

A COMPARISON OF 2 ASSESSMENT PROTOCOLS TO SPECIFICALLY TARGET ABDOMINAL MUSCLE ENDURANCE

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ABSTRACT

Objective: The purpose of this study was to compare 2 variations of a test designed to evaluate abdominal muscle endurance.

Methods: This study included 21 healthy adults (10 men and 11 women) aged 23.2 ± 3.3 years. Participants recruited from a chiropractic institution performed 2 fatiguing protocols (with a lordotic posture or free of instructions), each immediately preceded and followed by a maximum voluntary contraction. Force data and surface electromyography of 6 muscles were recorded. The influence of posture on endurance time as well as the effect of posture on MedF/time slopes for each individual muscle throughout the first 4 30-seconds time segments was assessed.

Results: Mean time until exhaustion was 261.3 ± 149.8 seconds for the lordotic condition and 358.8 ± 206.4 seconds for the free condition. The lordotic condition induced significantly more fatigue than the free condition in 3 muscles during the first 30 seconds. However, both conditions induced similar levels of fatigue for the following 30 seconds. After the first 60 seconds, no significant differences in fatigability were noted between the 2 experimental conditions.

Conclusion: For the subjects studied, lumbar lordosis had a significant influence on trunk muscle fatigue during abdominal muscle endurance assessment. Specifically targeting the abdominal muscles during an endurance task remains a challenge. (*J Manipulative Physiol Ther* 2011;34:188-194)

Key Indexing Terms: *Abdominal Muscles; Physical Examination; Physical Endurance; Muscle Fatigue; Chiropractic*

It has been argued that inadequate trunk muscle endurance may be a risk factor in the development and chonicization of low back pain (LBP).¹⁻⁴ Back extensor muscle isometric endurance has been studied extensively,⁵ but less attention has been given to the trunk flexor muscles. It is believed that abdominal muscles (especially the transversus abdominis and internal oblique) potentially contribute to lumbar spine stability through different neuromuscular mechanisms. Over the last decade, several authors have proposed that the abdominal muscles play a significant role in spinal stability because of their ability to maintain low-level isometric contractions to support the trunk in various positions.^{1-3,6-10} Although study results regarding the functional aspects of trunk

muscles are often conflicting, it has been reported that patients with LBP present lower levels of extensor and flexor muscle endurance^{2,3} and lower levels of maximal isometric voluntary contractions (MVCs).¹¹ It has also been observed that patients with LBP exhibit changes in muscle synergies in comparison to healthy populations.^{10,12,13} These premises led to a series of experiments where abdominal muscle fatigue was either investigated or considered as an independent variable to alter trunk sensory motor attributes.

Two different strategies are generally proposed to assess trunk flexor endurance: dynamic and static endurance tests. On one hand, dynamic protocols such as repetitive sit-ups¹⁴ or intensive aerobic exercise via expiratory muscle activation¹⁵ seem to be adapted to pain-free subjects or athletes. On the other hand, static protocols may be more appropriate for testing in LBP population because of the standardize position, relatively pain-free experimental protocols, and localize muscle fatigue. More complex techniques to induce abdominal muscle fatigue, such as magnetic stimulation of the spinal nerve, or to monitor abdominal fatigue such as gastric and esophageal pressure have also been suggested.^{15,16} However, these techniques have limited clinical relevance and usefulness. On the other hand, functional isometric testing combined with surface electromyography (EMG) provides a practical, cost-effective, and noninvasive method of assessing abdominal muscle fatigue and endurance.

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Grondin and Potvin¹ investigated spinal responses during sudden loading in the presence of back and abdominal muscle fatigue with a primary focus on the involvement of abdominal muscles in spinal stability. Participants were subjected to sudden trunk loadings both at known and unknown timings. These sudden loads were applied during 2 different conditions: back muscle fatigue as well as back extensor + abdominal muscle fatigue. Their study showed that, in both muscle fatigue conditions, the baseline activity of trunk muscles increased, and this increase was greater when the back extensor and abdominal muscles were fatigued. To induce abdominal muscle fatigue, Grondin and Potvin¹ imposed isometric abdominal contractions for 3 seconds in a position of 1/4 sit-ups in neutral, right rotation and left rotation until exhaustion. Surprisingly and despite the widespread clinical use of abdominal rehabilitation exercises, very few investigations into the assessment of abdominal muscle fatigability have been published. McIntosh et al³ attempted to establish a sex- and age-referenced table of normative values for 7 endurance protocols, 3 of which were abdominal muscle endurance protocols (ie, isometric 1/4 sit-ups, supine bilateral straight-leg raise, and dynamic 1/4 sit-ups). In 2002, McGill¹⁷ published a sex-referenced table of normative values for isometric 60° sit-ups with no specific directive regarding lumbar lordosis. The authors also presented reliability data for their fatigue protocol, which showed a reliability coefficient of .93.¹⁸

