PROSTHETICS/ORTHOTICS/DEVICES

Myotonometer Intra- and Interrater Reliabilities

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ABSTRACT. Leonard CT, Deshner WP, Romo JW, Suoja ES, Fehrer SC, Mikhailenok EL. Myotonometer intra- and interrater reliabilities. Arch Phys Med Rehabil 2003;84:928-32.

Objectives: To assess the intra- and interrater reliabilities of the Myotonometer®, a hand-held, computerized, electronic device that quantifies muscle stiffness (tone/compliance).

Design: Reliability study.

Setting: Research laboratory.

Participants: Thirty-five healthy, nondisabled adults (age range, 22–42y).

Interventions: Not applicable.

Main Outcome Measures: Two raters used the Myotonometer to evaluate subjects' lateral gastrocnemius and biceps brachii muscles. Muscles were measured in a relaxed state and during a voluntary isometric contraction. Coefficients were calculated for each muscle and each condition (relaxed, contracted). Results were analyzed by using Design II intraclass correlation coefficients.

Results: Reliability coefficients were highest when the instrument exerted moderate to strong forces against the muscle (range, 0.50–2.00kg; intrarater reliability R range, .84–.99; interrater reliability R range, .75–.96).

Conclusions: Myotonometer measurements had high to very high intra- and interrater reliabilities for measurements of the lateral gastrocnemius and biceps brachii muscles.

Key Words: Muscles; Myotonometer; Rehabilitation; Reliability and validity.

ACCURATE AND CLINICALLY viable (ie, not overly labor or time intensive) tests of muscle tone and stiffness and strength are among the most common and useful methods with which to assess different conditions. Examples include the effects of progressive central nervous system disorders, the fitness of an elite athlete, the effects of long periods of bedrest, and treatment intervention effectiveness. Unfortunately, the commonly used clinical tests are often the most inaccurate and unreliable. The most accurate research methods are too labor and/or time intensive to be of realistic clinical use.[1-3]

The Modified Ashworth Scale (MAS) and the assessment of deep tendon reflexes are perhaps the most commonly used clinical measures of muscle tone and spasticity.[4,5] These measures, however, are not quantitative, lack sufficient discriminative ranges, and cluster results into only a few grades.[5-9] Inherent in other biomechanical (eg, isokinetic pendulum tests) and electromyographic (eg, threshold angles and H-/M-reflex ratio) procedures are problems associated with overly complicated techniques, lack of interrater reliability, and poor validity.[7-9]

The quantitative assessment of muscle strength faces similar difficulties. The limitations of the manual muscle test (MMT), particularly above the grade of fair, are well documented and include the fact that testing is ordinal level data; therefore, there is not equal separation among grades, and the test is unable to detect small or moderate changes.[10,11] Hand-held dynamometers are an improvement, but the reliability and validity of measurements are affected by the strength of the tester, various problems encountered with healthy individuals at high force levels, stabilization, and confounding effects of muscle substitutions.[12,13]

Various isokinetic dynamometer testing devices and protocols have been established to better quantify muscle torque, but the results have been equivocal. Poor relationships between dynamometer and isokinetic testing results of muscle strength have been reported.[10] Reproducibility of results with some muscle groups has been questioned,[14,15] and some researchers have suggested that typical isokinetic testing protocols are unreliable and lack sufficient sensitivity.[2,16]

The Myotonometer®[a17] is a computerized, electronic tissue compliance meter that is capable of noninvasive assessment of muscle tone and stiffness at rest and during muscle contraction. Myotonometer data obtained from a relaxed muscle provide a direct measure of resting tone or stiffness of the muscle and underlying tissues. Data obtained during muscle contraction provide an indirect but valid measure of muscle strength.[17,18] This is possible because muscle stiffness increases linearly with force of contraction.[19-21] When a muscle fiber is stimulated, it becomes stiffer. Stiffness increases with the same time course as tension.[22] Tissue compliance meters have been used to assess muscle characteristics of healthy, nondisabled subjects and of individuals with various disabilities.[18,20,23,24] The devices have been used to measure the effects of nerve blocks, drugs, exercise, and physical therapy interventions.[20,25-27]

Previous studies have reported on the validity of using compliance meters and the Myotonometer to assess tone and strength differences of nondisabled individuals[28] and several medical conditions ranging from headache[26] to upper motoneuron involvement.[18] For an instrument or method to be truly valid, it must also be reliable.[29] The purpose of this study was to determine the intra- and interrater reliabilities of measurements taken with the Myotonometer.

