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Effects of Pelvic Stabilization on Lumbar Muscle Activity During Dynamic Exercise

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[1]*Department of Exercise and Nutritional Sciences, San Diego State University, San Diego, California;* [2]*U.S. Spine & Sport Foundation, San Diego, California;* [3]*Department of Exercise and Sports Science, University of Wisconsin, La Crosse, Wisconsin;* [4]*Department of Biology, San Diego State University, San Diego, California.*

Abstract. San Juan, J.G., J.A. Yaggie, S. S. Levy, V. Mooney, B. E. Udermann, and J.M. Mayer. Effects of pelvic stabilization on lumbar muscle activity during dynamic exercise. *J. Strength Cond. Res. 19(4):903–907. 2005.*—Many commonly utilized low-back exercise devices offer mechanisms to stabilize the pelvis and to isolate the lumbar spine, but the value of these mechanisms remains unclear. The purpose of this study was to examine the effect of pelvic stabilization on the activity of the lumbar and hip extensor muscles during dynamic back extension exercise. Fifteen volunteers in good general health performed dynamic extension exercise in a seated upright position on a lumbar extension machine with and without pelvic stabilization. During exercise, surface electromyographic activity of the lumbar multifidus and biceps femoris was recorded. The activity of the multifidus was 51% greater during the stabilized condition, whereas there was no difference in the activity of the biceps femoris between conditions. This study demonstrates that pelvic stabilization enhances lumbar muscle recruitment during dynamic exercise on machines. Exercise specialists can use these data when designing exercise programs to develop low back strength.

Key Words. pelvic stabilization, progressive resistance exercise, lumbar extensor muscles

Introduction

Progressive resistance exercise training of the lumbar extensor muscles on machines is a common treatment for low back pain and has been shown to be effective in improving painful symptoms, psychosocial status, and functional capacity (8, 10, 11, 14, 16). The marketplace offers a variety of low back extension exercise machines with generic design features that allow the user to sit and to lean back against a thoracic pad attached to a weight stack via a pulley system, and to perform multiple repetitions against resistance. Some of these machines have elaborate pelvic stabilization mechanisms designed to limit the contribution of the large pelvic and hip extensors (i.e., gluteals and hamstrings) during trunk extension, whereas others make little or no attempt to stabilize the pelvis.

Trunk extension is a compound movement involving the simultaneous rotation of the lumbar spine, pelvis, and hips (6, 13). This functional relationship, commonly known as the lumbo-pelvic rhythm, results in approximately 180° of trunk extension, with 72° of this motion in the lumbar spine and 108° of motion in the hip and pelvis (7, 13). It has been suggested that in order to effectively assess and to train the lumbar extensor muscles, the pelvis needs to be stabilized during trunk extension exercise to minimize the involvement of the hip and lower extremity muscles and to isolate the lumbar extensors (7, 13). If the pelvis is free to move during trunk extension, contraction of the gluteals and hamstrings causes the pelvis and hip to rotate and only a small portion of the total trunk extension force production is attributed to motion of the lumbar spine via contraction of the lumbar extensors (7, 12, 13).

At present, there is controversy regarding the need for pelvic stabilization to target the lumbar muscles effectively and to develop lumbar extension strength during resistance exercise on machines. Counterintuitively, several studies have reported that pelvic stabilization is not needed for optimal recruitment of the lumbar extensors. Udermann et al. (17) reported similar levels of lumbar paraspinal surface electromyographic (EMG) activity with and without pelvic stabilization during dynamic exercise on a back extension exercise device identical to the one used in the present study. Walsworth (18) found no difference in lumbar paraspinal surface EMG activity during back extension exercise on a device with intricate pelvic stabilization mechanisms vs. a device that offers little to no stabilization. Furthermore, Benson and colleagues (3) reported no difference in lumbar paraspinal surface EMG activity between the stabilized and unstabilized conditions during dynamic trunk extension exercise on a Roman chair. Following 12 weeks of progressive resistance exercise training, one study showed that pelvic stabilization is required to develop lumbar extension strength (7), whereas another study reported that pelvic stabilization is not necessary (9).

As a result, the purpose of this study was to examine the effect of pelvic stabilization on the surface EMG activity of the lumbar multifidus and biceps femoris muscles during dynamic exercise on a lumbar extension machine. A secondary purpose was to assess the recruitment patterns of these muscles during the early and late phases of the dynamic exercise in order to quantify the potential compensatory nature of the trunk extensor muscles with repeated contractions.