In a recent study, Tse et al¹⁹ compared endurance time and EMG parameters during an isometric sit-up with a 60° of trunk flexion relative to the floor (reference position)¹⁸ and the same position with an added 5° of trunk flexion (modified position). Their subjects, a group of male rowers, held the modified position significantly longer (193.38 ± 58 seconds) than the reference position (115.19 ± 37.24 seconds). The authors used the mean ratio of muscle EMG activity normalized to maximal voluntary contractions to compare muscle activity. Their results showed that mean trunk flexor muscle EMG activity was significantly greater during the reference position than during the modified position. The authors, however, did not report any EMG indicators of fatigue.

In light of these previous results, the purpose of our study was to compare 2 variations of a test designed to assess abdominal muscle endurance to determine which of the 2 procedures could more specifically target this group of muscles.

METHODS

Participants

Twenty-one healthy subjects, 11 women and 10 men, participated in this study. All participants were volunteers with no history of LBP, abdominal pain, or back or lower

Table 1. Baseline characteristics of participants (mean $\pm$ SD)

	Men	Women	Combined
Age (y)	22.3 $\pm$ 2.0	24.1 $\pm$ 4.1	23.2 $\pm$ 3.3
Weight (kg)	76.7 $\pm$ 9.7	61.2 $\pm$ 7.8	68.6 $\pm$ 11.7
Height (m)	1.80 $\pm$ 0.08	1.63 $\pm$ 0.05	1.71 $\pm$ 0.11
BMI (kg/m ²)	23.7 $\pm$ 2.5	22.8 $\pm$ 2.2	23.2 $\pm$ 2.3
Baecke-f score	23.29 $\pm$ 4.59	21.63 $\pm$ 5.16	22.42 $\pm$ 4.85

limb surgery. All of them gave their informed written consent according to the protocol approved by the Université du Québec à Trois-Rivières (Canada) Ethics Committee. Exclusion criteria were past or present LBP or thoracic pain, spinal trauma, and surgery.

The experimental session lasted approximately 1 hour and was conducted at the Université du Québec à Trois-Rivières Neuromechanics and Motor Control Laboratory. Each participant's height and weight were measured before the experimental task. The *Baecke-f* questionnaire was also completed to measure the participants' habitual physical activity levels.²⁰ The experimental task was thoroughly explained and demonstrated by the experimenter before any data were recorded. Table 1 reports age, weight, height, and body mass index (BMI) at baseline with mean values and SD.

Experimental Protocol

Participants were asked to perform sustained isometric contractions of the abdominal muscles in 2 different fatiguing conditions: (1) while maintaining their lumbar spine lordosis–lordotic condition and (2) allowing lumbar spine flexion–free condition. Both fatigue tasks were preceded and followed by maximal voluntary contractions of the abdominal muscles, and participants were allowed 15 minutes between each phase of the experimental session. The fatiguing tasks were counterbalanced across participants to control for sequence order effects. Participants were positioned against a wooden board (60°) that was placed behind them to offer support before the fatiguing task. A kinesthetic landmark, barely touching the sternal fork, was also installed to guide them. On the researcher's cue, an assistant removed the support provided by the wooden board, which started the timer for the fatigue protocol. During the fatigue task, participants were asked to keep their sternum below the kinesthetic landmark, head aligned with the trunk and knees together. The goal for all participants was to hold this position until the task became extremely difficult. To ensure that participants abide to those instructions, the same assistant observed the entire task for every participant. Failure to comply with instructions resulted in a warning by the assistant, and the task was ended if the participant failed to follow instructions a second time. Participants were asked to rate their perceived exertion on a 0-to-11 scale. A 0 value was described as no effort at all, whereas a value of 10 was described as extremely difficult. In line with Borg et al,²¹ the last anchor

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