METHODS

All procedures were approved by the University of Montana Institutional Review Board for Use of Human Subjects and conformed to the Helsinki Declaration.

Participants

A convenience sample of 35 healthy, nondisabled adults participated in this study. The mean age of the 32 subjects in the biceps brachii muscle test group was 27 years (age range,

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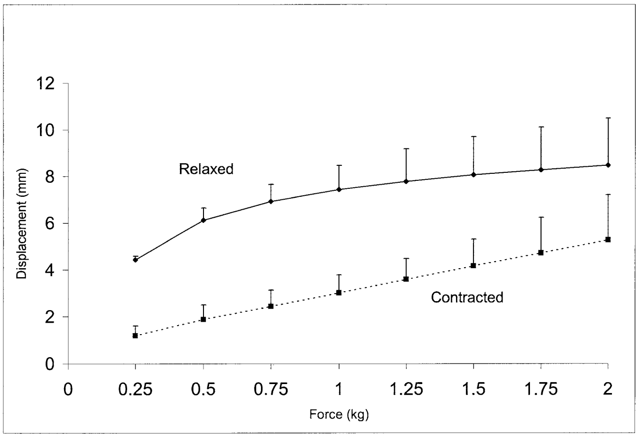

Fig 1. Myotonometer-generated graph showing millimeters of tissue displacement per kilogram of force (tissue resistance) for the relaxed and contracted biceps brachii muscle. The graph was generated by using group data obtained during intrarater reliability testing (table 2). Each data point represents the mean of the 32 subjects. Note the increased displacement per unit force during the relaxed state. NOTE. Error bars represent standard deviations.

22–42y). The mean age of the 33 subjects in the lateral gastrocnemius muscle (LG) test group was 27.5 years (range, 22–42y). Data from 2 biceps brachii and 3 LG test groups were not analyzed statistically secondary to missing data points resulting from examiner error at time of testing. Various somatotypes were represented. Subjects were not excluded from the study because of weight considerations. The biceps brachii and lateral gastrocnemius muscles were selected for measurement because an earlier validity study examined these muscles,[18] which are commonly tested clinically.

Instrument

The Myotonometer is a patented[17] electronic device that quantifies the amount of tissue displacement per unit force applied by a probe as it is pressed onto the skin overlying a muscle. The probe consists of an outer cylinder that remains stationary as an inner cylinder pushes onto and compresses underlying tissue. The distance between the outer and inner cylinders determines tissue displacement. The inner cylinder houses a force transducer that measures the amount of tissue resistance as the probe compresses the underlying tissue. Eight displacement measurements, corresponding to 8 increments of force (.25, .50, .75, 1.00, 1.25, 1.50, 1.75, 2.00kg), are obtained. Computational software creates force-displacement curves based on these data. A more compliant (lower tone) muscle will have more displacement per unit force than a muscle with less compliance (higher tone). Figure 1 shows a graph generated during Myotonometer muscle measurements at rest and during muscle activation.

Procedures

Two raters were involved in the study. For each subject, computer-generated random numbers, 1 or 2, determined the order of muscle testing (biceps brachii or lateral gastrocnemius). Computer-generated random numbers, 1 through 3, were used to determine rater order (1=rater 1; 2=rater 2; 3=rater 1). The number 3 was the second measurement by rater 1, whose measurements supplied the data used to determine intrarater reliability.

The right biceps brachii and lateral gastrocnemius muscles were tested. All subjects were right-hand dominant. For all measurements, subjects sat in an armchair with the elbow flexed to approximately 90° with the supinated forearm and the hand resting on the arm of the chair. Subjects' feet were placed shoulder-width apart, hips and knees were flexed to approximately 90°, with the ankles positioned close to neutral.