Methods

Experimental Approach to the Problem

The effect of pelvic stabilization on lumbar multifidus and biceps femoris muscle activity during dynamic exercise on a lumbar extension machine was evaluated using surface EMG data and a within-subject, repeated measures design. Dynamic lumbar extension exercise was performed in the seated upright position under 2 conditions of pelvic stabilization (with and without) through modification of the lower extremity and trunk restraints on the machine. We hypothesized that stabilizing the pelvis and isolating the lumbar region would increase the activity of the multifidus and decrease the activity of the biceps femoris. In addition, the activity of these muscles was scrutinized to determine the phasic relationships of the lumbar and pelvic/hip muscles during early and late phases of the dynamic exercise.

Subjects

Fifteen volunteers (8 men, 7 women; age 27.2 ± 9.3 years, height 168.7 ± 5.1 cm, body mass 65.0 ± 10.2 kg) in good general health were recruited from a university setting to participate in this study. Potential subjects were excluded from the study if they fit any of the following criteria: (a) younger than 18 or older than 45 years of age; (b) history of low back pain; (c) history of lumbar spine pathologies or deformities; (d) knee or hip disorders contraindicating the use of the pelvic restraint mechanisms on the testing device; (e) cardiovascular or orthopedic contraindications to resistance exercise; or (f) an answer of "yes" for any question on the physical activity readiness questionnaire at screening. The experimental protocol was approved by the authors' institutional review board and each subject provided written informed consent prior to participation.

Instrumentation

Surface EMG signals were collected from 2 areas of the body, namely, the right lumbar paraspinal region at the levels of L3–L4 and the right biceps femoris muscle. After carefully palpating the muscle to establish surface landmarks, the skin was scrubbed with an alcohol pad. Next, 2 round (1.5-cm diameter), self-adhesive disposable silver/silver chloride pregelled surface electrodes were applied to the skin. Signals were collected with a sampling rate of 1,000 Hz. Raw data were rectified, smoothed (using root-mean-square technique with an interval of 50 milliseconds), filtered (Median 5 filtering technique), and normalized (using the maximum voluntary isometric contraction values obtained from the isometric lumbar extension strength test) using the Myoresearch v.2.1 software (Noraxon USA Inc., Scottsdale, AZ).

A lumbar extension machine (MedX Corporation, Ocala, FL) was used for isometric lumbar extension strength testing and dynamic exercise. It is one of several commercially available clinical tools that attempts to restrain pelvic motion during lumbar extension. Figure 1 depicts the pelvic stabilization mechanisms of the machine. Features of the machine that allow for pelvic stabilization have been described fully elsewhere (7, 13).

Isometric Lumbar Extension Strength Testing

Isometric lumbar extension strength values were used to normalize the EMG data and to determine the load for the dynamic exercise. To begin the strength test, the subject was seated in an upright position in the lumbar extension machine. The knees were flexed at approximately 20° and were positioned so that the thighs were parallel to the seat. The feet were placed in the middle of a footboard in slight internal rotation. The anterior portion of the upper thigh was secured with the lap belt and femoral restraint placed over the anterior thigh, superior to the knee. The footboard then was cranked to its position of restraint. With the femoral restraint acting as a fulcrum,

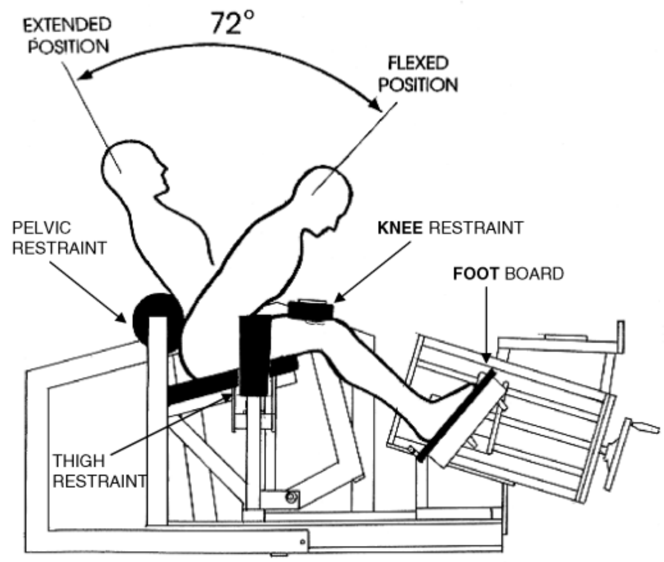

FIGURE 1. Diagram of the restraint mechanisms on the lumbar extension machine.

cranking the footboard causes a longitudinal force to be exerted along the lower extremities, which fixes the pelvis against a pelvic restraint pad.

