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Quantitative Assessment of Lumbar Paraspinal Muscle Endurance

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Objective: To evaluate the reliability and variability of repeated measurements of dynamic and static lumbar muscle endurance.

Design and Setting: Participants performed an isometric lumbar-extension strength test followed by 2 trials of 4 separate lumbar muscular-endurance tests (with a 24-hour rest period between tests). Data were collected at a university musculoskeletal research laboratory.

Subjects: Eight healthy, physically active volunteers (5 men, 3 women; age = 25.9 ± 4.3 years; height = 169.0 ± 4.6 cm; mass = 73.9 ± 33.1 kg) participated in this investigation.

Measurements: We initially tested each participant's isometric lumbar-extension peak torque on a lumbar-extension dynamometer. Static (holding time) and dynamic (repetitions) lumbar-endurance tests were subsequently performed on the lumbar-extension dynamometer and a horizontal roman chair.

Results: Interclass reliability was high for all endurance tests completed (r = 0.91 to 0.96, $P \le .05$). Variability (expressed as total error) for the static-dynamometer and roman-chair tests was 18.3 and 11.6 seconds, respectively, with 2.8 and 1.6 repetitions for the dynamic-dynamometer and roman-chair tests, respectively.

Conclusions: Lumbar muscle endurance can be reliably assessed by both static and dynamic protocols on high- and low-technology devices.

Key Words: reliability, variability, lumbar muscular endurance

Low back pain among athletes is common and can be extremely challenging for athletic trainers and health care professionals to assess, treat, and rehabilitate. Low back injuries account for approximately 10% to 15% of all athletic injuries[1] and have been well documented in a variety of sporting events, including football, soccer, volleyball, golf, gymnastics, and running.[2–6]

Spinal muscles hold the trunk in a fixed posture and enable controlled spinal motions.[7] The spinal muscles are particularly suited to holding an upright posture, having characteristics similar to other endurance-type muscles. Spinal muscles may protect the spine, especially during trunk-flexion movements. However, this protective action may be impaired if the spinal muscles become fatigued.[8] Patients with ongoing[9] or intermittent[10] low back pain have significantly shorter endurance times than healthy subjects. Biering-Sorensen[11] demonstrated that the time an individual can maintain a horizontal, unsupported posture (which is a measure of mechanical function and willingness) may be a predictor for first-time occurrence of low back pain. More recently, investigators have also shown that endurance can be used as a predictor for first-time low back injury.[12–14] Low levels of static endurance in the back extensor muscles are associated with higher rates of low back pain,[15,16] decreased proprioceptive awareness,[17] and decreased productivity in the workplace.[18]

Muscular endurance of the lumbar extensors is assessed less frequently than muscular strength,[19] although the endurance capabilities of these muscles may be as important or even more important than strength in the prevention and treatment of low back pain. As equipment used to assess, treat, and rehabilitate spinal disorders becomes increasingly available, an effort must be made to scientifically evaluate such instruments for use in a variety of health care settings (eg, athletic training rooms, clinics, industrial medical centers). To our knowledge, no previous studies have examined lumbar endurance in nonclinical and nonsedentary populations. Therefore, the purpose of our investigation was to evaluate the reliability and variability of repeated measurements of dynamic and static lumbar muscle endurance on a lumbar-extension dynamometer and a horizontal roman-chair apparatus in healthy, active individuals.

