Effects of Exercise Rehabilitation on Pain, Disability, and Muscle Strength after Posterior Lumbar Interbody Fusion Surgery: a Randomized Controlled Trial

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Abstract. [Purpose] The present study examined how exercise rehabilitation, extension exercise rehabilitation, and stabilization exercise rehabilitation programs for 8 weeks affected the lumbar region of elderly patients who underwent posterior lumbar interbody fusion surgery. [Methods] Sixty participants were divided into 3 groups. The participants' lumbar extensor muscle strength was evaluated at 7 angles (72°, 60°, 48°, 36°, 24°, 12°, and 0°) from flexion to extension by MedX after 8 weeks; and pain, disability, and maximum muscle strength were also measured. [Results] Extension exercise rehabilitation significantly decreased disability compared with the other exercise methods. On the other hand, stabilization exercise rehabilitation significantly increased lumbar deep muscle strength and endurance compared with the other exercise methods. When strength was compared using MedX, extension exercise rehabilitation increased strength significantly more than the other methods at the lumbar flexion angles of 12° and 0°. [Conclusion] The three exercise programs decreased pain and disability, and increased lumbar deep muscle strength of the posterior lumbar interbody fusion patients. Therefore, these methods help patients attain pain-free lives.

Key words: Posterior lumbar interbody fusion, Exercise rehabilitation, MedX

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INTRODUCTION

Many people have reduced quality of life owing to low back pain (LBP) caused by musculoskeletal dysfunction, psychological problems, a degenerative disk disease, or an inactive lifestyle¹⁻³⁾. When chronic LBP keeps increasing, surgical treatments, such as posterior lumbar interbody fusion (PLIF), can be used to reduce pain⁴⁾. PLIF was first introduced in 1944 by Briggs and Milligan⁵⁾ and is used widely to treat scoliosis, spondylolisthesis, spinal instability, and spinal stenosis. However, PLIF is very expensive, and patients may still suffer from LBP after the surgery as a result of adverse effects, such as muscle strength weakness due to extensive spinal muscle dissection, loss of trunk flexibility due to interbody fusion, a significant loss of performance ability, and are at risk of persistent dysfunction^{1, 4, 6)}.

Exercises involving the lumbar muscles are very important in the prevention and intervention of LBP. The McKenzie lumbar muscle strength reinforcement and lumbar stabilization exercises strengthen the lumbar muscles and reduce LBP⁷⁻⁹⁾. Decreased reposition sense due to decreased

sensory ability is a problem for spinal stability because of deep muscle imbalance and proprioceptive problems after PLIF, and some studies have investigated whether lumbar stabilization exercises increase spine proprioception^{10, 11)}. However, few studies have compared the efficacy of traditional exercise rehabilitation (ER), extension exercise rehabilitation (EER), and lumbar stability exercise rehabilitation (SER) using MedX (MedX Inc., USA) devices after PLIF.

Therefore, this study compared the differences in pain, disability, and muscle strength before and after ER and EER performed on MedX devices, and SER using the method of O'Sullivan (2000). We also discuss more efficient exercise methods for reducing pain and improving function after PLIF.

METHODS

The study subjects were 60 patients who underwent PLIF in 2011, at least 3 months before the start of the study. Patients with sudden or constant pain, neurological

problems, or mental problems, or who were pregnant, were excluded from this study. All the subjects received an explanation about the study and gave their voluntary informed consent before participation. Pain was self-assessed on a visual analog scale (VAS), and the low back disability index was evaluated by conducting a survey about LBP symptoms of the 60 PLIF patients. Lumbar extension strength was measured using MedX, and the maximum strength of the lumbar deep muscle was measured after 10 minutes of rest. Using SPSS, we randomized the patients into 3 groups according to the rehabilitation they underwent: ER, EER, or SER (exercise rehabilitation group, ERG; extension exercise rehabilitation group, EERG; and stability exercise rehabilitation group, SERG; respectively). A pretest was conducted after collecting physical and medical information. All the groups were treated by 3 professional physical therapists for 30 minutes, 3 times a week, with warm-up exercises lasting for approximately 5–10 minutes before and after the exercise training¹³. We varied each group's treatment time and instructed the subjects to not to talk about their treatment to blind them as to which group they were in. After 8 weeks, we measured the changes using the same methods used in the pretest.