After appropriate positioning, maximum voluntary isometric lumbar extension torque was recorded over the full range of motion in the sagittal plane at 3 positions: 72, 36, and 0° of lumbar flexion. At each angle, the subjects were instructed to gradually build up force against the thoracic pad and to push as hard as possible for at least 1 second using a monitor for visual feedback of performance. The investigator verbally encouraged the subjects to generate maximum torque during all tests. The isometric strength testing procedures have been described in detail elsewhere (7, 13).

Dynamic Lumbar Extension Exercise

Stabilized Pelvic Position. Following completion of the isometric strength test, the subject rested for 15–20 minutes, after which dynamic exercise commenced. The load used during dynamic exercise equaled 50% of the maximum voluntary isometric contraction generated during the strength test. For dynamic exercise, the subject was placed in the lumbar extension machine in the same manner as in the strength test. To start each set of dynamic exercise, the subjects were positioned at 72° of flexion (full flexion). The subjects were instructed to extend their lower backs against the upper back resistance pad until they reached 0° of flexion (full extension). Upon full extension, they were instructed to slowly return back to the starting position. To standardize the movement, a metronome was set at 60 bpm and subjects were instructed to complete each repetition at a rate of 2 seconds for the concentric and eccentric phases, with a brief pause between the phases (approximately 5 seconds total for each full repetition). Subjects were instructed to continue until they completed 20 repetitions or reached volitional failure, whichever came first.

Unstabilized Pelvic Position. Dynamic exercise for the unstabilized condition was conducted in a similar manner to the stabilized condition. However, modifications to the

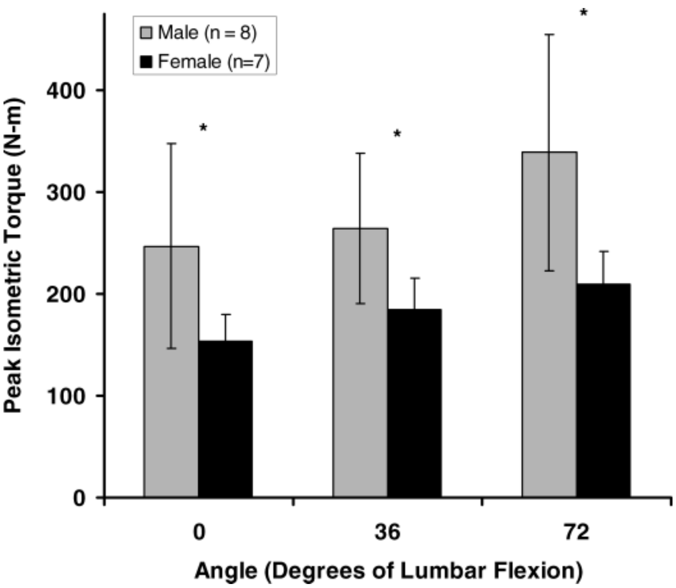

FIGURE 2. Peak isometric lumbar extension torque (N-m) plotted by gender and angle of lumbar flexion. * men > women ($p < 0.05$).

pelvic restraint mechanisms on the machine were made prior to assessment. The pelvic restraint pad was removed, the lap belt was not secured, the femoral restraint pad was not utilized, and the footboard was not cranked forward into a maximal position of restraint. The performance of the stabilized and unstabilized conditions was balanced across subjects to minimize the effect of order.

Electrode Placement

Surface EMG signals were monitored for the lumbar multifidus and biceps femoris muscles during each set of dynamic exercise. Electrodes were placed on the right side of the L3–L4 spinous process, approximately 3 cm from the midline of the torso. The second set of electrodes was placed on the right biceps femoris, midway between the ischial tuberosity and the medial epicondyle of the tibia (1). The 2 electrodes attached to the skin had a center–center distance of 2.5 cm and were placed in the belly of the muscle, parallel to its muscle fiber. The electrode distance was modeled after Basmajian et al. (2) to increase the specificity of signal detection.

