Original Article

Physical Therapy Rehabilitation Science

http://dx.doi.org/10.14474/ptrs.2016.5.1.40
pISSN 2287-7576
eISSN 2287-7584

Phys Ther Rehabil Sci
2016, 5 (1), 40-46
www.jptrs.org

Comparison of multifidus and external oblique abdominis activity in standing position according to the contraction patterns of the gluteus maximus

Hyuk-Soon Choi[a], **Su-Young Lee**[b]

[a]Department of Physical Therapy, Rehabilitation Center, Cheongdam Hospital, Seoul, Republic of Korea
[b]Department of Physical Therapy, Division of Health Science, Baekseok University, Cheonan, Republic of Korea

Objective: The purpose of this study was to examine the effect on multifidus and external oblique abdominis muscle activation during hip contraction of three types (concentric, isometric, eccentric) in standing position.
Design: Cross-sectional study.
Methods: Twenty healthy adult men volunteered to participate in this study. Muscle activation was recorded from gluteus maximus, both multifidus, and both external oblique abdominis by surface electromyography (EMG) while holding position in the type of gluteus maximus contraction. EMG values were normalized by maximum muscle contractions (% maximum voluntary isometric contraction). All subjects performed hip extension with three contraction methods. The type of gluteus maximus contraction using Thera-band was composed of concentric contraction (type 1), isometric contraction (type 2), and eccentric contraction (type 3). To measure muscle activation on the gluteus maximus contraction type, each position were maintained for 5 seconds with data collection taken place during middle three seconds. Muscle activation was measured in each position three times.
Results: For the results of this study, there was no significant difference within three contraction patterns of the gluteus maximus (concentric, isometric, and eccentric) each both multifidus, both external oblique abdominis, and gluteus maximus. And there was no significant difference among both multifidus, both external oblique abdominis, and gluteus maximus each hip extension contraction type.
Conclusions: These findings suggest that specific contraction types of the gluteus maximus does not lead to a more effective activation of the multifidus, external oblique abdominis, and gluteus maximus.

Key Words: Abdominal muscles, Electromyography, Paraspinal muscles

Introduction

Low back pain, regardless of the pain associated with the lower extremities, is pain and discomfort underneath the last rib and above the inferior gluteal fold [1], which is due to the spine coming out of the neutral position, which is due to shear load onto the spine, changes in the load position, and faulty posture, which all low back instability [2]. These types of back pain is experienced at least once in a person's lifetime in 80% of the population [3], and it can be easily recognized clinically, and, the prevalence rate is 60%-90% [4].

Also, low back pain causes a selective contraction of the multifidus and the paravertebral muscles, and the pain leads to non-use and decreased movement, causing increasing pain and inflammation in the low back area [5]. Specifically, if there is an issue with the trunk extensor muscles related to the musculoskeletal problems, it has an effect on the back extensor muscles, and there is an increase in back pain due to an imbalance between the hip and back muscle extensors [6]. Due to back pain, the soft tissue damage of the trunk

Received: 16 February, 2016 **Revised:** 13 March, 2016 **Accepted:** 17 March, 2016

Corresponding author: Su-Young Lee
Department of Physical Therapy, Division of Health Science, Baekseok University, 76 Munam-ro, Dongnam-gu, Cheonan 31065, Republic of Korea
Tel: 82-41-550-2546 **Fax:** 82-41-550-2829 **E-mail:** rosei118@bu.ac.kr

causes weakening, which reduces flexibility, therefore, limiting the ability to exercise freely within the available plane, and chronic back pain especially causes an imbalance near the vertebral area, and causes muscle atrophy and weakness, causing an limitation in the performance of daily activities, and affects the ability to maintain in a proper posture [7].

As a back treatment exercise method vertebra stabilization exercise, McKenzie exercise, Williams exercise, Emblass exercises are applied [8]. Recently, lumbar stabilization exercises for therapeutic or prevention purposes uses a Swiss ball or elastic band for local muscles, such as the multifidus, transverse abdominis and external oblique muscles [8]. Furthermore, spine stability and proper posture can be expected [8]. Hicks *et al.* [9] reported that when an exercise program was focused for low back stability, there was an effect on decreasing low back pain, and Sundstrup *et al.* [10] reported that vertebral stability exercises using the elastic band not only enhanced the functional ability in low back pain patients, it had an strengthening ability in the core muscles.

