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Effects of Lumbar Stabilization Exercise on Motor Neuron Excitability and Pain in Patients with Lumbar Disc Herniation

Background: Lumbar disc herniation (LDH) causes neurological symptoms by compression of the dura mater and nerve roots. Due to the changed in proprioception inputs that can result in abnormal postural pattern, delayed reaction time, and changed in deep tendon reflex.
Objective: To investigate the effects of lumbar stabilization exercises on motor neuron excitability and neurological symptoms in patients with LDH.
Design: Randomized Controlled Trial (single blind)
Methods: Thirty patients with LDH were recruited; they were randomly divided into the balance center stabilization resistance exercise group (n=15) and the Nordic walking group (n=15). Each group underwent their corresponding 20-minute intervention once a day, four times a week, for four weeks. Participants' motor neuron excitability and low back pain were assessed before and after the four-week intervention.
Results: There were significant differences in all variables within each group ($p<.05$). There were significant differences between the experimental and control groups in the changes of upper motor neuron excitability and pain ($p<.05$), but not in the changes of lower motor neuron excitability and Korean Oswestry Disability Index.
Conclusion: Lumbar stabilization exercises utilizing concurrent contraction of deep and superficial muscles improved low back function in patients with LDH by lowering upper motor neuron excitability than compared to exercises actively moving the limbs. Lumbar stabilization exercises without pain have a positive impact on improving motor neuron excitability.

Key words: *lumbar disc herniation; lumbar stabilization exercise; motor neuron excitability*

Jeongil Kang, PT, PhD[a], Daekeun Jeong, PT, PhD[a], Hyunho Choi, PT, MS[a]

[a]Department of Physical Therapy, Sehan University, Republic of Korea

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Address for correspondence
Hyunho Choi, PT, MS
Department of Physical Therapy, Sehan University, 1113 Noksaek-ro, Samho-eup, Yeongam-gun, Jeollanam-do, Korea
Tel: 82-61-469-1316
E-mail: hot486zz@naver.com

INTRODUCTION

Fifteen to 20 percent of adults have low back pain and 50 to 80 percent have experienced this symptom at least once in their lifetime [1]. The risk factors for developing symptoms are multidimensional and include physical characteristics, socioeconomic status, general medical conditions, psychological state, and work environmental factors [2]. In addition, spinal stenosis, spondylolisthesis, spondylolysis, spinal instability, and ossification of spinal ligament may be responsible for back pain. Among these disease, the most frequently occurring is LDH. [3]. LDH is a disorder that involves herniation of the intervertebral disc mostly in the low back region due to degenerative changes and external forces. This causes neurological symptoms by compression of the dura mater and nerve roots. This ultimately causes back pain and radiating pain in the lower limbs [4].

Primary symptoms of LDH are back pain, limited range of motion exercise in the back and lower limbs, muscular weakness, reduction in endurance, and Sensory abnormality. These symptoms limit activities of daily living such as sitting or standing. These symptoms reduce spinal stability as the passive support provided by passive ligaments and bone, and active muscle support, controlled by the central nervous system, are not able optimally with each other [5]. With reduction in somatosensory system due to changes in proprioception input there are disturbances in motor coordination that can result in abnormal postural pattern, delayed reaction time, and changes in deep tendon reflexes [6].

Moreover, due to constant pain, a feedback loop occurs in the since spinal peripheral nerves abnormal signals are sent to spinal cord. As a results in over activity of α-motor neurons and automatic hypertonia signals are sent to the muscles surrounding the spinal cord, aggravating the pain stimulus and pressing on capillaries. When treatment was not performed in the damaged area, increased levels are pain are transmitted to the central nerves [7,8]. Therefore, patients with LDH have difficulties in changing posture, maintaining or repeating same posture for a long period of time, and difficulty performing complex movements such as golf and tennis [6].