For ER, we used the traditional William and McKenzie exercise program. The exercises that could be done symmetrically were performed on both sides for 10 seconds for 3 sets. The subjects were given 10 seconds of rest between each exercise.

EER involved exercises using a MedX device and the McKenzie extension exercise. The MedX exercise involved 20 repetitions of an isotonic exercise at a resistance of 50% of the maximal extension muscle strength and the weight was increased by 5% when the patient could execute more than 20 repetitions. In ER, it is more efficient if 1 set of a trunk extension exercise makes the muscles more tired than when multiple sets of exercise are performed. This is because the nerve activity pattern decreases in the lumbar muscles over multiple sets¹⁴. Therefore, only 1 set was performed at 70% of the maximal isometric extension muscle strength.

SER uses the transverse abdominis and multifidus co-contraction method, which excludes gross contractions. After warm up, the exercise was conducted for 30 minutes using the SER method of O'Sullivan¹². This exercise was conducted in the standing, sitting, prone, and supine positions, with knee flexion and lying on the side for 10 seconds and 10 seconds of rest between repetitions.

VAS was used to assess pain. It is the most widely used pain measurement method, with a reliability of $r = 0.76\text{--}0.84$. VAS assesses the intensity of pain on a scale from 0 to 10, where 0 is no pain and 10 is unbearable pain¹⁵.

Lumbar disability was scored using the Oswestry disability index (ODI). The ODI consists of 10 items: pain intensity, personal management, lifting, walking, sitting, standing, sleeping, sexual activity (if applicable), social activity, and traveling. All the items are scored from 0 to 5, where 0 means no inconvenience in the patient's performance and 5 means severe inconvenience. Lower scores indicate lower physical ability; the reliability of the ODI is $r = 0.91$ ¹⁶.

The strength and endurance of the deep lumbar muscles were evaluated using a pressure biofeedback unit (PBU). With the patient lying on their backs, an air bag was placed underneath the waist; then, the strength and time required to push the bag to the ground by contracting the stomach were measured at 70 mm Hg. We measured how long the maximum contraction power was maintained using a stopwatch every 10 seconds. We also measured how long the maximum contraction power was maintained at 50% strength. The reliability of this method is $r = 0.60\text{--}0.68$ ¹⁷.

The MedX lumbar extension exercise method was used to measure the maximal muscle strength of the lumbar extensors. The examination was first explained to the subject, and the subject's pelvis and thighs were fixed to measure the maximum static lumbar extension strength. Counterbalancing was subsequently conducted so as not to affect the center of gravity. To ensure the preset lumbar flexion range of motion (ROM) from 0° to 72°, a passive ROM exercise was conducted approximately 3 times before conducting the muscle test. Starting at 72°, the isometric maximal strength of the lumbar extensor was measured at flexion angles of 72°, 60°, 48°, 36°, 24°, 12°, and 0°. For the independent evaluation and training of the lumbar extensor, the femur and pelvis were fixed by belts and pads to minimize the participation of the hip joint and influence of the leg muscles¹⁸. The subjects were instructed to contract in the back muscles for 2–3 seconds while sitting in the chair and watching a computer monitor displaying the angle. Ten seconds of rest were allowed between each angle, and a passive ROM exercise was conducted 3 times to relax the lumbar extensor. The reliability of this method is $r = 0.81\text{--}0.89$ ¹⁹.

All the statistical analyses were performed using SPSS v12.0. The paired t-test was used to determine the changes before and after each exercise. One-way ANOVA was conducted to determine the mean differences between the groups. Values of $p < 0.05$ were considered statistically significant.

RESULTS

The general characteristics of ERG, EERG, and SERG are shown in Table 1.