Wilke *et al.*'s [11] stabilization exercises indicated that exercising in lying position, versus standing, produced less pressure on the intervertebral disc, which reduced the pressure on the low back. However, our daily activities are performed more often in standing position instead of in lying position, and not only that performing stability exercises in standing position but also stimulates the proprioceptive sense and has been suggested to assist in neurological recovery [12].

When vertebral stabilization exercises are performed, a majority of the contraction patterns occur concentrically and isometrically in the back and pelvic area. However, eccentric contraction exercises may increase the muscle size, and there is a decrease in motor unit recruitment, thus leading to less muscle fatigability [13].

Nevertheless, it has been frequently excluded from the lumbar stabilization exercise programs (National Academy of Sports Medicine, 2013) [14].

In addition, the gluteus maximus (GM) muscle is a strong extensor muscle of the hip joint, controls movement and maintains posture [15], crosses over the sacroiliac joint, it physiologically moves the joint in full motion, and although it provides stability to the sacroiliac joint [16], there are currently no suggestions on the effective exercise method of the GM during the standing posture.

Therefore, the purpose of this study was to evaluate muscle activity in healthy adult male subjects in their twenties in standing position using an elastic band while performing GM concentric, isometric, and eccentric contractions and muscles related to back pain, which are the core vertebral muscles, such as the multifidus and external oblique.

Methods

Subjects

Twenty healthy, male students from Baekseok University at Cheonan city in Chungcheongnam-do were included in this study. All subjects were informed of the purpose and provided their consent of agreement in order to volunteer for the study. The study had taken place for a total of six months, starting from March to September of 2015, and the inclusion criteria were as follows: 1) those who have not received any orthopedic treatment, 2) those without any neurological issues, 3) those who have not received any health care for low back pain within 6 months, 4) those who do not have excess pain or discomfort during their daily activities or job performance, 5) those who are able to receive and understand the instructions of the researcher, 6) ability to perform 10^{o}-20^{o} of hip extension. The subjects were an average of 22.1 (3.7) years, 174.3 (1.9) cm in height, and 64.8 (5.9) kg in weight (Table 1).

Equipment

Thera-band

In order to induce concentric, isometric, and eccentric contractions of the GM, a silver thera-band was used for this study (Thera-band; The Hygenic Corporation, Akron, OH, USA).

Surface electromyography (*EMG*)

In order to measure the muscle activity of the GM, external oblique, and multifidus muscles, the Trigno surface EMG (Delsys Inc., MA, USA) was used with a common mode rejection ratio of 80 dB. After measuring the signals from the Trigno sensors, the Trigno base station with the wireless transmission of the EMG signals was analyzed using the EMGworks 3.7 software (Delsys Inc.). A sampling rate of 2,000 Hz and band-pass filter of 400-500 Hz was used

Table 1. General characteristics of subjects (N=20)

	Age (y)	Height (cm)	Weight (kg)
Mean (SD)	22.1 (3.7)	174.3 (1.9)	64.8 (5.9)

Table 2. Electrode placement

Muscle	Electrode placement
Gluteus maximus	1/3 point between femoral greater trochanter and 2nd sacrum
External oblique	15 cm lateral to the umbilicus
Multifidus	2 cm lateral to the spinous process of L3, parallel to the vertebrae

[17]. In order to measure for the dominant side gluteus maximus, bilateral external oblique, and bilateral multifidus muscle activity, the maximum voluntary contraction was induced and then electrodes were placed on to the risen areas of the muscle belly (Table 2) [18].

The measurements were taken a total of three times with a 1-minute rest period 5 seconds after each measurement was made. During the middle three seconds, the mean values were processed with the root mean square (RMS) used to normalize the maximal voluntary isometric contraction (MVIC).

Measurements

MVIC

To measure the MVIC of the GM, subjects were asked to lie in prone position with the knee in 90 degrees of flexion, and was instructed to raise the lower extremity up toward the ceiling while the experimenter applied downward pressure onto the posterior thigh. The MVIC of the multifidus was measured by having the subjects lie in prone position with their hands behind with head, and was asked to perform trunk extension. To measure the MVIC of the external oblique, subjects were asked to lie in prone with their hands behind their head and to flex forward and rotate onto one side [19].

The MVIC of each muscle was measured during the middle three seconds, with a frequency of three times and the mean values processed with the RMS used to quantify the muscle activity values. A one-minute rest period between each contraction was provided in order to prevent muscle fatigue.

