

Comparing the Immediate Effectiveness of Lumbar Flexion and Extension Exercise With Regards to Pain, Range of Motion, Pelvic Tilt, and Functional Gait Ability in Patients With Lumbar Spinal Stenosis

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Abstract

Background: In patients with lumbar spinal stenosis (LSS), lumbar flexion exercise (LFE) is considered a standard therapeutic exercise that widens the space between the spinal canal and intervertebral foramen. However, some researchers have reported that lumbar extension exercise (LEE) may improve lumbar pain and functional ability in patients with LSS. Although exercise intervention methods for patients with LSS have been widely applied in clinical settings, few studies have conducted comparative analysis of these exercise methods.

Objects: This study aimed to compare the effects of LFE, LEE, and lumbar flexion combined with lumbar flexion-extension exercise (LFEE) on pain, range of motion (ROM), pelvic tilt angle, and functional gait ability in patients with LSS.

Methods: A total of 30 patients with LSS, LFE ($n_1=10$), LEE ($n_2=10$), and LFEE ($n_3=10$) were assigned to each of the three exercise groups. The numerical pain rating scale (NPRS), modified-modified schober test (MMST)-flexion, MMST-extension, pelvic tilt inclinometer, and 6-minute walking test (6MWT) were measured.

Results: After the intervention, statistically significant differences were observed in the NPRS ($p=.043$), MMST-flexion ($p<.001$), MMST-extension ($p<.001$), and 6MWT ($p=.005$) between groups. According to the post hoc test, the NPRS was statistically significant difference between the LFEE and LEE groups ($p=.034$). The MMST-flexion was statistically significantly different between the LFE and LEE ($p=.000$), LFE and LFEE ($p=.001$), and LEE and LFEE ($p=.001$) groups. The MMST-extension was statistically significantly different between the LFE and LEE ($p<.001$), LFE and LFEE ($p=.002$), and LEE and LFEE ($p=.008$) groups. The 6MWT was statistically significantly different between the LFE and LFEE ($p=.042$) and the LEE and LFEE ($p=.004$) groups.

Conclusion: This study suggested that LFEE was the most effective exercise for pain and functional gait ability in patients with LSS, LFE was the most effective exercise for lumbar flexion ROM, and LEE was the most effective exercise for lumbar extension ROM.

Key Words: Lumbar extension exercise; Lumbar flexion exercise; Lumbar spinal stenosis.

Introduction

Lumbar spinal stenosis (LSS) is a degenerative disease that is frequently observed in the elderly. It presents with pain in the lumbar spine and legs due

to a narrowing space in the nerve and blood vessel distribution in the lumbar spinal canal. (Lafian and Torralba, 2018). Degenerative changes in the spinal area can lead to the deterioration of the spinal canal space and degeneration of the intervertebral disc,

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causing instability and hypermobility of the facet joints, resulting in an enlargement of the superior articular process of the facet joints and nerve and blood vessel compression (Costandi et al, 2015).

Common symptoms of LSS include features of neurogenic intermittent claudication (NIC) (Suzuki et al, 2010), which increases pain during walking and lumbar extension and decreases pain during lumbar flexion and rest and pain, numbness, and muscle weakness in the lumbar spine and leg (Lafian and Torralba, 2018). Pain expression during lumbar extension causes abnormal postural changes due to limited range of motion (ROM) and inadequate weight-bearing ability in the direction of extension (Costandi et al, 2015). Additionally, the major cause of LSS is degenerative change due to old age (Chen et al, 2017). Turner et al. (1992) reported that NIC was observed in approximately 62% of patients with LSS, which reduced functional gait and overall physical conditions (Tomkins-Lane et al, 2014). Suzuki et al. (2010) reported that positive sagittal balance and pelvic tilt were increased in patients with LSS complaining of NIC.

Therapeutic intervention for LSS is largely divided into surgical and conservative methods (Inoue et al, 2016). Surgical methods typically use laminectomy and foraminotomy for lumbar decompression if there is no improvement in conservative treatment, severe NICs are identified, and severe pain is experienced in daily life (Binder et al, 2002). In surgical methods, despite the reduction of pain and NIC, postoperative functional disorders still remain an unresolved problem (Inoue et al, 2016). Therefore, in consideration of postoperative functional impairment of LSS, most patients with LSS have undergone rehabilitation and physical therapy 3~6 months before surgery (Chen et al, 2017).

