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Activation of Paraspinal, Abdominal, and Hip Muscles During Various Low Back Stabilization Exercises in Males and Females

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Abstract

Many muscles of the trunk and hip are capable of contributing to the stabilization and protection of the lumbar spine. To have optimal effectiveness, a training program should include dynamic back/stomach/hip exercises. This study was designed to assess the L5 level paraspinal, external abdominal oblique, and gluteus maximus muscle activities during various low back stabilization exercises. Participants were 26 healthy adults (13 males, 13 Females), aged 21 to 28 years. The surface electromyography (EMG) was recorded from the L5 level paraspinal, external abdominal oblique, and gluteus maximus muscles. The recorded signal was averaged and normalized to the maximal electromyographic amplitude obtained during the maximal voluntary contraction. The measurements were taken during 3 low back stabilization exercises. One-way analysis of variance with repeated measures was used to examine the difference, and a post hoc test was performed with least significant difference. A level of significance was set at $p<.05$. The significance of difference between men and women, and between the electromyographic recording sites was evaluated by an independent t-test. The EMG activity for the externus oblique and gluteus maximus muscles had significant differences among 3 exercises ($p<.05$). In males, the EMG activity for the external abdominal oblique muscle had significantly increased differences during exercises 1 and exercise 2 ($p<.05$). The gluteus maximus muscle had significantly increased differences during exercise 2 and exercise 3 ($p<.05$). In females, the multifidus muscle had significantly increased difference during exercise 3 ($p<.05$), the external abdominal oblique muscle had significantly increased difference during exercise 1 ($p<.05$). and the gluteus maximus muscle had significantly decreased difference during exercise 3 ($p<.05$). The results were that the external abdominal oblique muscle was apparently activated during the curl-up exercise in females and males, and the multifidus muscle was apparently activated during the bridging exercise in females and during the sling exercise in males and females. In comparison of the %MVC between males and females, exercise 2 and exercise 3 apparently activated of the multifidus and gluteus maximus muscles in both males and females ($p<.05$). The EMG activity of the gluteus maximus muscle of the males significantly increased during exercise 2 and exercise 3 ($p<.05$). The EMG activity the multifidus muscle of the females was significantly increased during exercise 2 and exercise 3 ($p<.05$). More research is needed to understand the nature of motor control problems in the deep muscles in patients with low back pain.

Key Words: Low back stabilization exercise; Sling exercise; Surface electromyography.

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Introduction

Complaints and syndromes relating to the lumbar-sacral region affect 80% of the adult population (Herring, 1991). Low back pain is recognized as the leading cause of occupational injury in developed countries (Battie and Bigos, 1991; Guo et al, 1999). The function and coordination of the muscle that stabilize the lumbar spine, especially the lumbar back extensor muscles, are often impaired in patients with low back pain (LBP) (Hodges and Richardson, 1999; Magnusson et al, 1996; Wilder et al, 1996).

Muscles play an important role in etiology, presentation and treatment of low back disorder. It is known clinically that excessive motion beyond the normal physiologic limits, also sometimes referred to as spinal instability, may result in chronic low back pain (Hodges and Richardson, 1996). The stability of the lumbar spine is determinated by the osteoligamentous structures and trunk muscles. Because motion takes place in all 3 dimensions simultaneously, complex loading patterns act on the passive structures of osteoligamentous spine and, if unprotected, the lumbar spine is vulnerable to being damaged. Therefore, it is essential that the motions are precisely controlled by lumbar and abdominal muscles to produce the stiffness required to optimize the loading on the lumbar spine, and to prevent overload injury (Callghan and McGill, 1995; Kaigle et al, 1995; McGill 1997). There is increasing evidence that the lumbar mutifidus and transverse abdominis are preferentially affected in the presence of low back pain and lumbar stability. Back extension exercises have been used for rehabilitation of the injured low back, prevention of injury, and fitness training programs but excessive loading on low back can exacerbate existing structural weakness (Yoo et al, 2001).

