Endurance Times for Trunk-Stabilization Exercises in Healthy Women: Comparing 3 Kinds of Trunk-Flexor Exercises

Lu-Wen Chen, Liu-Ing Bih, Chi-Chung Ho, Mao-Hsuing Huang, Chin-Tien Chen, and Ta-Sen Wei

Objectives: To establish isometric endurance times for trunk-stabilization exercises in 6 different positions and compare 3 kinds of trunk-flexor exercises. Participants: 28 healthy young women with no history of disabling back pain. Design: Isometric endurance times were measured in 6 tests: 60° flexor, 45° flexor, curl-up, extensor, and left- and right-side-bridge exercises. Results: The mean endurance time was 375 ± 252 seconds for the 60° flexor test; 101 ± 51 seconds, 45° flexor test; 107 ± 54 seconds, curl-up test; 158 ± 45 seconds, extensor test; 70 ± 23 seconds, left-side-bridge test; and 68 ± 23 seconds, right-side-bridge test. Conclusions: Of the 3 flexor exercises, the 60° exercise was time consuming and had a larger variance. The 45° flexor exercise and curl-up exercise were time effective and showed less variance. The curl-up exercise is easy, convenient, and representative of trunk-flexor effort and can be considered a preferable alternative to the 60° flexor exercise. Key Words: isometric endurance time, strengthening exercise


Low back pain is a very common problem. Every person has more than an 80% chance of suffering from low back pain at least once during their lifetime. In most cases, however, symptoms improve with conservative treatment. In recent years, more emphasis has been placed on strength and endurance of the trunk muscles as key muscles involved in low back pain, and the importance of trunk-stabilization exercise training to improve low back pain has been suggested. Isometric exercises have the advantage of being easy to perform for most muscles, requiring minimum time and setup without special equipment needed. It rarely results in postexercise muscle soreness.
Before a patient starts low-back-stabilization exercises, an assessment must be made of his or her back pain and muscle strength and endurance.\textsuperscript{6-8} One of the methods used to assess endurance is to measure isometric-contraction endurance times,\textsuperscript{9,10} in particular through the performance of flexor and extensor exercises.\textsuperscript{11,12} More recent techniques include lumbar-spine-training exercises with minimal spine loading, such as the side-bridge exercise.\textsuperscript{9,13} Several methods of testing trunk-muscle endurance have been studied. Most commonly, these are measures of isometric, or static, endurance; active measures of endurance within a nonfixed range of motion (isotonic); and isokinetic testing that places patients in a fixed range of motion, as well as a fixed rate of joint-motion acceleration.\textsuperscript{14} McGill introduced a series of isometric muscle-endurance tests\textsuperscript{8} including flexor and extensor endurance tests and the side-bridge test on each side. He also reported normative values for these tests.

Although McGill’s method is more complete than previous methods, it has not yet been widely adopted in Taiwan. McGill found that the 60° flexor endurance test produced different endurance times with a relatively wide variance. This study examined whether other tests, namely the 45° flexor and the curl-up endurance tests, might be alternatives to assessing the endurance of the trunk flexors.

\textbf{Materials and Methods}

A 1 × 3 repeated-measures design was used to compare the 3 flexor endurance tests on isometric endurance time. The independent variable was a flexor endurance test at 3 levels (45°, 60°, and curl-up). Individual endurance time was the dependent variable evaluated.

\textbf{Participants}

Twenty-eight healthy women (age = 23.8 ± 2.4 years, weight = 53.8 ± 9.8 kg, height = 159.8 ± 4.0 cm) were enrolled. All were sedentary volunteers who had no history of low back pain, childbirth, or other systemic disorders including diabetes, hypertension, cardiovascular disease, respiratory disorder.

\textbf{Methods}

Six different trunk endurance tests were performed: 60° flexor exercise, 45° flexor exercise, curl-up exercise, extensor exercise, left-side-bridge exercise, and right-side-bridge exercise. In the first session, 1 of the 3 kinds of flexor exercises, the extensor exercise, and the bilateral side-bridge exercises were performed. The other 2 flexor tests were completed on 2 different days within 5 days after the initial testing. Informed consent, which was approved by the institutional review board, was obtained from each participant before testing.
Endurance Times for Trunk-Flexor Exercises

For the 60° and 45° flexor endurance tests (Figures 1a and 1b), participants sat on a test bench and placed the upper body against 60° and 45° triangular blocks, respectively. Both the knees and hips were flexed to 90°. The arms were folded across the chest with each hand placed on the opposite shoulder, and the feet were placed under ankle straps. Participants were instructed to maintain the body position while the supporting block was pulled back 10 cm from the initial posture to begin the test. The endurance time was manually recorded in seconds with a manual stopwatch from the point when the participant assumed the starting position until the upper body fell below the selected angle and touched the block again.