Thera-band exercises

GM concentric contraction

Concentric activation occurs as a muscle produces a pulling force as it contracts [15].

The starting position was considered to be standing with 90 degrees of knee flexion and neutral hip joint position. One end of the thera-band was fixated onto the leg of a table while the end of the thera-band was attached above the knee of the dominant lower extremity, providing resistance by pulling knee toward the front. During concentric contraction of the GM, the thera-band was connected from between the subject and a fixed point in order to be able to provide maximal resistance.

Subjects were instructed to perform hip extension motion to induce concentric GM contraction for 5 seconds until no more movement of the pelvis and trunk could occur. In order to provide visual feedback, a mirror was placed in front of the subject so that they can maintain a neutral pelvic and trunk position while performing the hip movements. During the contraction, if severe asymmetry was present, the subjects were allowed to place both hands on a chair during the examination (Figure 1A).

GM isometric contraction

Isometric activation occurs when a muscle is producing a pulling force while maintaining a constant length [15].

The starting position was in standing position with 90 degrees of knee flexion and 5 degrees of hip extension. One end of the thera-band was fixated onto the leg of a table while the end of the thera-band was attached above the knee of the dominant lower extremity, providing the maximal resistance by pulling the knee toward the front while maintaining 5 degrees of hip extension for 5 seconds. During concentric contraction of the GM, the thera-band was connected from between the subject and a fixed point in order to be able to provide maximal resistance. In order to provide visual feedback, a mirror was placed in front of the subject so that they can maintain a neutral pelvic and trunk position while performing the hip movements. During the contraction, if severe asymmetry was present, the subjects were allowed to place both hands on a chair during the examination (Figure 1B).

GM eccentric contraction

Eccentric activation occurs as a muscle produces a pulling force as it is being elongated by another more dominant force [15].

Figure 1. The start position on gluteus maximus (GM) contraction pattern. GM concentric contraction (A), GM isometric contraction (B), GM eccentric contraction (C).

The starting position was in standing position with 90 degrees of knee flexion and hip full extension. One end of the thera-band was fixated onto the leg of a table while the end of the thera-band was attached above the knee of the dominant lower extremity, providing resistance by pulling the knee toward the front. During concentric contraction of the GM, the thera-band was connected from between the subject and a fixed point in order to be able to provide maximal resistance (Subjects were to slowly perform hip flexion within 5 seconds to induce eccentric contraction of the GM.). In order to provide visual feedback, a mirror was placed in front of the subject so that they can maintain a neutral pelvic and trunk position while performing the hip movements. During the contraction, if severe asymmetry was present, the subjects were allowed to place both hands on a chair during the examination (Figure 1C).

Statistical analysis

For the general characteristics of the subjects including age, height, and weight, a descriptive statistics was used to obtain the mean and standard deviation. In order to compare the muscle activity of the multifidus, external oblique, and GM muscles according to the different contraction patterns of the GM, the repeated measures ANOVA was used, and in order to compare the muscle activity of bilateral multifidus, bilateral external oblique, and GM muscle according to the different contraction patterns of the gluteus maximus, the MANOVA was used. The data was analyzed using the PASW ver. 18.0 (IBM Co., Armonk, NY, USA) and the significance level was set at α=0.05.

Results

There was no significant difference in bilateral multifidus and external oblique muscle activation according to GM concentric, isometric, and eccentric muscle contraction (p>0.05). However, the muscle activity of the multifidus muscle was the greatest during GM concentric contraction, and the muscle activity of the external oblique was the greatest during GM eccentric contraction (Table 3).

There was no significant difference in bilateral multifidus and external oblique muscle activation during the different gluteus maximus muscle contraction patterns (p>0.05), there was the greatest amount of muscle activity in the dominant side multifidus during all types of contractions of the gluteus maximus (Table 3, Figure 2).

Discussion

Spinal segmental instability may possibly cause functional limitations, postural abnormality, sprains, localized pain, and referred pain. Excessive movement of the spinal segment results in producing a sense of decreased stability and decreased movement, and the ability to maintain a normal posture and provide postural support during functional activities disappears [20]. Patients use their neuromuscular system in order to effectively stabilize the core, which allows for a coordinated local and global muscles contractions of various muscles, which can affect the pelvic, hip, and spinal positions. The literature has reported that local muscles can effectively provide lumbar segmental stabilization [21].