Active rehabilitation has been increasingly advocated as a treatment for chronic low back pain (CLBP) (Deyo 1991; Twomey and Taylor, 1995). Exercise-based active rehabilitation programs can reduce LBP intensity, alleviate functional disability, and improve back extension strength, mobility, and endurance (Manniche et al, 1991; O'Sullivan et al, 1997). More recent studies suggest that muscles spasms and reflex inhibition of the trunk muscles can also contribute to the deconditioning syndrome (Hides et al, 1994; Hides et al, 1996; Indahl et al, 1995; Indahl et al, 1997). In active exercise treatment programs, these functional limitations can be improved, and this represents the basis and rationale for such programs (Parkkola et al, 1992; Rissanen et al, 1995).

Hides et al (2001) showed that simple therapeutic exercises are effective in activating lumbar paraspinal muscles, and that surface electromyographic measurements are highly comparable in the assessment of lumbar multifidus muscles function and the role of the abdominal and back muscles in stabilization.

Back exercise programs are of value to patients with low back pain, extensive review clearly revealed that more high-quality research is needed before firm conclusions can be drawn (Elnaggar et al, 1991). The need to vary the exercise programs and to make them a normal part of everyday life has been stressed as an important factor when recommending a training program. To have optimal effectiveness, a training program should include dynamic back/stomach/hip exercises in high doses, performed for a period of time sufficient to build muscles and supportive tissues (Ljunggren et al, 1997).

The purpose of this study was to assess the L5 level paraspinal, external abdominal oblique, and gluteus maximus muscle activities during various low back stabilization exercises in males and females.

Methods

Subjects

Twenty-six healthy adults (13 males, 13 females), aged from 21 to 28 years, who had no experience with muscle strength testing or the therapeutic exercises participated after signing a voluntary consent form. The subjects' characteristics are shown in Table 1.

Instruments

The muscle activity on the subjects' L5 level paraspinal, external abdominal oblique, gluteus maximus muscles were collected by the MP150 system[1)] using dual circular surface electromyographic disposable electrodes[2)]. The sampling rate was 1000 ㎐. The EMG signals were digitally notch (60 ㎐) filtered. The root mean square (RMS) value was calculated. The Acqknowledge 3.7.3 program was employed for data reduction processing.

Procedures

Surface electromyographic measurements were made during 3 low back stabilization exercises. After the skin was cleansed with alcohol. Surface electrodes were attached over the following muscles: external abdominal oblique, halfway between the anterior superior iliac spine (ASIS) and the inferior border of the ribcage at a slightly oblique angle running parallel with the underlying muscle fibers, and the multifidus muscles at L5, 2 ㎝ laterally from the midline running through multifidus muscles fibers (Hides et al, 1996; Indahl et al, 1995), and gluteus maximus, half the distance between the trochanter and sacral vertebrae in middle of the muscle on an oblique angle at the level of the trochanter or slightly above (Cram et al, 1998).

The full-wave rectified electromyographic amplitude was determinated by calculating the absolute value of each data point. These were plotted against time to assess the average electromyographic amplitude a mean value of all data points within the selected areas. In the exercises, 3 consecutive repetitions, each of 8 second data segments of isometric contractions, and each of the 3-second data segments of contraction, were selected for the assessment of average electromyographic amplitudes.

The electrographic signals recorded in each ex-

Table 1. General characteristics of the subjects (N=26)

Characteristic	Males	Females
Age (yrs)	26.5±2.2[a]	22.5±2.8
Weight (㎏)	68.4±5.5	58.0±6.4
Height (㎝)	171.6±5.3	158.5±7.2

[a]Mean±SD

1) Biopack system Inc. Santa Barbara, CA. USA.
2) Noraxon Inc. Scottsdale, AZ. USA.

ercise were normalized to the maximal electromyographic amplitude obtained during the maximal voluntary contraction. The MVCs of the back extensor, external abdominal oblique, and gluteus maximus muscles were tested in maximal isometric extension, flexion, and rotation-flexion, respectively. Three maximal trunk flexion and extension measurements were made, each lasting approximately 5 seconds. The average electromyographic amplitudes obtained were normalized to the amplitude at MVC (%MVC).

The subjects were taught to perform the 3 different exercises by practicing them under the guidance of physical therapists. Subjects had no experience with muscle strength testing or the therapeutic exercises. The aim of all the exercise studies was that the subjects keep their lumbar spine stationary. The exercises were always performed in the same order. The joint angles of the lower extremities were controlled with an inclinometer during the exercises. Subjects were able to perform all of the exercises. Subjects rested for 3 minutes between the exercises. The exercises were as follows. Exercise 1: The trunk flexion 45° to curl up position (Figure 1). Exercise 2: Back extension with lifting the hip up to a bridging position (Figure 2). Exercise 3: Back extension with lifting the hip up in a sling (Figure 3).