Therefore, lumbar stabilization exercises, which aim to strengthen the multifidus muscles, deep muscles of lumbar, and transverse abdominis muscle, are used as treatment [9, 10]. Lumbar stabilization exercise increase the stability of the back and help maintain posture by improving coordination of spine, pelvis, hip, and ventral muscle through strengthening the deep and superficial muscles such as erector spinae muscles and muscle rectus abdominis [11]. In addition, it eliminates repetitive flexion and rotational stress by stabilizing the spine through coordinated contraction of lumbar muscles, improvement of muscle strength, and increased abdominal pressure, while doing functional work. This reduces pressure on the part between intervertebral disc and spinal joint that causes lumbar degeneration [10, 12]. Therefore, lumbar stabilization exercise needs to be conducted to improve movement efficiency and activities of daily living and to reduce pain. However, most of the studies compare the effects of functional improvement rather than the symptomatic changes with origins in the nervous system such as radiating pain in the lower limbs or paresthesia, which are the main symptoms of patients with LDH, or over activity of α-motor neurons [9, 10]. Likewise, a quantitative study to test the effect of lumbar stabilization exercises needs to be conducted on the changes of motor neuron excitability and changes of local symptoms in patients with LDH.

Therefore, this research aims to look into the effect of lumbar stabilization exercise which improves coordination through stabilizing the part around back of patients with LDH who have a problem in regulatory system by central nervous system due to pain and radiating pain in lower limbs, and analyze the effect of lumbar stabilization exercise when it is performed on the nerve symptom of patients with LDH.

SUBJECTS AND METHODS

Subjects

This research has received the IRB (SH-IRB 2018-19) approval and was conducted for 8 weeks, from October 1, 2018 to November 30, 2018. Thirty patients, aged 25 to 50 years, diagnosed with LDH (level of herniation is below protrusion) and without spondylolisthesis, who had not undergone surgery related to LDH disease, were able to independently walk, and were able stand without any assistance were included. Subjects indicated they understood the purpose of this research and participated voluntarily. The general characteristics of participants are presented in Table 1.

Table 1. General characteristics

Items	Experimental group (n=15) M±SD	Control group (n=15) M±SD	p
Age (year)	39.12±9.15	38.32±10.15	.387
Height (㎝)	165.11±10.12	166.45±8.91	.583
Weight (㎏)	63.25±13.86	60.11±15.01	.815
SMM (㎏)	22.21±5.84	23.56±7.01	.881
BFM (㎏)	21.03±5.92	17.86±5.35	.221
BMI (㎏/㎡)	21.88±4.32	20.86±5.31	.518

SMM : skeletal muscle mass, BFM : body fat mass, BMI : body mass index.

Intervention

Fifteen subjects were randomly assigned to the balance center stabilization resistance exercise group, while the other 15 were assigned to the Nordic walking group as control group. The intervention programs were performed for 30 minutes, four days per week for four weeks Before the intervention, V/Mmax and H/Mmax were measured through using the H-wave, M-wave, and V-wave by wireless surface EMG. Back pain index and disability index were measured by questionnaire. After 4 weeks, these items were measured again with same methods and analyzed.

Measurement Methods

Motor Neuron Excitability

Motor neuron excitability was measured by using MP 150 system & STIM100A (Biopac, USA) 1 channel. The electrode was attached on the surface of skin after cleaning the surface with rubbing alcohol, after shaving the skin to prevent measurement failures.

The active electrode was attached on the left soleus muscle on the one third section of calf of distal part, the reference electrode was attached on the Achilles tendon, and the ground electrode was attached on the head of fibula.

The subject was prone, laying down, and with ankles and feet off the bed. Electronic stimulus was performed on the part of popliteal crease containing the tibial nerve [13]. The stimulus intensity was gradually increased until maxmal H (Hmax) and M (Mmax) responses were obtained. Vmax was determined by a ankle plantar flexion maximal voluntary, by raising stimulus intensity after checking the minimum for H-wave. On this occasion, new late-phase response was appeared instead of H-wave, and this wave is the V-wave [14].