Conservative treatment includes a variety of exercise treatments such as drug administration, acupuncture, strength training, stretching, and joint mobility (Zaina et al, 2016). Professional exercise therapies have been reported to have positive outcomes on pain and functional motor capacity of patients with LSS (Mu et al, 2018). Fritz et al. (1997) found

that treadmill walking exercise improves pain reduction and walking ability in patients with LSS. Mu et al. (2018) reported that exercise therapy combined with core stabilization exercises such as plank and bridge exercises improve walking and functional motor performance in patients with LSS. Goren et al. (2010) found that lumbar flexion and extension muscle strengthening combined with low-intensity bicycle exercise were effective in reducing lumbar and leg pain in patients with LSS.

The most recommended exercise therapy for patients with LSS is to limit the lumbar extension that can cause pain (Creighton et al, 2006). Because lumbar extension narrows the spinal and nerve root canal, lumbar flexion is recommended only (Fast, 1988). Creighton et al. (2006) reported that lumbar flexion exercise (LFE) improved pain and functional motor and walking ability in patients with LSS. Whitman et al. (2006) found that LFE combined with treadmill walking can improve pain and walking ability in patients with LSS. However, one researcher insisted the combination of lumbar flexion and extension exercises (Onel et al, 1993). Atlas et al. (2000) found that lumbar extension exercise (LEE) was effective for pain, functional motor capacity, and patient satisfaction in patients with LSS.

Hence, the results of the studies on exercise methods to improve pain and motor function of patients with LSS are controversial. This study aimed to compare the effectiveness of LFE, LEE, and lumbar flexion-extension exercise (LFEE) in pain, lumbar ROM, pelvic tilt angle (PTA), and functional gait ability in patients with LSS and to determine the most effective exercise method.

Methods

Instruments and measurement

Sustained lumbar extension provocation test

The subjects performed lumbar extension (10~30

degrees) after placing both hands in the hips in a standing position, and lumbar pain was noted if there was pain while maintaining this position. Subsequently, symptoms observed in this position were assessed. Complaints of lumbar and leg pain due to prolonged lumbar extension posture have been associated with LSS (Katz et al, 1995). The sensitivity and specificity of SLEPT were 51% (95% confidence interval (CI), 36%-66%) and 69% (95% CI, 53%-85%), respectively (Katz et al, 1995).

Modified lumbar extension test

The subjects extended their lumbar spine for 1 minute in a standing position. If symptoms did not appear for 1 minute, lumbar extension was performed again after 1 minute of rest. During this time, the lateral flexion was performed to the left and right lumbar spine, and if pain was felt in the ipsilateral side, it was positive in the ipsilateral direction and negative when the pain was felt in the opposite side. The sensitivity and specificity were 92% (95% CI, 72%-99%) and 40% (95% CI, 7%-82%), respectively (Dobbs et al, 2016).

Numerical pain rating scale

The NPRS subjectively measures pain. It consists of 11 items scored from 0 to 10, with 0 for "no pain" and 10 for "most severe pain." Subjects were asked about the degree of pain and were instructed to verbalize or indicate how they felt with the following classifications: 1 to 3 points were classified as mild pain, 4 to 6 points as moderate pain, and 7 to 10 points as severe pain. In clinical practice, a score of 4 points is usually defined as moderate pain (Krebs et al, 2007). The intraclass correlation coefficient (ICC) was .95 (Alghadir et al, 2018).

Modified modified schober test-flexion

The MMST-flexion was used to measure ROM for lumbar flexion. The first landmark was marked at the spinal intersection of the left and right posterior superior iliac spine (PSIS), and the second landmark was 15 cm above the first landmark. The examiner aligned

the tape measure between the two skin marks with zero at the inferior skin mark and 15 cm at the superior skin mark. The measuring tape was kept firmly against the subject's skin, while the subject was asked to bend forward with the following instruction: "Bend forward as far as you can while keeping the knee straight." At the end of flexion ROM, the distance between the two marks was noted. The ROM was the difference between 15 cm and length measured at the end of motion. This test has a high correlation with radiographic measurements (Battie et al, 1987). In this study, the ICC and test-retest reliability were .72 and .78~.89, respectively (Williams et al, 1993).