Statistical analysis

The statistical analysis of data was performed using SPSS 10.0. All values are expressed as mean±SD. One-way analysis of variance with repeated measures was used to examine the difference, and a post-hoc test was performed with least significant difference. The level of significance was set at $p<.05$. Significance of difference between men and women, and between the electromyographic recording sites were evaluated by independent t-test, respectively. Two-sided significance was defined as $p<.05$.

Results

1. Comparison of muscle activity (%MVC) among 3 exercises.

The EMG activity for the externus oblique and gluteus maximus muscles had significant differences during the three exercises done by males ($p<.05$) (Table 2). The EMG activity for the male external abdominal oblique muscle also had significantly increased difference during exercises 1 and exercise 2 ($p<.05$). In addition, The males' EMG activity for the gluteus maximus muscle had significantly increased differences during exercise 2 and exercise 3 ($p<.05$) (Figure 4).

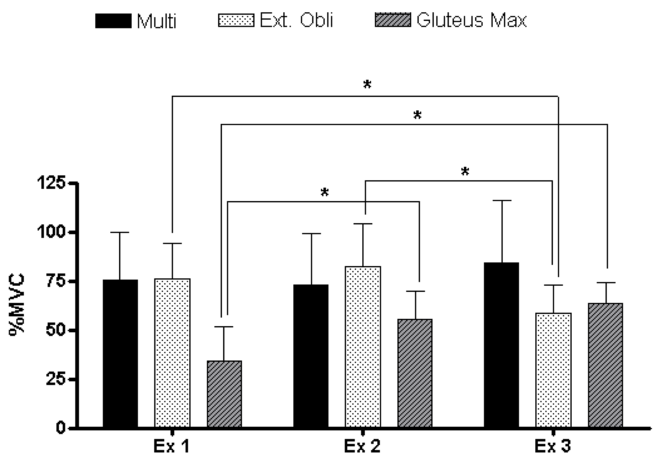
Figure 1. Exercise 1

Figure 2. Exercise 2

Figure 3. Exercise 3

Table 2. Results of the one-way repeated measure ANOVA performed on the data of the 3 exercises in males (N=13)

Muscle	Type Ⅲ sum of squares	Mean square	F	p
Multifidus	44.36	22.18	.07	.96
Externus oblique	3901.12	1950.56	11.33	.01
Gluteus maximus	6488.24	3244.12	12.82	.00



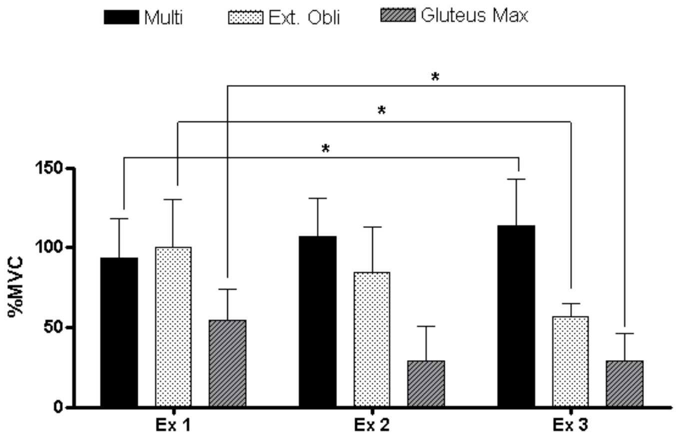
*p<.05

Figure 4. Results of the one-way repeated measure ANOVA performed on the data of the 3 exercises in males (%MVC)

The EMG activity for the multifidus, externus oblique, and gluteus maximus muscles had significant differences during the 3 exercises done by females (p<.05) (Table 3). The multifidus, external abdominal oblique, and gluteus maximus muscles during exercise 1 and exercise 3 also had significant differences in females (p<.05). The EMG activity of the multifidus muscle of the females was significantly increased during exercise 3 (p<.05). While the EMG activity of the gluteus maximus and external abdominal oblique muscles during exercise 3 were significantly decreased (p<.05) (Figure 5).