Table 3. Multifidus and external oblique muscle activation according to gluteus maximus contraction patterns (N=20)

Gluteus maximus contraction		Concentric	Isometric	Eccentric	*p*
Gluteus maximus (%MVIC)	Dominant	31.6 (17.0)	34.5 (18.1)	35.1 (17.2)	0.811
External oblique (%MVIC)	Non-dominant	25.7 (13.4)	27.3 (14.2)	30.3 (12.2)	0.833
	Dominant	31.9 (16.6)	33.4 (13.7)	34.1 (20.8)	0.856
Multifidus (%MVIC)	Non-dominant	34.2 (13.1)	31.0 (13.3)	32.1 (14.2)	0.969
	Dominant	38.1 (22.4)	34.8 (15.4)	35.2 (15.2)	0.824

Values are presented as mean (SD).
MVIC: maximal voluntary isometric contraction.

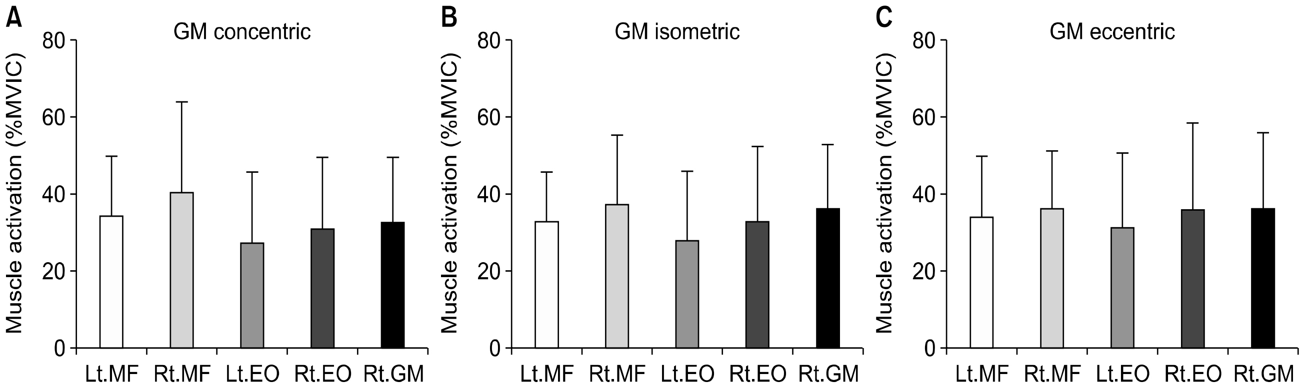

Figure 2. Multifidus and external oblique muscle activation according to gluteus maximus contraction patterns. MVIC: maximal voluntary isometric contraction, Lt.: non-dominant, MF: multifidus, Rt.: dominant, EO: external oblique, GM: gluteus maximus.

Therefore, mobilizing local muscle tension and contraction is the latest rehabilitation and training methods compared to the previous programs focused on global muscle contraction [20].

This study evaluated the effects of different GM muscle contractions on the multifidus and external oblique muscle in twenty university students in their twenties in order to develop an effective spine stability exercise.

The study hypothesis was that during the muscle contractions in our body, and compared with eccentric contraction, the neurological activity would be less than the isometric, or concentric contractions, and that although less energy would be consumed, there would be an effective advantage in strength enhancement [22], and by the GM eccentric contraction, there would be a significant difference in muscle activation. The study results showed that although there was no significant difference in the muscle activity of the multifidus and external oblique according to the different types of contractions of the GM, the muscle activity of bilateral multifidus was the greatest during GM concentric contraction, and the muscle activity of bilateral external oblique was the greatest during GM eccentric contraction ($p>0.05$). These results are in relation to the findings of Westing *et al*. [23] which includes the measured joint angle during maximum eccentric strength, and that although isometric strength is lower than eccentric strength in general, the fact that isometric strength may exceed eccentric strength is similar in content with this study. This is because during movement, it is difficult to maintain a high level of eccentric activity, and that nerve inhibition may occur during maximum eccentric activity [23]. Linnamo [24] stated that due to repeated eccentric activity damage to the structural muscles and delayed onset of muscle soreness occurs, and the recovery time for eccentric exercises is longer than concentric exercise, and this may be due to the frequency of repeated movements. Souza *et al*. [25], who is a researcher on the study of muscle activation according to stabilization exercises, did a study to find the muscle activation of the rectus abdominus, external oblique, and internal oblique during the performance of upper and lower extremity exercises in a neutral supine or quadruped position. They have found that, despite the exercise intensity, the ability to rotate the low back was prevented while lifting the lower extremity, the lumbar spine area will provide support in order to maintain a neutral spine position, and that the rectus abdominus significantly contributes to providing lumbar stabilization.