Modified modified schober test-extension

The same landmarks and procedure described for the flexion technique were used for measuring lumbar extension. The examiner gave the following instruction: "Place the palms of your hands on your buttock and bend backward as far as you can." When the subject bent backward into full lumbar extension, the new distance between the superior and inferior skin markings was measured using the tape, and the change in the distance between the marks was used to indicate the amount of ROM of lumbar extension. The ICC and test-retest reliability were .76 and .69~.91, respectively (Williams et al, 1993).

Pelvic tilt angle test

The subjects distributed their weight evenly on both feet in a barefoot standing position. Using the pelvic inclinometer (Baseline® AcuAngle Inclinometer, Fabrication Enterprises Inc., NY, USA) for the measurement, the examiner placed the tip of both calipers on the anterior superior iliac spine and PSIS and marked the indicated angles. The test-retest reliability of the pelvic inclinometer ranged from .96 to .99 (Youdas et al, 2000).

6-minute walking test

The 6-minute walking test (6MWT) is a sub-

maximal exercise test used to assess aerobic capacity, endurance, and gait performance capacity. The distance covered over a time of 6 minutes is used as the outcome to compare the changes in performance capacity. The best distance walked in meters is recorded. At least 30-minute rest was allowed between tests. The test-retest reliability of the 6MWT was .88~.94. (Rikli and Jones, 1998).

Intervention

The LFE applied William's exercise, LEE applied McKenzie exercise, and LFEE applied William and McKenzie exercise evenly. The three groups consisted of six exercise methods, and the exercise method of each group was performed equally in 10 seconds (5 times in 3 sets). Each of the three groups equally performed abdominal draw in maneuver for core stabilization. All three groups performed this maneuver for 40 minutes and were evaluated immediately before and after the intervention.

Lumbar flexion exercise

1) Hip flexor stretching: To relax the hip flexor muscles, the subjects held the ankle with one hand in a side-lying and extended their hip flexor muscles for 30 seconds. During this time, the subjects kept their pelvis tilted back and were extremely careful not to overextend their lumbar spine. 2) Double knee-to-chest: To relax the paraspinal muscles around the lumbar spine, the subjects held the thigh with both hands while in a supine and pulled it toward the chest while exhaling. 3) Lumbar flexion in long sitting: To restore and relax the lumbosacral muscle, erector spinae muscle, and hamstring muscle, the subjects extended their legs in a long sitting with their hands pointed at their toes and bent their lumbar spine. 4) Pelvic posterior tilt exercise: To prevent anterior tilting of the pelvis and reduce forward bending of the lumbar spine, the subjects tilted their pelvis backward in a hook-lying, allowing their lumbar spine to reach the floor. During this time, the subjects did not reach their legs on the floor. 5)

Partial sit-up exercise: To strengthen the abdominal muscles, the subjects, while in a hook-lying, put both of their hands behind the head and slowly raised their upper body until the scapula reached the floor. 6) Bending trunk in sitting: To improve stretching ability of the lumbosacral soft tissue, the subjects sat in a chair with both hands behind their heads, and they bent their trunk forward as far as possible without pain.

Lumbar extension exercise

1) Hold in prone: To relax the full body, the subjects put their arms in parallel to their body while breathing comfortably, slowly turning their head to both sides. 2) Lumbar extension on the elbow while in a prone: For lumbar extension, the subjects supported both of their elbows to the floor in prone and maintained lumbar extension within painless range. 3) Lumbar extension on the hand while in prone: For a larger range of lumbar extension, the subjects kept their lumbar extension with both arms extended while supporting the floor in a prone. 4) Superman exercise: For lumbar extensor muscle strengthening, the subjects lifted both of their hands slowly and simultaneously with extension of both elbows in a prone. 5) Bird-dog exercise: For lumbar extensor muscle strengthening and balancing left and right movements, the subjects' one hand and the other leg were simultaneously stretched parallel to the ground in one quadruped position and hold for 10 seconds and alternately as long as the subjects did not lose balance. 6) Lumbar extension in standing: To improve functional lumbar extension in standing with lumbar weight-bearing applied, the subjects extended their lumbar spine as far as possible without pain after placing both hands on both hips.