To determine the placement of the Myotonometer probe, a circle corresponding to the probe tip's diameter was drawn on the skin overlying the belly of each muscle. For the biceps brachii, this was located halfway between the most lateral aspect of the acromion process and the most distal aspect of the olecranon. For the lateral gastrocnemius, the distance from the superior aspect of the fibular head to the inferior aspect of the lateral malleolus was measured. One third of this distance (measured from the superior aspect of the fibular head) determined the location for measurement.

Each muscle was tested in a relaxed state and during a maximal voluntary contraction (MVC). Each rater placed the probe within the marked circle, maintained it perpendicular to the muscle, and pressed. The speed of applied pressure was not controlled. During biceps brachii testing, a hand-held force dynamometer[b] was secured to the right supinated palm. One end of an adjustable strap was attached to the chair, whereas the other was looped over the dynamometer. This setup provided the resistance needed to obtain MVCs and assured consistency of muscle torque output. For lateral gastrocnemius muscle testing, subjects stood on their right leg, placed their hands on a countertop for balance, and plantar flexed their weight-bearing ankle.

Each rater performed 5 probes of the muscle during the relaxed state and 5 probes during an isometric contraction. Computational software automatically averaged these measurements into a single data point for each force increment (.25–2.00kg). There was a 1-minute rest period between raters. During the isometric contraction tests, there was a 10-second rest period between measurements. All data were recorded and stored in a laptop computer for analysis. Neither rater had access to data results during testing. Individuals with potential conflicts of interest (inventors of the Myotonometer, people affiliated with Neurogenic Technologies Inc) did not participate in data collection. Testers were not paid for their work.

Statistical Analysis

Analysis of variance (ANOVA)–based intraclass correlation coefficients (ICCs) were used to determine the reliability of the Myotonometer (Design II, 2-way ANOVA random model). Standard error (SE) of measurement was calculated for each force measurement (.25–2.00kg) to represent the "standard deviation of measurement errors."[30] ICC scores for each of the 8 force measurements during relaxed and isometric testing were compared with the following scale for interpretation of correlation: 1.00 to .90, very high; .89 to .70, high; .69 to .50, moderate; .49 to .26, low; and less than .25, poor.[30]

Analyses permitted assessment of intrarater reliability, interrater reliability, differences in reliability between relaxed and contracted muscles, differences in reliability between the lateral gastrocnemius and biceps brachii muscles, and differences in reliability among the 8 force recordings (fig 1) for each trial.

RESULTS

Myotonometer Force/Displacement Recordings

A total of 60 measurements were taken for each subject, 30 for the biceps brachii and 30 for the lateral gastrocnemius.

Table 1: Biceps Brachii Muscle ICC Values

	Intrarater		Interrater	
Force (kg)	Relaxed	Contracted	Relaxed	Contracted
0.25	.77	.96	.52	.93
0.50	.85	.96	.87	.95
0.75	.93	.95	.90	.95
1.00	.94	.94	.91	.96
1.25	.95	.94	.89	.96
1.50	.93	.93	.86	.96
1.75	.92	.92	.85	.95
2.00	.91	.93	.82	.95

Table 3: Lateral Gastrocnemius Muscle ICC Values

	Intrarater		Interrater	
Force (kg)	Relaxed	Contracted	Relaxed	Contracted
0.25	.67	.96	.72	.94
0.50	.84	.98	.79	.96
0.75	.86	.99	.79	.96
1.00	.88	.98	.81	.96
1.25	.90	.98	.81	.96
1.50	.90	.98	.80	.95
1.75	.89	.98	.77	.95
2.00	.90	.97	.75	.94

Displacement measurements for the relaxed biceps brachii muscle ranged from 2.94mm at .25kg to 12.41mm at 2.00kg, whereas displacement for the contracted biceps brachii ranged from .38mm at .25kg to 9.18mm at 2.0kg. Displacement measurements for the relaxed lateral gastrocnemius muscle ranged from 1.92mm at .25kg to 11.19mm at 2.00kg, whereas displacement of the contracted lateral gastrocnemius ranged from .35mm at .25kg to 7.39mm at 2.00kg.