This study examined the effect of different types of GM muscle contractions on the GM, bilateral multifidus, and bilateral external oblique muscle activity and found that there was the greatest amount of activity in the dominant multifidus muscle during concentric contraction of the GM (p>0.05). Choi *et al*. [26] reported that the intensity used for strengthening the low back muscles was 25% MVIC, and that since the multifidus is composed of type 1 fibers, rather than a high intensity, a low intensity of 30%-40% MVIC should be used. The decreased amount of contraction in bilateral multifidus was because rather than the type 1 fibers that provide high resistance, there is a high amount of contraction from the fiber types that provide low resistance.

The multifidus is the largest muscle found around the low back, and as a muscle on the medial side, it is composed of five layers. Functionally, through its contraction, it assists to maintain trunk extension and maintains lumbar lordosis, and therefore, prevents unwanted contralateral rotation protects the intervertebral discs, thus playing an important role in providing spinal stability [26]. In addition, the multifidus is short in length and has an important role in providing a fast reaction time, which enables the maintenance of stability [27].

Although it is a short period of time within 24 hours after a back injury, atrophy of the multifidus can be seen in the lowback pain area [28]. This effect is seen as a result of muscle inhibition. After the first symptoms of acute low back pain appears, the function and cross-section of the multifidus cannot be recover without a treatment specified and targeted at this muscle [28].

Therefore, Richardson *et al*. [29] stated that for lumbar stabilization, the contractions of the global muscles, such as the rectus abdominus and erector spinae, must be minimized, and contractions of the local muscles, such as the multifidus and transverse abdominus, must be increased.

The study had a few limitations. First, due to the small sample size, it would be difficult to make any generalizations according to the study results. Second, it was difficult to maintain the GM contraction patterns and it was difficult to collect objective data on the precise muscle contraction patterns. Third, the study had healthy subjects performing contractions to produce spinal stability and since the central low back and pelvic muscles were not included in the study, it is difficult to find a comprehensive effect of spinal stability exercise position. Future studies warrant the use of not only elastic resistance bands, but medicine ball, body blade as well, and include actual subjects with low back pain in order to develop an effective spinal stabilization exercise program.

The purpose of the study was to compare the muscle activity of the multifidus and external oblique muscles according to the concentric, isometric, and eccentric contractions of the GM in twenty healthy subjects to develop lumbar stabilization exercises. As a result, this study suggest that specific contraction type of the GM doesn't lead more effective activation in multifidus, external oblique abdominis, and GM.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

References

1. Airaksinen O, Brox JI, Cedraschi C, Hildebrandt J, Klaber-Moffett J, Kovacs F, et al; COST B13 Working Group on Guidelines for Chronic Low Back Pain. Chapter 4. European guidelines for the management of chronic nonspecific low back pain. Eur Spine J 2006;15 Suppl 2:S192-300.
2. Wallden M. The neutral spine principle. J Bodyw Mov Ther 2009;13:350-61.
3. Kim K, Park RJ, Bae SS. Effect of diaphragmatic breathing exercise on activation of trunk muscle of patients with Low back pain. J Korean Soc Phys Ther 2005;17:311-27.
4. Lee JY, Han SY, Nam HW, Chung B, Lee CR, Han SW. Comparison of hip internal rotation angle in chronic low back pain patients according to the gender. J Korean CHUNA Man Med Spine Nerves 2010;5:9-16.
5. Danneels LA, Vanderstraeten GG, Cambier DC, Witvrouw EE, De Cuyper HJ. CT imaging of trunk muscles in chronic low back pain patients and healthy control subjects. Eur Spine J 2000;9: 266-72.
6. Graves JE, Webb DC, Pollock M, Matkozich J, Leggett SH, Carpenter DM, et al. Pelvic stabilization during resistance training: its effect on the development of lumbar extension strength. Arch Phys Med Rehabil 1994;75:210-5.
7. Shin MH. The effect of yoga activities in different temperature environments on spine muscles, pelvic bone asymmetry and plasma components in middle-aged women with chronic back pain [Doctor dissertation]. Jeonju: Woosuk University; 2014.
8. Lee SC, Lee DT. Effects of exercise therapy on lower back pain patients. Health Sport Med 2007;9:69-78.
9. Hicks GE, Fritz JM, Delitto A, McGill SM. Preliminary development of a clinical prediction rule for determining which patients with low back pain will respond to a stabilization exercise program. Arch Phys Med Rehabil 2005;86:1753-62.
10. Sundstrup E, Jakobsen MD, Andersen CH, Jay K, Andersen LL.

