s, and the minimum force was set at 20 N. There was a two minute rest between the tests at different velocities.

Intraclass correlation coefficients (ICC), type 1,1 (14) were used to determine the test-retest reliability of the peak and average torque of eccentric and concentric contractions at the three velocities, and the reliability of the peak isometric torque at the four angles. Dependent t-tests were used to examine differences between test sessions for each of the outcome measures. The variability in measurement was expressed as the standard error of measurement (SEM) (1). The torque measures at different angles of trunk flexion were not compared because the data were not adjusted for the effects of gravity.

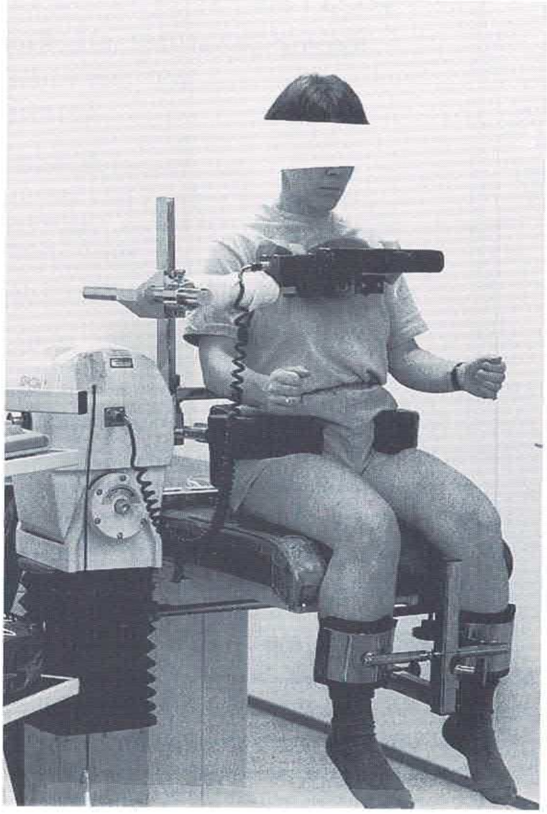

Fig. 1. Subject in KinCom test set-up showing pelvic stabilization unit and lever arm for testing of trunk strength.

To describe the artifact produced by the movement of the trunk at different velocities, two subjects were tested for both passive and active torque of trunk flexion. To measure passive torque, the subjects were set up exactly the same way as for the active exercise. The KinCom was set in the passive mode, and the subject's trunk was strapped to the dynamometer arm. During the exercise, the subject's trunk was flexed and extended passively through the test range. The exercises were repeated several times until the subject was relaxed throughout the movement and the resulting torque curves were consistent. The passive motion was performed at the three velocities used in the active tests. The active and passive torque-angle curves were graphed and compared visually for magnitude and shape.

RESULTS

The means and standard deviations for all the outcome measures are presented in Tables I and II. The

Table I. *Peak torque (Nm) of isometric trunk flexion—mean and standard deviation ( ), intraclass correlation coefficients (ICC), and standard error of measurement (SEM) in Nm*

	Angle			
	−20°	0°	20°	40°
Test 1	132.7 (56.6)	142.0 (53.5)	144.0 (49.6)	127.2 (43.2)
Test 2	132.5 (57.1)	144.5 (58.0)	143.2 (55.2)	126.3 (43.9)
ICC	0.97	0.97	0.94	0.89
SEM	9.6	9.9	12.7	14.5

test-retest reliability coefficients and SEMs are presented in Tables I and III. All coefficients were between 0.86 and 0.97. There were no significant differences between test sessions for any of the outcome measures.

Samples of active and passive torque-angle curves are presented in Figs. 2 to 4. The shapes of the curves were the same for both subjects, but the height of the deflections were greater for the heavier subject. The peak torque produced by the passive movement of the trunk from flexion to extension increased with increasing velocity and corresponded in time and magnitude to the peak of the active torque curve at the same velocity.

DISCUSSION

The present study is the first to examine between-day reliability of the isometric, concentric and eccentric torque of the trunk flexors isolating the movement to the spine and using a large heterogeneous sample. It is also the first study to demonstrate that the motion of the trunk contributes more and more to trunk flexion torque as the test velocity increases.