Table 3. Results of the one-way repeated measure ANOVA performed on the data of the 3 exercises in females (N=13)

Muscle	Type Ⅲ sum of squares	Mean square	F	p
Multifidus	3235.21	1626.65	4.92	.02
Externus oblique	8390.95	4195.47	4.54	.02
Gluteus maximus	11270.05	5635.02	3.97	.03



*p<.05

Figure 5. Results of the one-way repeated measure ANOVA performed on the data of the 3 exercises in females (%MVC)

2. Comparison of muscle activity (%MVC) between males and females

The EMG activity of the multifidus and gluteus maximus muscles during exercise 1 and 3 had significant differences between males and females (p<.05). The EMG activity of the gluteus maximus muscle of the males increased significantly during exercise 2 and exercise 3 (p<.05). During exercise 2 and exercise 3, the EMG activity of multifidus muscle of female significantly increased (p<.05) (Table 4) (Figure 6, 7, 8).

Table 4. Comparison of % MVC between males and females in 3 exercises (Unit: %)

	Muscles	Males (n=13)	Females (n=13)	t	p
		Mean±SD	Mean±SD		
Exercise 1	Multifidus	75.58±24.26	93.25±25.01	-1.30	.21
	Externus oblique	76.12±17.75	99.79±30.22	-1.08	.29
	Gluteus maximus	33.82±17.67	54.22±19.82	-.04	.97
Exercise 2	Multifidus	72.83±26.33	106.80±24.41	-2.45	.02
	Externus oblique	82.17±21.62	84.12±28.58	-.09	.93
	Gluteus maximus	55.09±14.75	28.86±21.42	2.29	.03
Exercise 3	Multifidus	84.03±32.07	113.31±29.55	-2.18	.04
	Externus oblique	58.59±14.16	56.77±7.82	-.11	.91
	Gluteus maximus	63.70±10.37	28.96±16.84	3.04	.01

*p<.05

Figure 6. Comparison of %MVC between males and females in exercise 1

*p<.05

Figure 7. Comparison of %MVC between males and females in exercise 2

*p<.05

Figure 8. Comparison of %MVC between males and females in exercise 3

Discussion

In our study, therapeutic exercises were effective in activating lumbar paraspinal, abdominal, hip muscles in healthy volunteers; surface electromyographic measurements were highly comparable in the assessment of lumbar multifidus, external abdominal oblique, and gluteus maximus muscles.

By changing the limb and trunk position, or by unbalancing trunk muscle movements, it is possible to increase trunk muscle activities (Peach and McGill, 1998; Wilder et al, 1996). This study has suggested that deep local stabilizing lumbar mutifidus muscles should be contacted independently of the global muscles, that is, the external abdominal oblique and gluteus maximus muscles. Lumbar paraspinal electromyography has been used to estimate back extensor force generation and spinal compression during lifting activities, because eletromyographic activity is related to the load acting on the lumbar disks (Cholewicki et al, 1999). Thus, the high activation level of the lumbar paraspinal muscles may lead to unfavorable forces impinging on the spine (Panjabi 1992). In our study, the activities of the multifidus muscles at L5 indicate that the lumbar muscles that current exercises are suitable for training provide the segmental stability of the lumbar spine.

Supports is growing for the functional differentiation between global and local muscles in relation to spinal control. More pertinently, links are now emerging between low back pain and motor control deficits in muscles of the local system, notably the transverses abdominis, lumbar, and multifidus muscles (Hides et al, 1996; Hodges and Richardson, 1996). The lumbar multifidus has been shown to react by inhibition at a segmental level in acute episodes of low back pain (Hides et al, 1994; Hides et al, 1996). Criso and Panjabi (1991) reported that lumbar stability is maintained in vivo by increasing the activity (stiffness) of the lumbar segmental muscles. The local muscle system consists of muscles that directly attach to the lumbar vertebrae and are responsible for providing segmental stability and directly controlling the lumbar segments. By definition, the lumbar multifidus, transverse abdominis, and posterior fibers of the internal oblique form part of this local muscle system. The co-contraction of deep abdominal muscles with the lumbar multifidus has the potential to provide a dynamic corset for the lumbar spine enhancing its segmental stability during functional tasks and the maintenance of neutral spinal postures. Specific exercise directed at the local muscle system have been advocated by physical therapists as an effective means of treating chronic low back pain condition by enhancing the dynamic stability of the lumbar spine. It has already been shown that specific exercise treatment is more effective than types of considerative treatment modalities for LBP (Richardson et al, 1999).