Swiss ball abdominal crunch with added elastic resistance is an effective alternative to training machines. Int J Sports Phys Ther 2012;7:372-80.

11. Wilke HJ, Neef P, Caimi M, Hoogland T, Claes LE. New in vivo measurements of pressures in the intervertebral disc in daily life. Spine 1999;24:755-762.
12. Johanson E, Brumagne S, Janssens L, Pijnenburg M, Claeys K, Pääsuke M. The effect of acute back muscle fatigue on postural control strategy in people with and without recurrent low back pain. Eur Spine J 2011;20:2152-59.
13. Kay D, St Clair Gibson A, Mitchell MJ, Lambert MI, Noakes TD. Different neuromuscular recruitment patterns during eccentric, concentric and isometric contractions. J Electromyogr Kinesiol 2000;10:425-31.
14. Clark MA, Lucett SC. NASM essentials of corrective exercise training. 1st ed. Philadelphia; Wolters Kluwer Health/Lippincott Williams & Wilkins; 2011. p. 290-315.
15. Neumann DA. Kinesiology of the musculoskeletal system: foundation for physical rehabilitation. St Louis: Mosby; 2002. p. 480-521.
16. Gibbons SGT, Mottram SL. Functional anatomy of gluteus maximus: deep sacral gluteus maximus-a new muscle? Paper presented at: The 5th Interdisciplinary World Congress on Low Back Pain; 2004 Nov 7-11; Melbourne, Australia. p. 7-11.
17. Jang SY, Lee SY. A comparison of vital capacity values and respiratory muscles activities on pelvic tilt position. Phys Ther Rehail Sci 2015;4:108-14.
18. Bohannon RW, Kindig J, Sabo G, Duni AE, Cram P. Isometric knee extension force measured using a handheld dynamometer with and without belt-stabilization. Physiother Theory Pract 2012;28:562-8.
19. Hislop HJ, Avers D, Brown M. Daniels and Worthingham's muscle testing. 9th ed. St Louis: Elsevier Inc; 2013. p. 212-20.
20. Brotzman SB, Manske RC. Clinical orthopaedic rehabilitation: An evidence-based approach. 3rd ed. St Louis: Elsevier Inc.; 2011. p. 467-91.
21. Wilke HJ, Wolf S, Claes LE, Arand M, Wiesend A. Stability increase of the lumbar spine with different muscle groups: a biomechanical in vitro study. Spine 1995;20:192-8.
22. Cermak NM, Snijders T, McKay BR, Parise G, Verdijk LB, Tamopolsky MA, et al. Eccentric exercise increases satellite cell content in type II muscle fibers. Med Sci Sports Exerc 2013;45:230-7.
23. Westing SH, Seger JY, Thorstensson A. Effects of electrical stimulation on eccentric and concentric torque-velocity relationships during knee extension in man. Acta Physiol Scand 1990;140:17-22.
24. Linnamo V. Motor unit activation and force production during eccentric, concentric and isometric actions [Academic dissertation]. Jyväskylän yliopisto, Finland: University of Jyväskylä; 2002.
25. Souza GM, Baker LL, Powers CM. Electromyographic activity of selected trunk muscles during dynamic spine stabilization exercises. Arch Phys Med Rehabil 2001;82:1551-7.
26. Choi HS, Kwon OY, Yi CH, Jeon HS, Oh JS. The comparison of trunk muscle activities during sling and mat exercise. Phys Ther Kor 2005;12:1-10.
27. Bae JH, Na JK, Yu JY, Park YO. Atrophy of multifidus muscle on low back pain patients. J Korean Acad Rehabil Med 2001;25:684-91.
28. Hides JA, Stokes MJ, Saide M, Jull GA, Cooper DH. Evidence of lumbar multifidus muscle wasting ipsilateral to symptoms in patients with acute/subacute low back pain. Spine 1994;19:165-72.
29. Richardson C, Jull G, Hodes P, Hides J. Therapeutic exercises for spinal segmental stabilization in low back pain: scientific basis and clinical approach. 2nd ed. Edinburg: Churchill Livingstone; 2004. p. 13-20.