Lumbar flexion combined extension exercise

The LFEE was combined with LFE and LEE 1) Hip flexor stretching. 2) Lumbar extension on the elbow while in prone. 3) Lumbar flexion in long

sitting. 4) Superman exercise. 5) Partial sit-up exercise. 6) Lumbar extension in standing.

Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) ver. 20.0 (IBM corp,

Armonk, NY, USA). The data are described as the mean±standard deviation. One-way analysis of variance (ANOVA) with the subjects' general characteristics was used to compare among the groups. A one-way ANOVA was used to identify the differences and changes in the NPRS, MMST-flexion,

Table 1. General characteristics of subjects

Variables (unit)		LFE ^a (n ₁ =10)	LEE ^b (n ₂ =10)	LFEE ^c (n ₃ =10)	p
Gender	Male	6 (20%)	4 (13%)	5 (17%)	
	Female	4 (13%)	6 (20%)	5 (17%)	
Age (year)		78.30±3.97 ^d	76.60±5.44	74.00±6.01	.197
Height (cm)		161.30±8.57	159.00±7.13	160.90±6.50	.764
Weight (kg)		59.10±8.53	58.70±8.05	56.80±6.52	.780

^alumbar flexion exercise, ^blumbar extension exercise, ^clumbar flexion combined extension exercise, ^dmean±standard deviation.

Table 2. Comparisons of LFE, LEE, LFEE on NPRS, MMST flexion, MMST extension, PTA, 6MWT

Variables		LFE ^a (n ₁ =10)	LEE ^b (n ₂ =10)	LFEE ^c (n ₃ =10)	p ₁
NPRS ^e (score)	Pre	2.70±.48 ^d	2.80±.42	2.80±.42	.845
	Post	2.00±.47	2.40±.51	1.70±.67	.032*
	p ₂	.001*	.037*	.001*	
	Change	-.70±.48	-0.40±.51	-1.10±.73	.043*
MMST-flexion ^f (cm)	Pre	5.20±1.40	5.67±1.34	6.95±2.02	.060
	Post	5.90±1.32	5.58±1.31	7.24±2.04	.065
	p ₂	<.001*	.324	<.001*	
	Change	.70±.24	-.09±.27	.29±.08	<.001*
MMST-extension ^g (cm)	Pre	2.00±.69	2.14±.70	2.13±.62	.875
	Post	1.99±.66	2.41±.65	2.27±.64	.354
	p ₂	.758	<.001*	.001*	
	Change	-.01±.99	.27±.08	.14±.08	<.001*
PTA ^h (°)	Pre	13.20±2.09	13.60±2.36	14.10±2.96	.725
	Post	12.70±1.82	13.50±2.27	14.20±2.57	.342
	p ₂	.015*	.726	.726	
	Change	-.50±.52	-.10±.87	.10±.87	.231
6MWT ⁱ (m)	Pre	165.20±29.20	155.80±21.33	162.90±30.50	.728
	Post	167.50±29.91	156.20±19.83	170.30±28.74	.464
	p ₂	.199	.768	<.001*	
	Change	2.30±5.25	.40±4.16	7.40±3.83	.005*

^alumbar flexion exercise, ^blumbar extension exercise, ^clumbar flexion combined extension exercise, ^dmean±standard deviation, ^enumerical pain rating scale, ^fmodified modified schober test-flexion, ^gmodified modified schober test-extension, ^hpelvic tilt angle, ⁱ6 minute walking test, *p<.05.

