Reliability of Measurements of Concentric and Eccentric Isokinetic Loading

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The purpose of this study was to assess the reliability of a method for testing peak torque and work output of the knee extensor muscle during concentric and eccentric loading at three velocities of exercise (60°, 120°, and 180°/sec). Fourteen healthy men (23–32 years of age) performed exercises of the quadriceps femoris muscles during concentric and eccentric loading, with a five-second pause between each contraction. Three different tests were performed on different occasions. The first exercise session was a practice session, and the next two sessions were established to collect data in a test-retest format. Peak torque and work were measured for the two testing sessions. The results of this study demonstrated that with a very specific protocol, the reliability of concentric peak torque and work measurements was excellent at 60° and 120°/sec and good at 180°/sec. In contrast, reliability of eccentric peak torque and work measurements was good at 120° and 180°/sec but low at 60°/sec.

Key Words: Lower extremity, equipment; Muscle contraction; Muscle performance, measurement; Tests and measurements, general.

In 1965, Hill suggested that an instrument should be developed to record eccentric and concentric forces in human muscle. As early as 1969, Komi produced a dynamometer that measured forces at constant speeds during both eccentric and concentric exercise. This study investigates a relatively new dynamometer, the KIN/COM®, or “kinetic communicator.” The KIN/COM® is a hydraulically driven, microcomputer-controlled device designed to measure torque and work during eccentric and concentric isokinetic loading. The device’s controlled modes of exercise include isokinetic, isotonic (dynamic), and passive joint movement. When a subject performs a movement on the KIN/COM®, the dynamometer provides resistance via a rotating lever arm. The KIN/COM® and its on-line industrial microsystem computer are capable of recording concentric and eccentric torque and work at velocities of movement from 0° to 210°/sec. The purpose of this study was to assess the reliability of a method of measuring knee extensor muscle peak torque and work during eccentric and concentric exercise at three velocities of movement (60°, 120°, and 180°/sec) in 14 healthy male volunteers.

A major prerequisite for measurement of muscular performance is reliability. Reliability is defined as “consistency of a measurement when all conditions are thought to be held constant.” The mechanical reliability of the KIN/COM® dynamometer has been established; however, reports of the reliability of measurements during concentric and eccentric isokinetic exercise have not been published. A previous report by Griffin demonstrated some variability in test-retest peak torque values for elbow flexor muscles during concentric and eccentric exercise. She suggested that the variability in testing may be due to fatigue, incomplete stabilization, sequence of testing, and lack of familiarization with procedures. This study was conducted to assess reliability of an isokinetic testing protocol for the knee extensor muscles when mechanical stabilization, separation of eccentric and concentric exercise, and a prettrial practice session were incorporated into the testing procedure.

METHOD

Subjects

Fourteen healthy male volunteers between the ages of 23 and 32 years (X = 26 ± 3 years) from the university community participated in this study. Before testing, the subjects were informed of the procedure and risks of the study and signed an informed consent form. Subjects with any known lower extremity orthopedic problems were excluded from the study.

Instrumentation

We used the KIN/COM® dynamometer to measure knee extensor muscle peak torque at three velocities (60°, 120°, and 180°/sec). Work measurements were calculated by the on-line industrial microsystem computer of the dynamometer.

Sessions

Subjects were scheduled to participate in three exercise sessions on three separate occasions. The first session was designed to familiarize subjects with the
KIN/COM® and to control the effects of learning. This practice session simulated the actual test sessions. The first test session in which the torque and work data were recorded was held two days after the pretrial session. The second test session was conducted one week after the first test session. Each test session took place on the same day of the week and at the same time of the day in an attempt to ensure consistent activity levels.

Procedure

Each subject was positioned supine on the KIN/COM® such that the popliteal fossa of his right knee was against the front of the seat. The left hip and knee were flexed so that the foot rested flat on the elevated seat. A strap was secured across the subject's anterior superior iliac spines and around the bottom of the seat to stabilize the pelvis during exercise. The axis of rotation on the mechanical arm of the dynamometer was set about 2 cm inferior and 2 cm posterior to the anatomical axis of the right knee. This adjustment compensated for the inferior-posterior movement of the knee axis into the seat cushion during exercise. The mechanical arm of the apparatus was aligned with the subject's tested lower leg. A shin pad, attached to the distal end of the mechanical arm, was secured to the subject's leg about 5 cm superior to the medial malleolus. The lever arm radius was recorded for use in subsequent sessions. The purpose of standardizing the lever arm radius was to minimize any variability in measurement that would have been due to lever arm position. From this position, start and return angles for movement were set at 90° and 10° of knee flexion, respectively. These angles were set for each subject by goniometric measurements. The same examiner (T.J.T.) performed the testing procedures for all subjects.