METHODS

Subjects

Eight healthy, athletic volunteers (5 men, 3 women; age = 25.9 ± 4.3 years; height = 169.0 ± 4.6 cm; mass = 73.9 ±

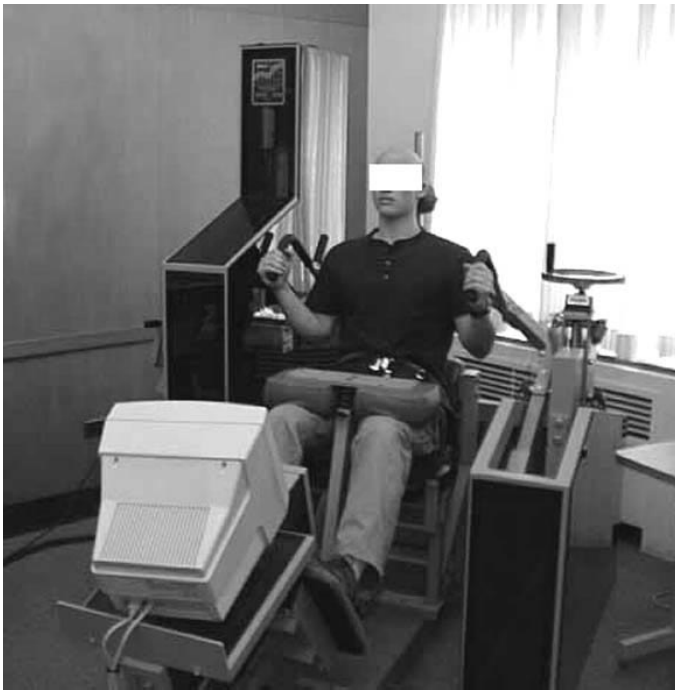

Figure 1. The lumbar-extension dynamometer.

Figure 2. The roman chair.

33.1 kg) participated in this investigation. All volunteers completed a medical history questionnaire and reported no low back pain in the past 6 months. The experimental design and testing protocol for this study were approved by the institutional review board of the sponsoring university. Written informed consent was obtained from all participants.

Procedures

Before the endurance tests, participants completed a 7-angle, isometric lumbar-extension strength test on a lumbar-extension dynamometer to establish maximal lumbar-extension peak-torque values. This dynamometer (Figure 1), which has been shown to be reliable for isometric lumbar-extension testing, uses a unique pelvic-stabilization system that has previously been described in detail.[20] Next, participants completed 2 trials of 4 lumbar muscular-endurance tests (1 trial per day for 8 days). Tests were separated by 24 hours to reduce the possibility of a fatigue effect. Testing order was balanced across participants, and all tests were performed by a single investigator. Static hold-time and dynamic repetition back-extension endurance tests were completed on a horizontal roman-chair apparatus (model 9910348, Backstrong Intl, Brea, CA) and the dynamometer (model 571931, MedX, Ocala, FL). The static hold-time test on the dynamometer was performed at 45° of lumbar flexion, with a load equal to 40% of peak torque. Participants were encouraged to statically hold the required resistance level for as long as possible. The test was finished once the participant could no longer maintain the desired torque value (digital torque readout decreased by 5 N/m). The static hold-time test on the roman chair was performed with the participant prone in 0° of lumbar flexion (Figure 2). The mechanics of the static hold-time test on the roman chair were similar to a test reported by Biering-Sorensen,[11] which quantified lumbar paraspinal muscular endurance. Participants were instructed on how to mount the apparatus, and the test began once they positioned themselves in 0° of lumbar flexion. Participants were encouraged to maintain their postural position in 0° of lumbar flexion as long as possible. The test was finished when the participant's upper body broke the horizontal plane of 0° of lumbar flexion (as determined by visual observation).

The dynamic-repetition test on the dynamometer was conducted through the standard 72° lumbar range of motion with a load equal to 40% of the subject's peak torque. Participants were instructed to perform the concentric contraction (lumbar extension) in 2 seconds and the eccentric contraction (lumbar flexion) in 4 seconds. The test was finished when the participants could no longer complete a repetition through the complete range of motion. The dynamic-repetition test on the roman chair began with the participants situated in the resting position on the apparatus (prone position with a 90° bend at the waist). Using torso mass as resistance, participants performed the concentric contraction (raising themselves to 0° of lumbar flexion) in 2 seconds and the eccentric contraction (lowering themselves to a 90° bend at the waist) in 4 seconds. The test was finished when the participants could no longer complete a repetition through the full range of motion.