The high ICC values and the t-test results reported in this study indicate that isometric and isokinetic torque of the trunk flexors can be measured reliably in healthy subjects. These results are similar to those found for concentric-eccentric testing at lower velocities (18) and for concentric testing alone (5).

The SEMs can be used to estimate the limits of the true score of an individual (1). For example, the SEM for peak eccentric torque at 30°/s was 19.6 Nm, indicating that the true score for an individual could be the recorded value ±19.6 Nm. Thus, any improvement in score of less than 39.2 Nm could be due to measurement error. Delitto et al. (5) are the only other investigators to report SEMs for assessing the reliability of trunk flexion. They reported relative rather than absolute torque.

The effect of velocity on the shape of the torque curves can be explained by considering the factors contributing to the recorded torque. These factors are summarized in the following equation, considering flexion as the positive direction:

$$1. \quad M_N = M_f + \sin\theta\,(M_t + M_a) - (M_e + M_p + I\alpha)$$

where: M_N = net recorded flexor moment (torque), M_f = flexor muscle moment, θ = angular deviation of the trunk and the resistance arm from the vertical, M_t = moment produced by the trunk in the horizontal position, M_a = moment produced by the resistance arm of the dynamometer in the horizontal position, M_e = extensor muscle moment, M_p = extensor moment

Table II. *Torque (Nm) of isokinetic trunk flexion—mean and standard deviation ( )*

	Velocity					
	30°/s		60°/s		90°/s	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
Peak concentric	136.5 (45.7)	138.9 (58.1)	156.8 (49.7)	153.1 (51.6)	168.1 (55.0)	165.7 (53.2)
Average concentric	102.9 (39.5)	101.2 (43.9)	102.4 (35.4)	100.6 (37.3)	98.6 (34.8)	98.1 (34.0)
Peak eccentric	154.4 (51.2)	154.2 (63.3)	170.0 (52.8)	167.6 (55.4)	193.9 (57.6)	191.0 (59.1)
Average eccentric	116.0 (45.4)	118.9 (54.4)	120.9 (46.8)	122.0 (48.4)	122.2 (45.7)	124.7 (44.8)

Table III. *Intraclass correlation coefficients (ICC) and standard error of measurement (SEM) in Nm for isokinetic trunk flexion*

Peak Concentric			
ICC	0.86	0.93	0.94
SEM	19.5	13.3	13.6
Average Concentric			
ICC	0.90	0.93	0.96
SEM	12.8	9.5	6.9
Peak Eccentric			
ICC	0.88	0.96	0.96
SEM	19.6	11.5	11.5
Average Eccentric			
ICC	0.92	0.97	0.94
SEM	14.1	7.7	10.8

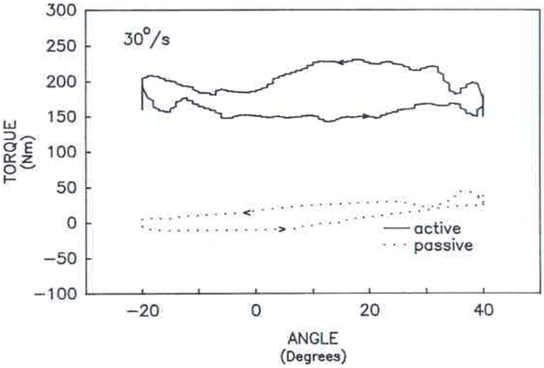

Fig. 2. Effect of trunk mass on torque at 30°/s. Both passive and active movement commenced at 20° extension. The direction of the arrows indicate the direction of trunk movement during the time each torque curve was recorded.

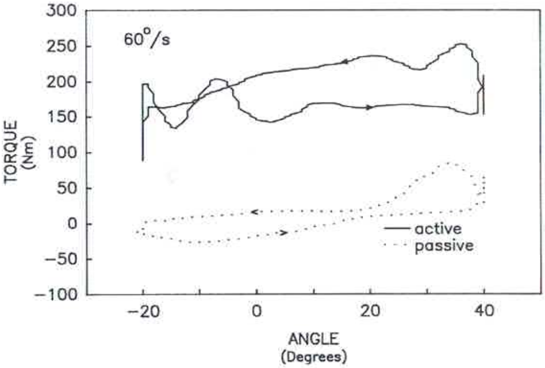

Fig. 3. Effect of trunk mass on torque at 60/s. Both passive and active movement commenced at 20° extension. The direction of the arrows indicate the direction of trunk movement during the time each torque curve was recorded.