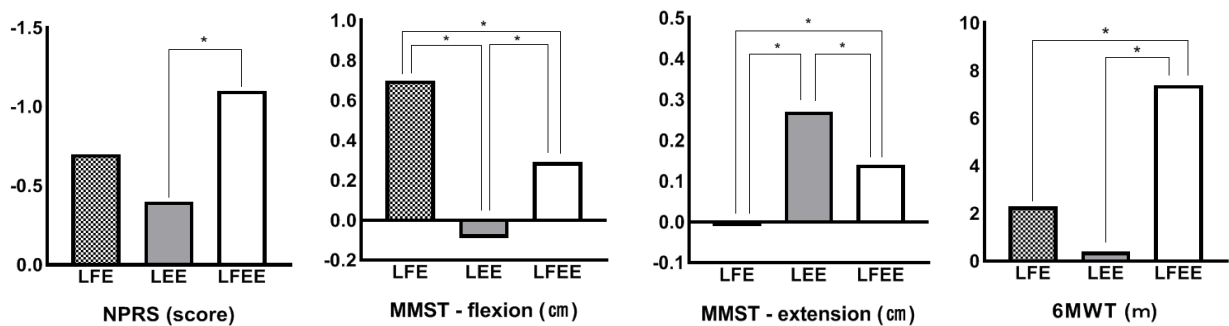


Figure 1. Post-Hoc comparisons of LFE, LEE, LFEE on changes value of NPRS, MMST flexion, MMST extension, 6MWT (LFE: lumbar flexion exercise, LEE: lumbar extension exercise, LFEE: lumbar flexion combined extension exercise, NPRS: numerical pain rating scale, MMST-flexion: modified modified schober test-flexion, MMST-extension: modified modified schober test-extension, 6MWT: 6-minute walking test).

MMST-extension, PTA, and 6MWT among the three groups before and after the intervention. A paired t-test was performed to compare the outcome changes before and after the intervention in each group. If the analysis revealed statistical significance, post hoc Turkey was performed to determine the differences in pairwise comparison. The level of significance was set at $p < .05$.

Results

General characteristics of study subjects

The general characteristics of the study subjects are presented in Table 1. There were no significant differences in age, height, and weight of the subjects among the groups ($p > .05$).

Comparisons of LFE, LEE, LFEE on NPRS, MMST flexion, MMST extension, PTA, 6MWT

According to the comparison among the groups by change value, significant differences were observed for NPRS ($p = .043$), MMST-flexion ($p < .001$), MMST-extension ($p < .001$), and 6MWT ($p = .005$) but not PTA. LFE demonstrated significant differences in NPRS ($p = .001$), MMST-flexion ($p < .001$), and PTA ($p = .015$), but not for MMST-extension and 6MWT,

before and after the intervention. LEE demonstrated significant differences in NPRS ($p = .037$) and MMST-extension ($p < .001$), but not for MMST-flexion, PTA, and 6MWT, before and after the intervention. LFEE demonstrated significant differences in NPRS ($p = .001$), MMST-extension ($p = .001$), and 6MWT ($p < .001$), but not for PTA, before and after the intervention (Table 2).

Post-Hoc comparisons of LFE, LEE, LFEE on changes value of NPRS, MMST flexion, MMST extension, 6MWT

LFEE was significantly more effective than LEE at improving NPRS ($p = .043$), LFE was more effective than LEE and LFEE at improving MMST-flexion ($p < .001$), LEE was more effective than LFE and LFEE at improving MMST-extension ($p < .001$), and LFEE was more effective than LFE and LEE at improving 6MWT ($p = .005$) (Figure 1).

Discussion

LFE, LEE, and LFEE were applied to patients with LSS to compare the effectiveness of these exercises by measuring pain, lumbar ROM, PTA to measure postural abnormalities, and functional gait ability. As a result, LFE showed a significant difference in pain, lumbar flexion ROM, and PTA, LEE

showed significant difference in pain and lumbar extension ROM, and LFEE showed significant difference in pain, lumbar flexion ROM, lumbar extension ROM, and walking ability. Additionally, LFEE was most effective in pain and gait performance, LFE was most effective in lumbar flexion ROM, and LEE was most effective in lumbar extension ROM.

We used a safe and efficient MMST-flexion and MMST-extension measure in standing to measure the lumbar ROM of patients experiencing pain and difficulty in the measurement process (Tousignant et al, 2005). Additionally, PTA, which can predict postural abnormalities, was immediately applied in standing (Youdas et al, 2000), and a simple and universal 6MWT was used to evaluate walking ability (Bohannon and Crouch, 2017). Therefore, the measurements used in this study are considered clinically and highly efficient tools. These tools were similarly used in patients with LSS in the study of Tomkins-Lane et al. (2014).