Data Analysis

For each endurance test, test 1 and test 2 values were compared using a paired *t* test. A reliability analysis comparing test 1 and test 2 values was completed by calculating the interclass correlation and total error (E), where $E = \sqrt{\Sigma(y_1 - y_2)^2/N}$. Statistical significance was set at $P \leq .05$.

RESULTS

Interclass correlation was high for all endurance tests (static dynamometer, $r = 0.95$; dynamic dynamometer, $r = 0.91$; static roman chair, $r = 0.92$; dynamic roman chair, $r = 0.96$; $P \leq .05$; see Table). Variability (total error) for the static-dynamometer and roman-chair tests was 18.3 seconds and ll.6 seconds, respectively. Variability for the dynamic-dynamometer and roman-chair tests was 2.8 and 1.6 repetitions, respectively, representing 7.1% to 10.5% of the observed mean values. The dynamic-dynamometer comparison showed a significant difference ($P = .03$) between trial 1 (25.8 ± 2.1 repetitions) and trial 2 (27.8 ± 2.4 repetitions), whereas no difference was found between trials for the other endurance tests completed ($P > .05$).

Test Values, Interclass Correlation Coefficients, and Total Error for Endurance Tests

Protocol	n	Test 1	Test 2	r	Total Error
Dynamometer					
Static (s)	8	216.0 ± 20.8	214.0 ± 18.6	0.95	18.3
Dynamic (repetitions)	8	25.8 ± 2.2	27.8 ± 2.4*	0.91	2.8
Roman chair					
Static (s)	8	124.0 ± 11.4	129.0 ± 9.5	0.92	11.6
Dynamic (repetitions)	8	22.6 ± 2.1	22.5 ± 1.9	0.96	1.6

*Test 2 > test 1, $P \leq 0.05$.

DISCUSSION

Muscular endurance is defined as the ability to produce work over time or the ability to sustain effort.[21] Poor endurance of the lumbar paraspinal muscles is a contributing factor in developing idiopathic low back pain[22–24] and a predictor for first-time occurrence of low back injuries.[12–14] Muscular endurance of the lumbar extensors is assessed less frequently than muscular strength.[19] The reasons for this may be a lack of endurance-testing protocols that have been scientifically proven as reliable or protocols that have been assessed with complicated, time-consuming, and expensive methods such as electromyographic frequency analysis[8,24] and computerized dynamometers.[25,26] Our data suggest that a low-technology roman chair can be used reliably to assess lumbar-extension muscle endurance. Such assessment could occur in a variety of settings where health care professionals interact with athletes suffering from low back pain.

Pain may also be a strong inhibiting factor in the attempt to quantify lumbar muscular performance. An advantage of using endurance-based protocols to quantify the capabilities of the low back is avoiding a maximal voluntary contraction, which may be a distinct advantage when testing in the presence of pain.[19]

Our investigation examined dynamic as well as static endurance protocols on a lumbar-extension dynamometer and a roman-chair apparatus, 2 forms of equipment that may be employed by health care professionals in the management and treatment of low back pain. Athletic and physically active populations will more than likely continue to suffer from low back pain, in part because of their increased levels of activity and the physical stress placed on the body.[27] The availability of standardized endurance protocols that have been shown to be reliable is important for clinicians working with symptomatic populations in order to aid in the quantification of lumbar muscular-endurance function, to monitor therapeutic exercise progression, and to help with the possible identification of individuals susceptible to low back injuries.

Our findings show that lumbar muscle endurance can be reliably assessed by both static and dynamic tests on a lumbar-extension dynamometer and a roman chair. Based on these findings, we recommend that the dynamometer or roman chair be used to assess lumbar muscular endurance in healthy, active populations. As shown in previous research, a single bout of exercise on a dynamometer may be associated with an increase in performance.[27] Therefore, we recommend that a practice test be completed on the dynamometer in order to familiarize users with the equipment and testing protocol before testing.

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