Numerical values of motor neuron excitability was analyzed by using formulas below.

H/Mmax = Hmax / Mmax , V/Mmax = Vmax / Mmax

Korean Oswestry Disability Index

The Korean version of Korean Oswestry Disability Index (KODI) developed by Kim et al [15], questionnaire was used for this experiment. The back pain disability index has 9 items and it evaluates the level of pain during personal hygiene, picking up something, walking, sitting, standing, sleeping, social activity, travel, and moving. The reliability of examination and re-examination of the Korean version of back pain disability index is high (r=.92). Back pain disability index is a 6-point scale, with a maximum of 45 points, and the degree of functional performance decreases as the points increase.

Pain Index

Pain index is assessed by marking where the location are along continuous values on the 100 mm straight line. On the far left side of this straight line is zero (0), which means "no pain", and the far right side is 100, which means "maximum pain imaginable" [16].

Exercise Methods

balance center stabilization resistance exercise

balance center stabilization resistance exercise was performed by the test subjects by using complex center and balance training for 30 minutes in stages. This program includes postures in which one holds up a handle and stands with one's legs astride or performs push and pull movement with one's legs crossed. The level of handle was adjusted to waist level, chest level, and shoulder level. The intensity level was set in range that did not induce trunk sway. Every test subject is controlling the handle lever, checking whether the appropriate level of power is applied to the handle or not when they are strengthening the power on the turning circular plate [17].

Nordic Walking

When one is grasping the Nordic Walker (Nordic Walker, Co-Wound Technology, Finland), the angle of elbow at 90 degrees. The pole length must be selected considering the subject's height; if the pole is too long, it is difficult to handle, and if it too short, the training stimulus is too low. In addition, you need to release the pole at hip level. In other words, the cardiovascular workout occurs as one walks while griping and releasing the pole, and in this way, it promotes the circulation in arms and shoulders reducing damage body [18].

Data analysis

Data were assessed for normality by Shapiro-Wilks test of normality in SPSS 20.0. Equal variances in groups were assessed by Levene's test. In addition, comparisons between changes of motor neuron excitability, back pain disability index, and pain between each group were conducted using paired t-test, and those between motor neuron excitability, back pain disability index, and pain in each group were carried out using ANCOVA with significance level of α=.05.

RESULTS

After exercise, the excitability of upper motor neurons & VAS after intervention in both experimental group ($p<.01$) and control group ($p<.05$) decreased significantly (Table 2). The excitability of lower motor neurons & KODI after intervention in both experimental group and control group decreased significantly ($p<.05$)(Table 2). However, there were also statistically significant differences in the intergroup comparisons only in upper motor neurons & VAS ($p<.05$)(Table 3).

Table 2. Comparisons of changes within groups on dependent variable

Items	Groups	Pre-test (M±SD)	Post-test (M±SD)	t	p
V/Mmax (%)	Experimental group	25.21±13.58	16.45±8.15	6.361	.008**
	Control group	22.56±12.97	17.25±9.63	9.262	.035*
H/Mmax (%)	Experimental group	47.15±10.61	40.12±11.73	1.384	.015*
	Control group	51.24±9.23	40.53±10.36	1.365	.026*
KODI (point)	Experimental group	26.2±4.31	18.3±8.59	8.894	.042*
	Control group	26.8±5.18	16.2±5.75	11.918	.040*
VAS (point)	Experimental group	7.4±1.07	2.9±1.28	14.643	.003**
	Control group	6.7±1.49	3.7±1.42	5.031	.041*

'Paired t-test, * $p<.05$, ** $p<.01$
V/Mmax : upper motor neuron excitability, H/Mmax : lower motor neuron excitability
KODI : korean oswestry disability index, VAS : visual analogue scale