The lumbar flexion and extension directions were performed to improve lumbar pain and functional motor ability of patients with LSS. LFE was based on the William exercise method, and LEE was applied based on the McKenzie exercise method. The William exercise method induces lumbar flexion to widen the intervertebral disk space by mechanically inducing lumbar flexion to reduce structure compression (Williams, 1955). The McKenzie method induces lumbar extension, which reduces the loading of the posterior longitudinal ligament of the intervertebral disc (Clare et al, 2004). Elnaggar et al. (1991) compared lumbar flexion and extension in chronic mechanical LBP patients; they found that both groups were effective in reducing pain and improving thoracolumbar spinal mobility. However, there was no difference between the groups. Hammerich (2014) reported that LEE was negatively associated with pain relief in patients with LSS. Moreover, Nwuga (1985) reported that LEE was more effective in reducing pain than flexion exercise. As such, the previous studies that determined the most effective ex-

ercise are insufficient, with varying findings.

Universally, patients with LSS often benefit from conservative treatment and participation in a physical therapy program. However, the North American Spine Society guideline states that there is insufficient evidence to support the effectiveness of physical therapy (Kreiner et al, 2013). LEE should be avoided in this population as spinal extension and increased lumbar lordosis are known to worsen LSS. Flexion exercises for the lumbar spine should be emphasized as they reduce lumbar lordosis and decrease stress on the spine. Spinal flexion exercises increase the spinal canal dimension, thus reducing NIC. Williams' flexion-based exercises increase lumbar lordosis, paraspinal and hamstring inflexibility, and abdominal muscle weakness. These exercises incorporate knee-to-chest maneuvers, pelvic tilts, wall-standing lumbar flexion, and avoidance of lumbar extension.

However, the LEE method that can induce lumbar extensor muscle strengthening effect improves pain and motor function in patients with LSS and has been applied clinically. In this study, it was found that the LEE is effective in improving lumbar extension ROM and functional exercise ability in patients with LSS. The LEE method has been excluded from the structural point of view because of the narrowing of the spinal canal in patients with LSS. However, neuromuscularly, the improvement of lumbar extension ROM was shown by the improvement of mutual control between the agonist and antagonist muscles around the lumbar spine by strengthening lumbar extension muscle in patients with LSS (Steele et al, 2013). Additionally, the LEE should be included in patients with LSS as the LFEE is the most effective exercise method in improving pain, lumbar ROM, and walking ability, because the advantages of LFE and LEE have been combined together.

Lumbar pain and postural abnormalities observed in elderly patients with LSS are highly associated with lumbar extensor muscle weakness. Moreover, extensor muscle (such as the multifidus and erector spinae

muscle) weakness (with fat accumulation) is considered the major problem for patients with LSS (Jiang et al, 2017). Nevertheless, studies on exercise methods to improve mobility and restore extensor muscle strengthening in patients with LSS are significantly insufficient. In this study, several representative methods such as the LEE were applied, and related effects were observed. In particular, the six exercise methods for strengthening the lumbar extensor muscles and lower extremity muscles while in a prone position were significantly associated with motor function in the lumbar spine and lower extremity.

There are some limitations in interpreting the results of this study. First, the small sample size lacks the power of this study. Second, the training effect was unknown because the short intervention time was applied due to the pain and various variables of the subjects. Third, it was not an intervention method considering the differences of individuals with various problems in pain degree, site, duration, and motor function. Lastly, the results of this study cannot be generalized because subjects with LSS with mild pain less than 4 points of NPRS participated in this study. Therefore, further studies should be conducted to several patients with LSS who have a NPRS 4 or more by applying an intervention method that specifically considers the functional level of each patient.

Conclusion

This study aimed to evaluate which exercise method is more effective through pain, lumbar ROM, PTA, and functional gait ability by applying LFE, LEE, and LFEE in patients with LSS. The results showed that LFEE was the most effective exercise for pain and functional gait ability, LFE was the most effective exercise for lumbar flexion ROM, and LEE was the most effective exercise for lumbar extension ROM. This study suggests that LFEE exercises for lumbar extensor muscle recovery may be effective in improving pain and motor function in patients with LSS.

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