Intrarater Reliabilities

Biceps brachii muscle. Table 1 lists reliability coefficients for the measurements of the biceps brachii muscle. Intrarater reliability for both the relaxed and contracted biceps brachii muscle ranged from high to very high. Correlation coefficients for measurements during contraction ranged from .92 to .96. Correlation coefficients ranged from .77 to .95 for measurements of the relaxed biceps brachii. Table 2 lists the means, standard deviations (SDs), and SE of measurements for bicep brachii intrarater reliability data.

Lateral gastrocnemius muscle. Intrarater reliabilities for measurements made of the lateral gastrocnemius muscle are listed in table 3. Correlation coefficients for measurements of the relaxed lateral gastrocnemius muscle ranged from .67 to .90. The ICCs of the contracted lateral gastrocnemius muscle measurements ranged from .96 to .99. With the exception of intrarater reliability of the resting condition at .25kg of force (ICC=.67), all reliabilities were high to very high. Table 4 lists the means, SDs, and SE of measurements for lateral gastrocnemius intrarater reliability data.

Interrater Reliabilities

Biceps brachii muscle. Correlation coefficients of measurements of the relaxed biceps brachii muscle ranged from .52 to .91 (table 1). Correlation coefficients of measurements of the contracted muscle ranged from .93 to .96. Interrater reliability measurements of both the relaxed and contracted biceps brachii muscle ranged from high to very high, with the exception of measurements of the relaxed muscle at .25kg of force (ICC=.52). Table 2 lists the means, SDs, and SE of measurements for biceps brachii interrater reliability data.

Lateral gastrocnemius muscle. Correlation coefficients of measurements of the resting lateral gastrocnemius ranged from .72 to .81 (table 3). Interrater correlation coefficients of the contracted lateral gastrocnemius ranged from .94 to .96. Table 4 lists the means, SDs, and SE of measurements for lateral gastrocnemius interrater reliability data.

Summary

Myotonometer reliabilities were (1) highest during measurements of the contracted biceps brachii and lateral gastrocnemius muscles, (2) lowest for .25kg measurements taken during the relaxed condition, and (3) higher for measurements of the resting biceps brachii muscle compared with measurements of the lateral gastrocnemius muscle at rest.

DISCUSSION

Myotonometer measurements had very high intra- and interrater reliabilities for testing of isometrically contracted muscles and high to very high intra- and interrater reliabilities for testing of relaxed muscles. The exception was moderate reliability of measurements at the lowest force level of measurement (.25kg).

Hand-held and computerized isokinetic dynamometry provide more quantifiable muscle strength data than does the MMT. A summary of 18 studies that examined hand-held dynamometry intertester reliability during muscle contraction reported that reliability coefficients ranged from −.19 to .99.[31] Typically, reliability measurements of the upper extremities

Table 2: Biceps Brachii Descriptive Statistics and SE of Measurement (SEM)

	Intrarater						Interrater					
	Relaxed			Contracted			Relaxed			Contracted		
Force (kg)	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM
0.25	4.43	0.16	.08	1.20	0.41	.08	4.26	0.31	.21	1.07	0.38	.10
0.50	6.12	0.53	.20	1.88	0.62	.12	5.98	0.45	.16	1.92	0.63	.14
0.75	6.93	0.73	.19	2.43	0.70	.16	6.80	0.59	.19	2.49	0.72	.16
1.00	7.44	1.03	.25	3.01	0.77	.19	7.33	0.89	.27	3.07	0.78	.16
1.25	7.78	1.40	.31	3.58	0.90	.22	7.68	1.28	.42	3.61	0.85	.17
1.50	8.07	1.63	.43	4.16	1.14	.30	7.98	1.60	.58	4.18	1.10	.22
1.75	8.28	1.83	.52	4.72	1.52	.43	8.21	2.00	.77	4.73	1.36	.30
2.00	8.48	2.02	.61	5.27	1.94	.51	8.42	2.33	.99	5.26	1.76	.39