Figure 1  Participant performing isometric flexion exercises: (a) 60° flexor, (b) 45° flexor, and (c) curl-up exercise.

The curl-up test (Figure 1c) required participants to lie on the test bench with the knees flexed to 90°. The arms were folded across the chest with each hand placed on the opposite shoulder, and the feet were placed under ankle straps. During the exercise, the scapulas were not allowed to touch the test bench. The test ended when the lower poles of the scapulas came in contact with the test bench.

The extensor endurance exercise (Figure 2) was modified from the Biering-Sorensen test. Participants were required to lie prone with the lower body fixed to the test bench 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 25 cm above the surface of the floor. Participants 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 it was horizontal. Participants were instructed to maintain the horizontal position as long as possible. The test ended when the upper body came in contact with the floor.

The side-bridge exercise (Figure 3) required participants to lie on an exercise mat on their sides with legs extended. The top foot was placed in

Figure 2  Participant secured on the test bench performing an isometric back-extension exercise.

Figure 3  Participant performing a left-side-bridge isometric exercise.
Endurance Times for Trunk-Flexor Exercises

Participants were instructed to lift their hips off the mat to maintain a straight line over their full body length and support themselves on 1 elbow and their feet. The uninvolved arm was held across the chest with the hand placed on the opposite shoulder. Participants were instructed to maintain this position as long as possible, and the test ended when the hips returned to the exercise mat. This exercise was performed on both right and left sides.

During each test, participants performed the following 4 endurance tests in random order: 1 of the 3 flexor exercises, the extensor exercise, and the side-bridge exercise on both the left and the right. A minimum of 5 minutes was provided between efforts to facilitate recovery from fatigue. Another 2 flexor tests were completed on 2 different days within 5 days after the initial testing. Participants were required to keep their necks flexed during the flexor exercise and straight during the extensor exercise.13 During all tests, only the participant and evaluator were present in the testing room, and participants were not provided any clues to their scores until the conclusion of the test.

Statistical Analysis

Mean values and standard deviations of the endurance time for the 6 trunk-stabilization exercises were obtained. A repeated-measures ANOVA was

<table>
<thead>
<tr>
<th>Position</th>
<th>Mean ± SD (range), in seconds</th>
<th>Q*</th>
<th>Critical q*</th>
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</thead>
<tbody>
<tr>
<td>60° flexor</td>
<td>375.4 ± 252.5 (93–940)</td>
<td>vs 45° flexor 0.04,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>vs curl-up 9.81</td>
<td>vs 45° flexor 3.41,†</td>
</tr>
<tr>
<td>45° flexor</td>
<td>101.0 ± 51.4 (37–236)</td>
<td>vs curl-up 0.23</td>
<td>vs curl-up 2.84†</td>
</tr>
<tr>
<td>Curl-up</td>
<td>107.4 ± 54.0 (37–247)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extensor</td>
<td>158.3 ± 45.5 (68–229)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left-side bridge</td>
<td>70.0 ± 23.5 (36–127)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right-side bridge</td>
<td>68.3 ± 23.3 (30–117)</td>
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</table>

*Repeated-measures ANOVA, Newman–Keul multiple comparison as post hoc comparison.†Statistically significant, P < .05.
performed to study the difference between results from the 3 flexor tests: the 60° flexor, 45° flexor, and curl-up endurance exercise tests. A Newman–Keul multiple comparison was used for post hoc comparisons.

**Results**

The mean endurance times for the 6 different positions are shown in Table 1. The endurance time of the 60° flexor exercise was significantly longer than those of the other flexor exercises. No significant difference was found, however, between the 45° flexor and the curl-up endurance exercises.

**Discussion**

The concept of trunk-stabilization exercise can be traced back to the 1960s. Studies have established that trunk-muscle exercise with minimal spine loading can reduce the chance of repeated injury to the low back. Since the 1980s, a variety of studies on trunk-stabilization exercise have been performed. Lumbar stabilization involves elimination of repetitive microtrauma to the lumbar motion segments, thereby limiting the injury and allowing healing to occur. The concept of muscle fusion essentially involves using the muscles to brace the spine and protect the motion segments against repetitive microtrauma and excessively high single-occurrence loads. Abdominal muscle strengthening is the cornerstone of the stabilization program, which involves the cocontraction of the abdominal muscles to maintain a corseting effect on the lumbar spine, using the midline ligament and thoracolumbar fascia along with proper pelvic positioning. The use of the spinal extensor muscles to reduce translational stress to the intervertebral segments is important during activity and for balancing shear stress to the intervertebral segments. Electromyographic (EMG) activity of trunk muscles performing various exercises has been studied, and researchers found that in addition to the abdominal muscles, the quadratus lumborum muscle is an important active stabilizer, especially when one is in an upright position. After we assessed muscle-recruitment patterns and spine loading that resulted from a variety of exercises, the side-bridge exercise was identified as an optimal challenge for the quadratus lumborum while minimizing the load on the lumbar spine. Side-bridge exercises have been emphasized among low-back-stabilization exercises in general. Normative data regarding endurance times and their ratios were obtained for various stabilization exercises to investigate their relationship to physiological deficiency, and specific training aimed at a particular deficiency should be intensified.

