Endurance Times for Low Back Stabilization Exercises: Clinical Targets for Testing and Training From a Normal Database

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Objective: To establish isometric endurance holding times, as well as ratios between torso extensors, flexors, and lateral flexors (stabilizers), for clinical assessment and rehabilitation targets.

Design: Simple measurement of endurance times in four tests performed in random order by a healthy cohort. To measure reliability, a subsample also performed the tests again 8 weeks later.

Setting: University laboratory.

Participants: Seventy-five young healthy subjects (31 men, 44 women).

Results: Women had longer endurance times than men for torso extension, but not for torso flexion or for the "side bridge" exercise, which challenges the lateral flexors (stabilizers). Men could sustain the "side bridge" for 65% of their extensor time and 99% of their flexor time, whereas women could sustain the "side bridge" for only 39% of their extensor time and 79% of their flexor time. The tests proved reliable, with reliability coefficients of >.97 for the repeated tests on 5 consecutive days and again 8 weeks later.

Conclusion: Healthy young men and women possess different endurance profiles for the spine stabilizing musculature. Given the growing support for quantification of endurance, these data of endurance times and their ratios between extensor, flexor, and lateral flexor groups in healthy normal subjects are useful for patient evaluation and for providing clinical training targets.

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THERE HAVE BEEN MANY recent research developments related to torso stabilization,1,4 endurance,5,6 and motor control training7,8 for rehabilitation of the low back. For several years, our group has been working to quantify the stability of the low back in a variety of occupational and rehabilitation tasks, identify the structures that are best able to stabilize the back, and identify exercises to enhance these stabilizers.

Several research questions have been systematically addressed to meet these objectives. For example, Cholewicki and McGill9 (and others such as Stokes and Gardner-Morse10) identified several muscles that have the potential to assist in stability. Juker and colleagues11 implanted intramuscular electrodes in the deep musculature of the torso to identify which muscular components were recruited when stability was needed. In their study, subjects stood upright with their arms at their sides and loads were progressively applied to their hands, producing spine compression in the absence of major torque demands. This paradigm was motivated by the pioneering work of Lucas and Bresler,12 who found that the lumbar spine, under pure compression, will buckle or become unstable at very low levels of approximately 90 Newtons (or 20 pounds). Monitoring the deep muscles together with the surface musculature demonstrated that the quadratus lumborum was the muscle most favorably activated by the motor control system to provide stability in this task,13 as well as in other tasks that required substantial flexor and extensor moment development. Although the abdominals are important stabilizers, the quadratus was more active in this upright posture, in the absence of bending moments but when the risk of buckling from compression was high. This observation, coupled with the engineering stability analysis of Cholewicki and McGill,9 demonstrated that the quadratus lumborum was architecturally best suited to be the major stabilizer of the lumbar spine. In our opinion, this combination of data proved that the quadratus lumborum is preferentially recruited to maintain sufficient stability in the spine.

The next clinical question was to find the preferred method to challenge the quadratus and enhance its stabilizing role, but in a way that minimized loading on the spine. After assessing muscle recruitment patterns and spine loading that resulted from a variety of exercises,11,13 the "side support" or "side bridge" exercise was identified as optimizing the challenge to the quadratus lumborum while minimizing load on the lumbar spine. This exercise has now been incorporated into several exercise programs throughout the world, including the American College of Sports Medicine textbook.14 As it has gained exposure, clinicians have been requesting guidelines for duration times and endurance relationships between different sets of torso muscles. Thus, normal values for flexor, extensor, and lateral flexion (and stabilizing) endurance times, and their ratios to each another, are needed to guide clinicians in determining training targets to use when assessing endurance in low back rehabilitation patients.

The purpose of this study was to collect isometric endurance times from a healthy normal population performing the "side bridge" or lateral flexion exercise, as well as isometric flexion and isometric extension exercises. These endurance times can be used to form "normal" relative ratios to guide clinicians and identify endurance deficits within specific patients.

METHOD

Seventy-five subjects were selected from a university community, 31 men and 44 women with a mean age of 23 years.
Given the objective of obtaining a healthy population, a health status questionnaire was used for screening to exclude individuals who were not in good health, particularly those who had experienced disabling low back pain. Additional data collected included measures of height, weight, activity level, and dominant hand (post hoc analysis revealed that not enough subjects were left-handed to allow further analysis). Five subjects were selected to perform reliability tests; they performed the tests at the initial session, then, after 8 weeks, repeated the tests daily for 5 consecutive days. Each new subject was familiarized with the tests. Subjects performed the following four endurance tests, with the order randomized among the subjects: the isometric extensor exercise, the isometric flexor exercise, and the "side bridge" exercise on both right and left sides. A minimum of 5 minutes was provided between efforts to facilitate recovery.

The extensor endurance test (fig 1) was modified from the Biering-Sorensen test, which has been shown to be consistently reliable as a measure of back extensor endurance. Subjects laid prone with the lower body fixed to the test bed at the ankles, knees, and hips and the upper body extended in a cantilevered fashion over the edge of the test bench. The test bench surface was approximately 25cm above the surface of the floor. Subjects rested their upper bodies on the floor before the exertion. At the beginning of the exertion the upper limbs were held across the chest with the hands resting on the opposite shoulders, and the upper body was lifted off the floor until the upper torso was horizontal to the floor. Subjects were instructed to maintain the horizontal position as long as possible. The endurance time was manually recorded in seconds with a stopwatch from the point at which the subject assumed the horizontal position until the upper body came in contact with the floor.