After the training, the ODI scores of EERG (36.38 ± 5.07) were significantly greater than those of ERG (30.60 ± 2.85) and SERG (31.16 ± 4.61). The PBU scores of SERG (-4.28 ± 1.56) were significantly greater than those of ERG (-2.75 ± 2.63) and EERG (-0.71 ± 0.78). The MedX value at 12° of EERG (-22.14 ± 15.94) was significantly greater than that of ERG (-8.95 ± 11.58) but not of SERG (-13.05 ± 15.25). The MedX value at 0° of EERG (-24.00 ± 18.16) was significantly greater than those of ERG (-4.55 ± 11.96) and SERG (-10.80 ± 16.42). No statistically significant differences were observed between the groups with respect to the VAS scores or MedX values at 72°, 60°, 48°, 36°, or 24° (Table 2).

DISCUSSION

This study aimed to elucidate the effects of the ER, EER,

Table 1. General characteristics of the subjects

	EG	EEG	SEG
Gender (male/female)	11/9	11/10	9/10
Age (year)	60.5 ± 9.7	61.2 ± 9.8	60.2 ± 10.1
Weight (kg)	65.2 ± 12.4	63.6 ± 9.9	62.3 ± 11.4
Height (cm)	164.3 ± 7.9	165.6 ± 7.6	166.1 ± 8.0

Note. All variables are mean ± standard division (SD). EG: exercise group. EEG: extension exercise group. SEG: stabilization exercise group

Table 2. Comparison of pain and muscular strength after each training

	EG		EEG		SEG	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
VAS (score)	6.01 ± 0.73	2.42 ± 0.64 [†]	6.05 ± 0.93	2.16 ± 0.40 [†]	6.12 ± 0.73	2.58 ± 0.52 [†]
ODI ^{††ac} (score)	53.15 ± 3.65	22.55 ± 2.96 [†]	55.90 ± 5.06	19.52 ± 3.88 [†]	52.50 ± 3.99	21.33 ± 2.59 [†]
PBUJ ^{††abc} (mmHg)	10.65 ± 1.81	13.40 ± 3.35 [†]	10.90 ± 1.92	11.62 ± 1.99 [†]	11.39 ± 1.09	15.67 ± 1.68 [†]
Medx (ft-lbs)						
72°	148.44 ± 8.74	161.94 ± 9.39 [†]	154.38 ± 15.47	165.14 ± 16.10 [†]	149.95 ± 18.99	161.40 ± 18.79 [†]
60°	126.39 ± 8.85	137.33 ± 9.17 [†]	129.10 ± 13.35	141.86 ± 15.97 [†]	127.05 ± 18.70	137.10 ± 18.10 [†]
48°	104.44 ± 8.68	115.00 ± 8.32 [†]	109.14 ± 9.95	124.86 ± 13.60 [†]	105.85 ± 17.67	117.85 ± 17.38 [†]
36°	79.94 ± 9.43	92.06 ± 7.85 [†]	88.71 ± 8.56	106.67 ± 12.24 [†]	84.55 ± 16.25	97.75 ± 15.96 [†]
24°	65.28 ± 10.95	78.50 ± 7.66 [†]	76.10 ± 7.92	95.14 ± 13.60 [†]	70.80 ± 17.35	85.75 ± 14.80 [†]
12° ^{††c}	44.61 ± 8.68	53.56 ± 7.66 [†]	49.86 ± 7.09	72.00 ± 13.87 [†]	49.45 ± 15.68	62.50 ± 17.49 [†]
0° ^{††ac}	37.83 ± 8.23	42.39 ± 11.13	31.90 ± 6.81	55.90 ± 15.47 [†]	36.25 ± 16.30	47.05 ± 17.49 [†]

Note. All variables are mean ± standard division (SD). [†]Statistically significant difference between pre and post test ($p < 0.05$). ^{††}Statistically significant difference among the three groups ($p < 0.05$). ^aStatistically significant difference between EG and EEG ($p < 0.05$). ^bStatistically significant difference between EG and SEG ($p < 0.05$). ^cStatistically significant difference between EEG and SEG ($p < 0.05$). EG: exercise group. EEG: extension exercise group. SEG: stabilization exercise group. VAS: visual analogue scale. ODI: oswestry disability index. PBU: pressure biofeedback unit

and SER programs for patients who underwent PLIF more than 3 months before the study by comparing pain, disability, and muscle strength before and after exercise.