Table 3. Comparisons of changes between groups on dependent variable

Items	Groups	Pre-test (M±SD)	Post-test (M±SD)	t	p
V/Mmax (%)	Experimental group	25.21±13.58	16.45±8.15	2.212	.031*
	Control group	22.56±12.97	17.25±9.63		
H/Mmax (%)	Experimental group	47.15±10.61	40.12±11.73	.504	.354
	Control group	51.24±9.23	40.53±10.36		
KODI (point)	Experimental group	26.2±4.31	18.3±8.59	3.13	.184
	Control group	26.8±5.18	16.2±5.75		
VAS (point)	Experimental group	7.4±1.07	6.7±1.49	3.482	.048*
	Control group	2.9±1.28	3.7±1.42		

'ANCOVA, * $p<.05$
V/Mmax : upper motor neuron excitability, H/Mmax : lower motor neuron excitability
KODI : korean oswestry disability index, VAS : visual analogue scale

DISCUSSION

In this study, we analyzed the effects of lumbar stabilization exercises on motor neuron excitability and neurological symptoms in patients with LDH. Patients with LDH have pain and radiating pain in lower limbs as nerve root and dorsal root ganglion are damaged. This creates a feedback loop problem as regulatory control by central nervous system is disrupted. Therefore, it limits changing or maintaining posture, and movements that requires coordination and repetitive actions.

Lumbar stabilization exercises improves coordination of hip and abdominal muscles by both strengthening and co-contracting deep muscles and superficial muscles [9, 10].

Couillandre et al [19]. as a result of applying the balance center stabilization resistance exercise in 12 adults for 2months, increased coordination, strengthens the muscles of back and legs, and improves center of pressure control. This is a positive effect on somatosensory system. Likewise, there were statistically significant improvements in each group in this research. These results are attributed from the fact that balance center stabilization resistance exercise, which simultaneously improves balance and improving postures by having patients moving the pelvis symmetrically, improves coordination more than exercises that include movements which are not controlled. Research by Boucher et al [20]. supports these results as they concluded that lumbar stabilization exercise improves the ability to adjust postures. They determined that this was due to improved central nervous system regulation at the nerve root. In addition, Letafatkar et al [17]. as a result of applying the balance center stabilization resistance exercise to the 53 patients reported reduces back pain and positively affects proprioceptive sense. There were also statistically significant differences of upper motor neuron excitability and pain in both experimental group and control group decreased. However, there were no statistically significant differences of lower motor neuron excitability in both experimental group and control group. This is because active movement stimulates the sensory system more than passive movement. However passive movement from balance center resistance exercise stimulated sensory system more than the active movement since balance center resistance exercise corrects training by receiving visual biofeedback through LED screen.

Ye et al [21]. as a result of applying the lumbar stabilization exercise to the 63 patients with LDH indicated that lumbar stabilization exercise improves function and lowers back pain of the patients more than normal exercise. Likewise, there were statistically significant differences in the lumbar stabilization exercise group in this research. However, back function did not have a statistically significant change in either the experimental group or control group. Light exercise in the range of no pain of for lumbar stabilization exercises are more effective as it increases the amount of blood in intervertebral foramen and spinal nerves, overall increasing circulation around back [22]. Nordic walking has benefits of increased co-contracted muscles of the upper body. This reduces pain more than normal walking [23]. However, it was not able to activate involved muscles the way that balance center stabilization resistance exercise to reduce pain significantly.

In this study, we examined herniated disc patients who were recruited from one facility. Other variables, such as medication and daily activity, were not controlled for and could affect the outcomes of the research.

CONCLUSION

In this study, the lumbar stabilization exercise was shown to control or reduce pain induce greater excitability of motor neurons than normal exercise. In addition to this, it can be suggested as more stable treatment than treatment for patients with symptoms of neurological abnormality to patients with LDH, and more various lumbar stabilization exercise needs to be verified the effects to motor neurons or nervous system by adding upper motor neurons, lower motor neurons, back pain disability index, and variables except pain and studying the interrelations of these variables.

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