In our study, we used curl-up, bridging, and sling exercises to find the stabilizing method. In the males, the EMG activity for the external abdominal oblique muscle showed significantly increased differences during exercises 1 and exercise 2. While the gluteus maximus muscle showed significantly increased differences during exercise 2 and exercise 3. In the females, a significantly increased difference was seen in the multifidus during exercises 3 and the external abdominal muscle oblique during exercise 1, while difference was not seen in the gluteus maximus muscle during exercise 3.

The results were that the external abdominal oblique muscle was apparently activated during curl-up exercise in females and males, and the multifidus muscle was apparently activated during the bridging exercise in females and during the sling exercise in males and females.

In comparison of %MVC between males and females, exercise 2 and exercise 3 showed significant differences of the multifidus and gluteus maximus muscles between males and females. During exercise 2 and exercise 3, the EMG activity of the gluteus maximus muscle of the males significantly increased ($p<.05$). The EMG activity of the multifidus muscle of the female was significantly increased. While the gluteus maximus muscle of the females apparently wasn't as active as that of the males. Excessive activation of the multifidus muscle can exacerbate existing structural weakness and the low back pain. Co-contraction of trunk and hip muscle is applied for stabilization of low back. Therefore, we suggest that females should avoid, for example, excessive exercise in a sling when lying supine.

In clinical practice, we should find the safest method to exercise the local stabilizing muscles of the lumbar spine. The loading of the trunk muscles should be defined. Excessive spine loading should be avoided in patients with back pain to prevent further structural damage (Callaghan et al, 1998; McGill 1998). Yoo et al (2001) has suggested that patients with back pain should avoid, for example, exercise in which the upper body and legs are raised simultaneously when lying prone. These exercises are accompanied with high levels of spinal loading (Callaghan et al, 1998). It has already been suggested that back muscle contraction as low as 25% of MVC is able to provide maximal joint stiffness (Yoo et al, 2001). The theory behind the use of spine stabilization exercises for patients with spine dysfunction stresses the importance of the deep local stabilizing muscles, especially the mutifidus and transverse abdominis muscles (Richardson et al, 1999). Stabilization exercises are beneficial for patients with symptomatic spondylolysis or spondylolisthesis, and long-term results suggest that specific exercise therapy in addition to medical management and resumption of normal activity may be more effective in reducing LBP recurrence than medical management and normal activity alone (Hides et al, 2001). However, stabilization exercises have no effect on the cross-sectional area of the multifidus muscles; intensive lumbar resistance training is necessary to restore the size of multifidus muscles in patients with CLBP (Danneels et al, 2001). More research is needed to understand the nature of motor control problems in the deep muscles in patients with low back pain.

Conclusion

This study was done to assess the L5 level paraspinal, external abdominal oblique, and gluteus maximus muscle activities during various low back stabilization exercises in males and females. Twenty six healthy men (13 men, 13 women), aged 23 to 26 years, participated in our study.

In the males, the EMG activity for the external abdominal oblique muscle showed significantly increased difference during exercise 1 ($p<.05$), the EMG activity for the gluteus maximus muscle showed significantly increased differences during exercise 2 and exercise 3 ($p<.05$).

In the females, the EMG activity for the multifidus muscle showed significantly increased difference during exercise 3 ($p<.05$), the EMG activity for the external abdominal oblique muscle showed significantly increased difference during exercise 1 ($p<.05$), and the EMG activity for the gluteus maximus muscle showed significantly decreased difference during exercise 3 ($p<.05$). The results were that the external abdominal oblique muscle was apparently activated during the curl-up exercise in females and males, and the multifidus muscle was apparently activated during the bridging exercise in females and during the sling exercise in males and females.

In comparison of the EMG activity between males and females, the EMG activity of the gluteus maximus muscle of males significantly increased during exercise 2 and exercise 3 ($p<.05$), the EMG activity of the multifidus muscle of the females was significantly increased during exercise 2 and 3 ($p<.05$). The gluteus maximus muscle of the females apparently wasn't as active as that of the males. Excessive activation of the multifidus muscle can exacerbate existing structural weakness and low back pain. For the future, various exercises for the lumbar stabilization should be studied with CLBP.

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