Although the PLIF is performed to reduce pain and ODI, trunk flexion and extension ROM is inhibited¹⁹. The occurrence and relapse of LBP are promoted by repetitive everyday actions and habits. Moreover, LBP is aggravated by decreasing muscle ability and increased fatigue. To counter this, lumbar muscle strengthening and flexibility exercises are generally prescribed for LBP patients, for pain relief and to prevent recurrence¹¹. Some authors of recent studies focusing on lumbar extensor strengthening and stability exercises have suggested that improving the strength and endurance of the extensors is the main factor in the treatment and rehabilitation of lumbar damage⁷⁻¹⁰.

In this study the VAS and ODI values decreased significantly in all 3 groups. However, there were no significant differences among the exercise group. Also, no significant differences were found in the post-exercise data of the groups, even though the subjective expression of pain and inconvenience in daily living decreased significantly in all 3 groups. The ODI scores of EERG (36.38 ± 5.07) were significantly greater than those of ERG (30.60 ± 2.85) and SERG (31.16 ± 4.61). Hides et al. (2001) conducted lumbar stabilization exercises for chronic LBP patients for 4 weeks

and analyzed the effects after 10 weeks and 1 year. They found significantly decreased pain, ODI, and pain recurrence rates compared to a control group¹¹. Kladny et al. (2003) conducted stabilization exercises and conservative treatment for 2 groups including 99 patients with LBP caused by degenerative disk disease⁹. Both groups reported decreased pain, but without statistical significance; SER improved the functional score to a greater extent than the other methods. Similar results were obtained in this study. Therefore, we conclude that SER and EER reduce pain and increase patients' ability to perform daily living as well as ER.

Cairns et al. (1994) studied the effects of a method using a pressure gauge on subjects with LBP, those with a history of LBP, and controls¹⁷. They concluded that a pressure gauge can be used to measure stomach muscle contraction ability of subjects with LBP. Hides et al. (2008) and Wallwork et al. (2009) reported similar local weakness in the cross-sectional area of the multifidus of chronic LBP patient and normal controls. Moreover, after conducting lumbar stabilization exercises for 13 weeks, the multifidus cross-sectional area increased significantly at the L2-L5 levels^{7, 8}. The PBU scores of SERG (-4.28 ± 1.56) were significantly greater than those of ERG (-2.75 ± 2.63) and EERG (-0.71 ± 0.78). The results of the present study confirm that SER increases deep muscle strength, thus reducing pain.

The MedX value at 12° of EERG (-22.14 ± 15.94) was significantly greater than that of ERG (-8.95 ± 11.58), but not of SERG (-13.05 ± 15.25). However, the MedX value at 0° of EERG (-24.00 ± 18.16) was significantly greater than those of ERG (-4.55 ± 11.96) and SERG (-10.80 ± 16.42). In this study, both groups showed a decreasing tendency when maximal voluntary isometric contraction in the trunk shifted to extension from flexion. Muscle length and strength are inversely related. When the muscle length is medium, concentric contraction is maximized and as the muscle shortens, concentric contractions become proportionally shorter¹³). In addition, gravity can affect the measurement of lumbar extension strength when measured in the standing or sitting position. Although some authors state that measurements must be adjusted for the effects of gravity, most physical movements are not affected by gravity. Movements of the lumbar muscles in the sitting or standing position are affected by trunk weight¹⁸).

In summary, this study compared the differences in pain, ODI, and lumbar muscle strength before and after ER, EER, and SER in patients who underwent PLIF at least 3 months before the study. The ODI scores of EERG were significantly lower than those of the other exercise groups. Regarding deep muscle strength and endurance, SERG had a significantly greater PBU value than the other exercise groups. Regarding strength measured using MedX, EERG exhibited significantly greater increase in strength than the other groups at lumbar flexion angles of 12° and 0°. As well as ER, EER and SER also decreased pain and ODI scores, and increased the muscle strength of the PLIF patients. Therefore, using the correct rehabilitation methods would help patients attain pain-free and happier lives.

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