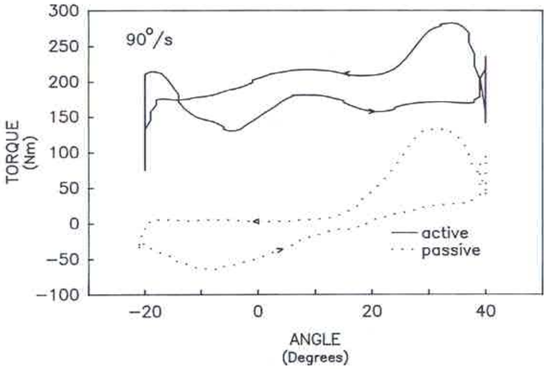

Fig. 4. Effect of trunk mass on torque at 90°/s. Both passive and active movement commenced at 20° extension. The direction of the arrows indicate the direction of trunk movement during the time each torque curve was recorded.

due to intraabdominal pressure, I = moment of inertia, and α-angular acceleration. M_e will be produced by cocontraction of the trunk extensors during a maximal flexor effort (9). Contraction of the abdominals also contributes to extensor torque by increasing the intraabdominal pressure (24). There is no way of calculating M_e and M_p in the present study. However, the purpose of the test was to measure the net flexor moment produced by the maximal effort of the subject.

In the passive exercise, when there is no muscle moment, the equation would be the following:

2. $M_N = \sin\theta\,(M_t + M_a) - I\alpha$

If the angular velocity remains constant (i.e. $\alpha = 0$), then the equation is reduced to:

3. $M_N = \sin\theta\,(M_t + M_a)$

and the resultant torque would vary as the sine of the angle.

During testing, the velocity is not constant at the beginning and end of the test range. Therefore, $I\alpha$ will either increase or reduce the recorded torque. Because I remains constant for any subject in this test situation, recorded torque will be increased due to the acceleration. On the KinCom, the acceleration, and thus the effect of $I\alpha$, is greater with increasing velocity.

The passive and active curves depicted in Figs. 2 to 4 demonstrate the combined effect of $\sin\theta\,(M_t + M_a)$ and $I\alpha$ at the beginning of both trunk flexion and extension. At the beginning of concentric flexion, the torque is deflected in a negative direction, because $I\alpha$ is negative (equation 1). However, because of the oscillations in the system, the negative deflection is followed by a positive deflection. At the beginning of the eccentric phase, an initial positive defection (because $I\alpha$ is now positive) is followed by a negative deflection.

Investigators have attempted to decrease the effect of the artifact on the results of isokinetic testing (17). One way is to measure the torque in the central range of the torque-angle curve, i.e. truncate the curve. This would be effective at slow velocities when the artifact only influences the torque in a small part of the range (18). However, when testing at high velocities, the acceleration phase (6, 13) and thus the artifacts comprise a major portion of the test range (see Fig. 4).

The effect of the artifact can also be reduced by determining the mean rather than the peak torque. Examination of the torque curves indicate initial peaks followed by valleys (or vice versa) at the beginning of each phase of the movement. These peaks and valleys tend to cancel out one another when the average torque is used. Table II demonstrates an increase in peak torque with increasing velocity; this trend is opposite to the normal torque-velocity characteristics of muscle. However, when the average is used as the outcome measure, torque remains relatively stable across velocities. Thus, mean torque is less affected by the artifact than is the peak torque.

On the newer KinCom model (Kin-Com 500H, Chattecx Corp, Chattanooga, TN, USA), the acceleration phase can be adjusted. Prolonging the acceleration phase would tend to decrease the artifact. However, the constant velocity would not be reached until well into the range of motion.

Based on the results of this study, it is recommended that isokinetic testing of trunk flexors be performed at low velocities, and with the pelvis well stabilized. The results support the view of Thorstensson & Nilsson (22) that testing at high velocities is inappropriate for the trunk.

CONCLUSIONS

Testing trunk flexor strength at high velocities does not provide accurate information on muscle effort because the magnitude of the artifact produced by the mass of the trunk increases with increasing test velocity. Isometric tests and isokinetic tests at 30°/s are reliable and display minimal artifact.

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