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Original Research

Electromyographic Changes in Trunk Muscles During Graded Lumbar Stabilization Exercises

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Abstract

Background: Lumbar stabilization exercises are effective for the treatment of patients with low back pain. However, personalized exercise programs are required to facilitate more efficient treatment, as each individual exhibits the different characteristics of the trunk muscles and pain.

Objective: To determine the effects of graded lumbar stabilization exercises on the trunk muscles in healthy individuals, using surface electromyography.

Design: A cross-sectional prospective study.

Setting: Outpatient pain clinic.

Participants: Ten healthy male participants without low back pain were recruited on a volunteer basis.

Methods: Four common lumbar stabilization exercises were selected, including the curl up, dead bug, Superman, and bird dog exercises. Each exercise was divided into 5 intensity levels, with participants performing all exercises at each intensity level, to a total of 20 exercises. Electromyographic changes in the trunk muscles according to intensity level were analyzed.

Main Outcome Measurements: Using superficial electromyography, the peak amplitude and area under the curve for each of the rectus abdominis (RA), external oblique abdominis (EO), multifidus (MF), and erector spinae (ES) muscles were measured.

Results: In general, as the level of intensity increased, the activity of the related lumbar stabilizing muscles also increased significantly ($P < .05$). Specifically, the peak amplitudes of the RA ($P = .008$) and EO ($P < .001$) were increased during the curl up exercise, whereas the peak amplitudes of the MF ($P < .001$) and ES ($P = .002$) were increased during the bird dog exercise. The prolonged exercise duration of the Superman exercise increased the mean area under the curve of MF, ES, and RA ($P < .001$).

Conclusions: Using a graded exercise program, an appropriate level of exercise intensity can be prescribed and modulated according to patient tolerance and physical ability. Therefore, a graded lumbar stabilization exercise program may represent an effective way to strengthen the lumbar stabilizing muscles in patients with low back pain.

Introduction

The lumbar stabilizing muscles are divided into local and global muscles, based on their role in stabilizing the trunk [1]. The multifidus (MF), transversus abdominis, and internal oblique abdominis constitute the local stabilizing system, whereas the longissimus thoracis, rectus abdominis (RA), and external oblique abdominis (EO) constitute the global stabilizing muscles. Lumbar stability is primarily managed by the local muscles, whereas the global muscles, which are generally multisegmental, are the primary producers of movement. Although global musculature, in combination with local musculature, plays an important role in stability, global muscles

contribute primarily compressive forces to stability, and are limited in their ability to control segmental shear forces [2-4]. Various lumbar stabilization exercises for strengthening these muscles have been developed as a means to treat low back pain (LBP). Examples of widely known lumbar stabilization exercises include the so-called trunk curl, dead bug, quadruped, and bridge exercises [5-7], with previous studies showing that these lumbar stabilization exercises provide therapeutic effect for pain relief and normal performance [8-11].

However, as none of these lumbar stabilization exercises can strengthen all lumbar stabilizing muscles simultaneously [12-14], several stabilization exercises should be combined to achieve a balanced result [15].

Furthermore, each individual has different lumbar stabilizing muscle strength, and the relative intensity of exercises varies; hence, lumbar stabilization exercise programs should comprise different exercises of varying intensity to maximize therapeutic benefit. Although several studies have investigated the effects of individual exercises and differing exercise loads on the lumbar stabilizing muscles [13,16-18], research is scarce regarding the effects of a graded exercise program implementing various lumbar stabilization exercises in LBP patients.

Therefore, in this study, we selected 4 commonly prescribed lumbar stabilization exercises and categorized each exercise into 5 sub-exercises according to intensity. To improve patient compliance with the exercise program, the intensity level of each exercise was modified according to patient capacity, with changes in the postures of the upper and lower extremities or neck and in the duration of exercise time. Postures were selected arbitrarily for each intensity level by the authors, but were loosely based on previous studies. Subsequently, we evaluated which lumbar stabilizing muscles were activated in each exercise, and whether increasing intensity would result in muscle activity changes, as intended. Superficial electromyography (SEMG) was used to evaluate changes in the activity of the lumbar stabilizing muscles.

Methods

Study Participants

This cross-sectional study was conducted in March 2014. Ten healthy men, with an average age of 30.0 ± 2.7 years, were recruited voluntarily. The mean height, body weight, and body mass index were 174.0 ± 4.6 cm, 73.6 ± 7.4 kg, and 24.3 ± 2.0 kg/m², respectively. Only individuals older than 20 years but younger than 40 years of age, in good health, and without current LBP during the past 3 months were included. Subjects were excluded if they had previous respiratory, cardiovascular, neurological, or psychological abnormalities, as well as musculoskeletal disorders affecting the spine or limbs. The study protocol was approved by the relevant institutional review board, and all participants provided written informed consent.

Exercise Protocol

We selected 4 commonly prescribed lumbar stabilization exercises, and organized each exercise into 5 graded intensity levels (Figure 1). Exercises were selected based on several criteria after reviewing various core-strengthening exercises. Primarily, exercises in which intensity could be increased progressively with ease, and in which changes could be easily understood by the participants, were selected. Furthermore, static exercises

with minimal muscle movement during measurement with SEMG were given priority. Given that the intention is to implement this program in LBP patients in the future, the program was composed of exercises performed in stable postures (supine or prone lying position). The so-called curl up and dead bug exercises were performed in the supine position, and the Superman and bird dog exercises were performed in the prone position. Determination of the intensity levels was based on previous studies [12,13,16,18,19] but was ultimately at the discretion of the research team, given the relative lack of comparable literature. The participants were carefully instructed to perform 20 therapeutic exercises under the guidance of a physiotherapist. Correct performance of the exercises was verified before taking measurements. The majority of exercises were performed for 20 seconds, with the exception of variants 2D and 2E of the dead bug exercise, 3E of the Superman exercise, and 4E of the bird dog exercise. Exercises were always performed in the same order, and the participants were allowed to rest for 2 minutes after each exercise.

Curl Up Exercises

The curl up exercises were as follows: exercise 1A: abdominal bracing with knees bent and feet flat on the floor; exercise 1B: while performing exercise 1A, subjects flexed their neck and pointed their chin down towards their chest; exercise 1C: while performing exercise 1B, subjects performed a trunk curl, resting their hands on their knees; exercise 1D: while performing the trunk curl, subjects placed their hands on opposite shoulders; exercise 1E: while performing the trunk curl, subjects placed their hands behind their head, with fingers interlocked.

Dead Bug Exercises

The dead bug exercises were as follows: exercise 2A: subjects lay down on their back with their knees bent and arms fully extended. Subsequently, subjects alternated their arms constantly; exercise 2B: while performing exercise 2A, subjects lifted their right leg and held it; exercise 2C: subjects performed the dead bug exercise while alternating both the arms and legs for 20 seconds; exercise 2D: subjects performed exercise 2C for 25 seconds; exercise 2E: subjects performed exercise 2C for 30 seconds.

Superman Exercises

The Superman exercises were as follows: exercise 3A: subjects lay down on their stomach with their legs and arms extended; exercise 3B: while performing exercise 3A, subjects lifted their right arm; exercise 3C: while performing exercise 3A, subjects lifted their right arm and left leg; exercise 3D: Superman posture: subjects

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