The flexor endurance test (fig 2) required subjects to sit on the test bench and place the upper body against a support with an angle of 60° from the test bed. Both the knees and hips were flexed to 90°. The arms were folded across the chest with the hands placed on the opposite shoulder and toes were placed under toe straps. Subjects were instructed to maintain the body position while the supporting wedge was pulled back 10cm to begin the test. The test ended when the upper body fell below the 60° angle.

The side bridge test (fig 3) consisted of subjects laying on an exercise mat (thickness, 2.5cm) on their sides with legs extended. The top foot was placed in front of the lower foot on the mat for support. Subjects were instructed to support themselves lifting their hips off the mat to maintain a straight line over their full body length, and support themselves on one elbow and their feet. The uninvolved arm was held across the chest with hand placed on the opposite shoulder. The test ended when the hips returned to the exercise mat.

During all tests, subjects were reminded to maintain the position as long as possible. Only the subject and evaluator were present in the testing room. Subjects were not provided with any clues to their scores until the conclusion of the test.

Statistical analysis consisted of the calculation of reliability coefficients on a subset of five subjects for repeated tests both daily over 5 consecutive days and again over an 8-week period. While t tests were conducted to assess effects of hand dominance, it happened by chance that only four subjects were left-handed, invalidating the implications. Student t tests (p < .05) assessed differences between pairs of scores for similar exercises between the genders and between exercises within each gender. (An analysis of variance was not used...
because the issues addressed in this work required comparison of only specific cells.)

RESULTS

Mean endurance times for the exercises and ratios of endurance times between exercises are listed in table 1. The ratios of endurance times were normalized to the extensor-hold exercise because subjects were able to hold their position the longest during this exercise. There was no significant difference in endurance times between the side bridge performed on the left side and the side bridge performed on the right side. Women had longer endurance times than men for the extensor exercise ($t$ test, $p = .0018$), but not the flexor exercise; men had more endurance in the side bridge exercise ($p < .0001$). The ratios for clinical use showed that men could maintain the side bridge exercise for a period that was 65% of their extensor time ($p < .0001$), whereas women could maintain the side bridge for approximately 39% of their extensor time ($p < .0001$).

The reliability study with the five subjects found that the repeated tests, on 5 consecutive days, produced excellent reliability coefficients of .98 for the extensor exercise, .97 for the flexor exercise, and .99 for the side bridge on the left and right sides. The reliability remained excellent over a period of 8 weeks. When all test scores, including the 8-week 5-day repeated tests, were added to assess reliability, the reliability coefficients were .99 for the extensor exercise, .93 for the flexor exercise, .96 for the right side bridge, and .99 for the left side bridge.

DISCUSSION

Given the growing popularity of stabilization exercises, this study was motivated by requests from clinicians to establish a normal database for endurance times of the isometric exercises identified in this study. Clinicians also requested the establishment of ratios of the endurance times of tasks relative to each other. These ratios can be used to identify endurance deficits in patients, thereby guiding clinical decisions to restore normal relative endurance between muscle groups and normal function. The side bridge has been justified as an ideal training exercise to challenge the quadratus lumborum and the abdominal wall with minimal spinal loading. This exercise, together with the flexor and extensor exercises, may also be used to evaluate endurance capabilities and ratios of endurance balance around the torso. It appears that the side bridge qualifies as a good test on the criteria of cost (it requires no special equipment), safety (it has been documented to provide substantial challenge to the quadratus lumborum, approximately 50% of maximum activation), and reliability (excellent reliability, as documented by the reliability coefficients calculated here).

There are few data sets to compare with the data from this study. Alaranta and associates documented much lower endurance times in the isometric back endurance test for normal men and women (97 and 87 seconds, respectively) 35 to 54 years of age. Our subjects, however, were younger. We were unable to find comparable data sets for the endurance ratios in our study. There are several limitations to be considered for the interpretation of these data. Our subjects were relatively young and healthy. It was the objective of this study to establish what is normal and healthy; however, the performance of older individuals may be different. Our hope is that others will establish data on older subjects and different classifications of back pain.

Recent evidence is compelling to justify rehabilitation approaches that emphasize spine endurance and stabilization exercises for the injured back. The side bridge exercise has been documented to challenge the quadratus lumborum and the muscles of the abdominal wall to enhance spine stability. The ratios we report provide clinicians with guidance for normal endurance ratios between torso flexion, extension, and lateral bending exercises. The isometric endurance exercises performed in this study are intended for quantification of patient status only. During training and rehabilitation, these exercises would be held for shorter periods of time, with repeated sets. Further work is required to identify optimal holding times and numbers of repetitions.

Table 1: Mean Endurance Times (sec) With Standard Deviations and Ratios Normalized to the Extensor Exercise

<table>
<thead>
<tr>
<th>Task</th>
<th>Men</th>
<th></th>
<th>Woman</th>
<th></th>
<th>All</th>
<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td>$\bar{x}$</td>
<td>SD</td>
<td>Ratio</td>
<td>$\bar{x}$</td>
<td>SD</td>
<td>Ratio</td>
</tr>
<tr>
<td>Extensor</td>
<td>146</td>
<td>51</td>
<td>1.0</td>
<td>189</td>
<td>60</td>
<td>1.0</td>
</tr>
<tr>
<td>Flexor</td>
<td>144</td>
<td>76</td>
<td>.99</td>
<td>149</td>
<td>99</td>
<td>.79</td>
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<tr>
<td>Side bridge, right</td>
<td>94</td>
<td>34</td>
<td>.64</td>
<td>72</td>
<td>31</td>
<td>.38</td>
</tr>
<tr>
<td>Side bridge, left</td>
<td>97</td>
<td>35</td>
<td>.66</td>
<td>77</td>
<td>35</td>
<td>.40</td>
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References