Statistical Analyses

A 2 × 2 repeated measures design was implemented in this study. The independent variables were restraint condition (stabilized pelvis and unstabilized pelvis) and time (early phase and late phase of exercise). The first time interval (early phase) was the first 10 seconds of the dynamic exercise (first 2 repetitions), and the second time interval (late phase) was the last 10 seconds of the exercise (last 2 repetitions). The dependent variable was surface EMG activity expressed as both the raw value (mV) and normalized value (%). The raw (rectified, smoothed, and filtered) EMG values were used for the main statistical analyses and normalized EMG values were evaluated secondarily. For each muscle (i.e., multifidus and biceps femoris), a 2 × 2 (condition by time) repeated measures analysis of variance was utilized to evaluate differences among the 2 conditions and 2 times, and any condition by time interactions. No statistical comparisons were made between the 2 muscles. The α level was set at 0.05. The SPSS 11.5 statistical package (SPSS Inc., Chicago, IL) was utilized for all analyses.

RESULTS

Reliability of EMG Data

For each muscle group, intraclass correlation coefficients were calculated to examine the internal consistency of the EMG data across restraint condition and time. Coefficients for the multifidus EMG values for the early phase and late phase were acceptable in the stabilized ($r = 0.95$; $p = 0.05$) and unstabilized ($r = 0.99$; $p = 0.05$) conditions. Coefficients for the biceps femoris EMG values for the early phase and late phase also were acceptable in the stabilized ($r = 0.95$; $p = 0.05$) and unstabilized ($r = 0.96$; $p = 0.05$) conditions.

Gender Effects

Isometric lumbar extension torque output (means ± *SD*) plotted by angle of measurement for men and women is depicted in Figure 2. Isometric torque was greater for men than for women at each angle ($p = 0.001$). All relative torque data were within normative values for men and women and were consistent with the existing literature (10). For surface EMG activity, there was no significant ($p = 0.05$) gender main effect or any interactions involving gender with restraint condition and time for the multifidus and biceps femoris muscles.

Multifidus Activation

Table 1 shows the means and standard deviations for the raw and normalized EMG data by restraint condition and time. For the raw EMG values, a significant effect of restraint condition was observed ($p = 0.006$; partial $\eta^2 = 0.45$; observed power = 0.99). There was no significant

TABLE 1. Surface EMG values of the lumbar multifidus and biceps femoris during dynamic lumbar extension exercise with the pelvis stabilized and unstabilized, and during the early and late phases of exercise.

	Multifidus				Biceps femoris			
	Raw (mV)		Normalized (%)		Raw (mV)		Normalized (%)	
Condition (time)	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Stabilized (early)	102.3	39.65	85.69	48.4	41.41	23.82	48.8	18.57
Stabilized (late)	102.6	46.63	84.76	49.32	45.5	26.54	59.24	25.01
Unstabilized (early)	67.04	41.72	59.31	32.6	41.99	27.07	50.51	20.87
Unstabilized (late)	68.84	48.62	61.11	39.48	48.2	32.5	60.12	25.83

time main effect ($p = 0.72$) or interaction involving condition by time ($p = 0.76$). Post hoc analysis using Bonferroni comparisons revealed that exercise during the stabilized condition resulted in significantly greater ($p = 0.005$) muscle activity than during the unstabilized condition. Specifically, a 50.8% relative increase for the stabilized condition was observed. Similar results were noted when analyses were conducted using the normalized EMG data. The standard deviations of the data exhibited a large amount of variability, indicating the range of signal dispersal during the data capture.

Biceps Femoris Activation

Table 1 shows the means and standard deviations for the raw and normalized EMG data by restraint condition and time. For the raw EMG values, a significant main effect for time was observed ($p = 0.05$; partial $\eta^2 = 0.23$; observed power = 0.91). There was no significant main effect for condition ($p = 0.77$) or interaction involving time by condition ($p = 0.56$). Post hoc analysis using Bonferroni comparisons showed that the biceps femoris had significantly greater muscle activity ($p = 0.05$) during the late phase of the exercise than during the early phase. Specifically, a 12.5% relative increase during the late phase was observed. Similar results were obtained when analyses were conducted using the normalized EMG data. The standard deviations for the multifidus and the biceps femoris were remarkably similar given the variability of the measures (i.e., large *SD* values).