Each session included five warm-up and three test repetitions of eccentric and concentric loading at each test speed (60°, 120°, and 180°/sec). Of the five warm-up repetitions, the first four were submaximal efforts and the final repetition was a maximal effort. A threshold force requirement of 50 N was arbitrarily imposed for the five warm-up contractions. During the three test contractions, this force requirement was increased to 150 N in an attempt to minimize force oscillation that often occurs during eccentric exercise on the KIN/COM®.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Intraclass Correlation Coefficients (Shrout and Fleiss Equation 1,1)* for Intertest Reliability</th>
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<tbody>
<tr>
<td>Mode</td>
<td>Speed</td>
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<tr>
<td>---------</td>
<td>--------</td>
</tr>
<tr>
<td>Concentric torque</td>
<td>.89</td>
</tr>
<tr>
<td>Eccentric torque</td>
<td>.47</td>
</tr>
<tr>
<td>Concentric work</td>
<td>.85</td>
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<tr>
<td>Eccentric work</td>
<td>.68</td>
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<tr>
<th>TABLE 2</th>
<th>Means and Standard Deviations for Peak Torque Values (in Newton-meters) During Trial 1 and Trial 2</th>
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<tr>
<td>Mode</td>
<td>Velocity (°/sec)</td>
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<tr>
<td>---------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Concentric</td>
<td>60</td>
</tr>
<tr>
<td>Concentric</td>
<td>120</td>
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<tr>
<td>Concentric</td>
<td>180</td>
</tr>
<tr>
<td>Eccentric</td>
<td>60</td>
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<tr>
<td>Eccentric</td>
<td>120</td>
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<tr>
<td>Eccentric</td>
<td>180</td>
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Fig. 1. Torque curves for eccentric and concentric loading at 60°/sec.
Each concentric and eccentric contraction was separated by a five-second pause. The purpose of the five-second pause was to allow the subject to rest between the concentric and eccentric efforts. Previous research by Komi has demonstrated that a concentric contraction is potentiated if it is preceded by an eccentric contraction. The potentiation of the concentric force is influenced by the time delay between the eccentric and concentric phases of exercises. We attempted, therefore, to minimize the effect of potentiation between the eccentric and concentric phases by introducing a five-second pause. A two-minute rest period was interposed between the warm-up and maximal test repetitions, and a threeminute rest period separated testing at each velocity.

Data Analysis

Average values for the torque and work produced during each contraction were recorded, and the means of the three concentric and three eccentric trials were computed for each subject at each velocity. We calculated intraclass correlation coefficients (ICC[1,1]) to determine the degree of agreement for the measurements during trial 1 and trial 2. In addition, we calculated means and standard deviations for peak torque and work measurements for both modes of exercise at each test velocity.

RESULTS

The ICCs for the paired torque measurements ranged from .47 to .97 (Tab. 1). Intraclass correlation coefficients for the paired work measurements ranged from .68 to .95 (Tab. 1). The mean values and standard deviations for the torque and work measurements during both modes of loading at all three velocities are reported in Tables 2 and 3.

DISCUSSION

We found that with our test protocol, at 60° and 120°/sec, ICC values for concentric measurements were higher than for eccentric measurements. At 180°/sec, however, ICC values were higher for eccentric loading than for concentric loading. The reliability of the concentric peak torque and work measurements was excellent at the two lower speeds and good at the highest speed. The reason for the low reliability measurements during slow-speed eccentric exercise is unknown. A visual analysis of our data, however, revealed that many subjects had more eccentric force oscillations, as described by Hart et al., at the lower velocities than at the highest velocity (Figs. 1–3). We believe that during eccentric isokinetic testing at 60°/sec, clinicians should be cautious in making major clinical decisions about neuromuscular performance of the knee extensor muscles from peak torque measurements.

We suggest that our reliability findings should not be generalized for all testing on the KIN/COM®. The following factors should be considered before generalizing on the basis of our results:

1. Our study was limited to the measurement of knee extensor muscle function in the isokinetic mode at three velocities of exercise (60°, 120°, and 180°/sec) in healthy subjects.
2. All of our subjects participated in a prettrial practice session with the KIN/COM®, which may have improved the reliability of the data.
3. The protocol included a five-second pause between eccentric and concentric loading to minimize the poten-
Fig. 3. Torque curves for eccentric and concentric loading at 180°/sec.

CONCLUSION

We have found that by using a very precise testing protocol, knee extension peak torque and work can be measured reliably during eccentric and concentric loading in healthy male subjects at 120° and 180°/sec. At 60°/sec, however, eccentric peak torque measurements are not as reliable as eccentric work measurements. We suggest that the force oscillations that occur during eccentric loading at 60°/sec may contribute to the variability in peak torque measurements.

Acknowledgments. We thank Kirk Johnson for his assistance in data analysis and John Firth of the Chattecx Corporation for loaning us a KIN/COM® for this project.

REFERENCES