McGill found that the 60° flexor test produced different endurance times with a relatively larger variance. We therefore added a 45° flexor and curl-up test and examined whether they could improve the test results, reducing variance. In our study, the 60° flexor test had a mean endurance time of
375 seconds, which was even longer than the mean endurance time of 149 seconds of McGill’s study. The endurance times for the 45° flexor test and curl-up test were 101 seconds and 107 seconds, respectively, which were shorter than that of the 60° flexor test in our study and McGill’s study. The coefficient of variance for the 60° flexor test was significantly greater than the coefficient of variance of the 45° flexor test or the curl-up exercise (.67 vs .50). In summary, the results of the 45° flexor test and curl-up test were significantly more satisfactory than those of the 60° flexor test.

The 60° flexor test is categorized as an isometric bent-knee sit-up exercise. The fulcrum is located at L4-5. EMG data have shown that this exercise mainly involves the abdominal oblique muscle and the rectus abdominis muscle.13 The 45° flexor test is also categorized as an isometric bent-knee sit-up exercise and has the same fulcrum location. With regard to the muscle length–force relationship, the rectus abdominis and the abdominal oblique muscle are longer in the 45° flexor position than in the 60° flexor position, and the abdominal-muscle force required for the 45° flexor exercise is therefore greater than the force required for the 60° flexor exercise. Juker’s13 study examined abdominal-muscle activity during dynamic bent-knee sit-ups. A time analysis of intramuscular EMG signals showed that the muscle force required for the 45° flexor exercise was greater than the force required for the 60° flexor exercise.13 Although the fulcrum is the same for the 45° and 60° flexor exercises, the 60° flexor endurance time of 375 seconds was significantly longer than the 45° flexor endurance time of 101 seconds, indicating that these results were influenced by other factors such as length of the moment arm and muscle length–force relationship (Table 2).

In the curl-up test the fulcrum is located at the 11th to 12th thoracic-vertebra level. The test is therefore not representative for the abdominal oblique muscle, but it is highly representative for the rectus abdominis muscle.13 The mean curl-up endurance time in this study was 107 seconds, which is slightly longer than the mean 45° flexor endurance time of 101 seconds. There was no significant difference, however, between the results of these 2 tests.

<table>
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</tr>
<tr>
<td>60° flexor vs curl-up</td>
<td>9.81</td>
<td>2.84*</td>
</tr>
<tr>
<td>45° flexor vs curl-up</td>
<td>0.23</td>
<td>2.84</td>
</tr>
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</table>

*Statistically significant, P < .05.
Among 3 kinds of flexor tests, the endurance time for the $60^\circ$ flexor test was the longest and had the largest variance. Meanwhile, the endurance times for the $45^\circ$ flexor test and curl-up test were much shorter and had smaller variance. From this point of view, the $45^\circ$ flexor test and curl-up test are better than the $60^\circ$ flexor test as endurance tests. Curl-up exercise recruits high abdominal-muscle activity and produces low psoas-muscle activity\textsuperscript{13,19} and is therefore suited for longer-duration, higher-repetition cycles to optimize endurance together with strength gains. Bent-knee sit-up exercises do not strongly challenge the abdominal wall but are characterized by higher psoas activity; therefore, any form of sit-up is contraindicated for an unstable spine.\textsuperscript{13} Furthermore, the curl-up test does not require any equipment and is easy to perform. Therefore, it is recommended as the best choice of trunk-flexor exercise test.

Conclusions from this study are limited by the following methodological restrictions: Myoelectric activities of tested muscles were not recorded concurrently; therefore, the results from other studies were cited to amplify the results of our study. Furthermore, the participant pool was quite homogeneous (they were young, healthy, sedentary women) and might not represent a wider population. Further study with different populations, including patients with low back pain, is needed.

**Conclusion**

Trunk-flexor exercises with a lesser degree of flexion, such as $45^\circ$ flexion or curl-up, as compared with the larger-degree ($60^\circ$) flexor exercise, were time effective and showed less variance in the current study. The curl-up exercise is easy to perform, convenient (not requiring any equipment), safe, and representative of trunk-flexor exercises. It can be considered preferable to $60^\circ$ flexor exercise.

**References**