Discussion

The findings of the present study indicate that pelvic stabilization is necessary to achieve optimal recruitment of the lumbar extensor muscles during dynamic extension exercise on a lumbar extension machine. Namely, when the pelvis is stabilized during dynamic exercise, the multifidus is significantly more active. In contrast to these findings, a previous study using the same lumbar extensor machine used during the present study found that pelvic restraint does not improve EMG activation of the lumbar extensors (17). This disparity in the findings possibly is related to differences in study design. In the previous study, exercise during the unrestrained condition utilized the knee restraint and pelvic restraint pads of the device, though the restraints were not tightened completely. In the present study, these restraint mechanisms were removed completely from the device, leaving the pelvis and hip free to rotate. The results of the present study are in accordance with the results of a study conducted by Shirado et al. (15), which found that pelvic stabilization is necessary to increase activation of the lumbar extensor muscles during isometric exercise on a low-back exercise apparatus.

The present study noted that the biceps femoris is significantly more active during the last 10 seconds (late phase) of the exercise than during the first 10 seconds (early phase). Consistent with these findings, Clark et al. (4, 5), reported that during trunk extension exercise on a Roman chair, the normalized surface EMG activity of the biceps femoris increases as the muscle fatigues and as more repetitions of exercise are performed. In contrast to the increased activity of the biceps femoris during the late phase of exercise in the present study, the activity of multifidus was fairly constant during throughout the entire exercise set. In contrast to this finding, Clark et al. (5) found that lumbar paraspinal surface EMG activity decreases during fatiguing trunk extension contractions on a Roman chair. Discrepancies in the findings of the study by Clark et al. (5) and the present study may be related to differences in the level of pelvic stabilization offered by the machines or to the fact that fatigue of the involved muscles was not monitored in the present study. Future research is warranted to evaluate the effect of fatiguing contractions on the patterns of activation of the trunk extensors during exercise on a variety of machines.

There are several limitations of this study that need to be addressed. First, the study was conducted with volunteers in good general health, so direct generalizations to patients with low back pain cannot be made. Future research also is needed to assess the clinical applicability of the present study's findings in patients with low back pain. Further, the finding that pelvic stabilization enhances lumbar muscle recruitment on the machine tested in this study does not necessarily mean these results can be generalized to other machines and exercise techniques. Additional research is needed to test the effect of pelvic stabilization using other machines and techniques. Finally, the device used in the present study is relatively costly and inconvenient (large), so its use outside of clinical rehabilitation and university settings may be limited. Unfortunately, the ability of less expensive and more convenient alternatives (e.g., Roman chairs, stability ball exercises) to isolate the lumbar spine and effectively targeting the lumbar extensors has not been established. Future study is needed to compare lumbar muscle recruitment during exercise on the device of the present study with less expensive and more convenient alternatives.

Practical Applications

Because lumbar muscle strength and endurance is related to functional capacity and the prevention and treatment of low back pain (8, 10, 11, 14, 16), any data that describe methods to enhance the recruitment of low back muscles during exercise are potentially valuable to physicians, therapists, and trainers in clinical, fitness, and athletic settings. Our data show that pelvic stabilization is necessary to effectively recruit the lumbar muscles and these data can be used when designing exercise programs to condition the low back muscles. If the lumbar extension machines currently used in health and fitness clubs, university strength centers, and rehabilitation clinics do not utilize pelvic stabilization mechanisms, it is possible that the lumbar muscles may not be adequately trained. Future research is needed to evaluate the overload stimulus required to elicit lumbar extensor strength gains.

In summary, our study demonstrated that the surface EMG activity of the lumbar multifidus during dynamic exercise in the seated upright position on a lumbar extension machine is greater when the pelvis is stabilized than when it is unstabilized, although there is no difference in activity between the early and late phases of exercise. In contrast to the multifidus, the activity of the biceps femoris is not different between stabilized and unstabilized conditions, and increases during the late phase of exercise. Clinicians, trainers, and therapists can use these data when designing exercise programs to strengthen the low back muscles.

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