Table 4: Lateral Gastrocnemius Descriptive Statistics and SE of Measurement

	Intrarater						Interrater					
	Relaxed			Contracted			Relaxed			Contracted		
Force (kg)	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM
0.25	2.91	.18	.10	1.49	.24	.05	2.78	.21	.11	1.49	.23	.06
0.50	4.69	.27	.11	2.48	.48	.07	4.62	.34	.16	2.45	.45	.09
0.75	5.74	.36	.14	3.16	.61	.06	5.69	.48	.22	3.11	.57	.11
1.00	6.53	.44	.15	3.77	.65	.09	6.47	.52	.23	3.69	.61	.12
1.25	7.08	.48	.15	4.26	.70	.10	7.01	.59	.26	4.17	.67	.13
1.50	7.49	.59	.19	4.69	.72	.10	7.45	.71	.32	4.62	.72	.16
1.75	7.83	.70	.23	5.04	.74	.10	7.79	.86	.41	4.98	.76	.17
2.00	8.10	.78	.25	5.36	.78	.13	8.07	.99	.49	5.29	.83	.20

were higher than measurements of the lower extremities. Myotonometer reliabilities were also slightly higher for the upper extremities. The reasons for this were not apparent, but might include the subjects' ability to maintain a more consistent contraction level with the upper extremity; a toe-raise task for lateral gastrocnemius muscle testing might have added variability, or the differences in the thickness of the biceps brachii and lateral gastrocnemius muscles may be a factor. Intrarater reliabilities of hand-held dynamometry have reported "unexpectedly low" values.[12] Seventy-two percent of the intrarater correlation coefficients of healthy subjects achieved *r* values of less than *r* equal to .80 (*r* range, −.05 to .95). Van Langeveld et al[12] suggested that differences in the forces generated by the testers negatively influenced reliabilities.

Isokinetic dynamometry perhaps provides more precise muscle strength measurements than hand-held dynamometry and problems associated with a tester's muscle strength are avoided. Researchers report, however, that reproducibility of results is poor,[14] and the reliability and sensitivity of the tests are not sufficient to differentiate change in nondisabled populations.[2] Similar to hand-held dynamometry, it is possible to obtain data relating to torque generated about a joint (eg, elbow flexors), but it is generally not possible to relate this torque to a specific muscle. The possibility of substitutions from muscles not directly being assessed by hand-held or isokinetic dynamometry is another potential confounding variable in these measurements. Tester strength and muscle substitutions do not influence Myotonometer measurements. Limitations with Myotonometer use involve not being able to measure deep muscles (eg, iliopsoas) and the importance of limb positioning during pre- and posttesting. A muscle placed in a lengthened position will be stiffer than when it is in a shortened position.

The Myotonometer also quantifies muscle tone and stiffness of a noncontracting muscle. Myotonometer data correlate to the MAS,[18] a qualitative test of muscle tone. Myotonometer measurements, however, were better able to detect small changes in muscle tone. Our study indicates that Myotonometer inter- and intrarater reliabilities were higher than previously published results of interrater reliabilities for the MAS.[6,32-35] It is also not necessary to move a muscle or joint through a range of motion to obtain tone and stiffness measurements with the Myotonometer. This might prove useful with patients who have pain with movement or who have limited range.

Reliability needs to be established specifically for the populations and conditions for which a device or method is intended.[36,37] The Myotonometer can be useful in quantifying muscle changes for measurements of healthy, nondisabled individuals as well as for various patient populations. This study examined the reliability of the instrument with healthy, nondisabled individuals. Future studies, with subjects with various disabilities will be needed to assess the reliability of Myotonometer measurements specific to patient populations.

CONCLUSION

The Myotonometer is a reliable instrument for assessing muscle stiffness, tone, and compliance of the relaxed or contracted biceps brachii and lateral gastrocnemius muscles of nondisabled subjects. Its speed and ease of use approaches that of hand-held dynamometry. Myotonometer measurements provide quantifiable data that are not influenced by confounding variables such as tester strength, clinical experience of the tester, subject pain at high force levels, and muscle substitutions.

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Suppliers

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