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Core Stabilization With the Lumbar Extension Exercise in Low Back Pain

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Abstract

Background: We developed a novel integrative lumbar stabilization technique that combines lumbar extension (LE) exercise with abdominal drawing-in maneuver (ADIM) to ameliorate low back pain (LBP) associated with neuromuscular imbalance and instability, based on the collective evidence of contemporary spinal rehabilitation.

Objects: The specific aim of the present study was to investigate the effects of LE exercise with and without ADIM on core muscle strength, lumbar spinal instability, and pain, as well as functional characteristics in individuals with LBP using advanced radiographic imaging techniques.

Methods: patients with mechanical LBP (N = 40, 6 males; 35.1±7.6 years) were recruited and randomly assigned either to the combined LE and ADIM (experimental group) or the LE alone (control group). Outcome measures included the visual analog scale, the modified Oswestry Disability Index, muscle strength imbalance (MSI), and radiographic imaging. The lumbar intervertebral displacement (LID), intervertebral (IV) and total lumbar extension (TLE) angles were calculated to evaluate the lumbar segmental instability.

Results: The experimental group showed significant differences in the L3-L4, L5-S1 LIDs, L4-L5 and L5-S1 IV angles, and TLE angle as compared to the controls ($p<.05$). Immediate pain reduction and muscle strength imbalance ratio were significantly different between the groups ($p<.05$).

Conclusion: These results suggest that the addition of ADIM significantly increased lumbar spinal stabilization in individuals with LBP, thereby reducing pain associated with functional lumbar flexion during daily activities.

Key Words: Abdominal drawing-in maneuver; Low back pain; Lumbar extension exercise.

Introduction

Posterior derangement syndrome (PDS) is a common type of mechanical low back pain (LBP) that presents as mechanical obstruction of affected lumbar joint movement and pain (Mckenzie and May, 2003). Pathomechanically, PDS may involve mechanical obstruction of the affected joint structure that compresses the intervertebral disc and nerve root, resulting in either centralized or peripheralized pain during repetitive lumbar flexion (Harris-Hayes et al, 2005; Shirazi-Adl et al, 2005). The lumbar extension (LE) exercise is a commonly used and effective technique to mechanically centralize peripheralized pain and re-

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store lumbar spinal movement in individuals with PDS (Browder et al, 2007; Donelson et al, 1997; Mckenzie and May, 2003).

Accumulating clinical evidence suggests that lumbar core stabilization exercises can reduce low back pain and associated radiating pain during lumbar extension in individuals with mechanical low back (Akuthota and Nadler, 2004) or lumbar radiculopathy (Hibbs et al, 2008). Muscle strength imbalances (MSI) between deep core muscles (weak or underactive) and superficial (strong or overactive rectus abdominal and external oblique) or antagonist (strong or overactive erector spinae) muscles is a potentially important pathomarker of lumbar spine instability. Such lumbar core instability contributes to intervertebral (IV) angle and total lumbar extension (TLE) angle (Dupuis et al, 1985; Kong et al, 2009), which may be linked to PDS (Fredericson et al, 2001). As such, clinical improvements in low back pain and spinal movement suggest that the combination of core stabilization with LE exercise produces an augmented or additive effect in individuals with PDS and associated core instability (Hosseinifar et al, 2013; Miller et al, 2005).

We developed a novel integrative lumbar stabilization technique that combines LE exercise with abdominal drawing-in maneuver (ADIM) to ameliorate LBP associated with neuromuscular imbalance and instability, based on the collective evidence of contemporary spinal rehabilitation (Teyhen et al, 2008; Vasseljen et al, 2012). ADIM is a lumbar stabilization exercise that focuses on the activation of the deep core muscles such Transverse abdominis (TrA) and internal oblique (IO) in coordination with superficial abdominal muscles. ADIM is effective for improving lumbopelvic stability and reducing pain in individuals with LBP (Hodges and Richardson, 1999; Richardson et al, 2002). This core stabilization exercise helps restore neuromuscular control in impaired active and neural subsystems, thereby increasing lumbopelvic core stability or stiffness and reducing concurrent pain in individuals with LBP (Cresswell et al, 1992; Hodges and Richardson, 1999). Our combined exercise would be effective not only mechanical pain but also lumbopelvic stability. The specific aim of the present study was to investigate the effects of LE exercise with and without ADIM on core muscle strength, lumbar spinal instability, and pain, as well as functional characteristics in individuals with LBP using advanced radiographic imaging techniques.

Methods

Subjects

The PDS was evaluated by a physical therapist that was specialized in the McKenzie method. The experimental protocol was approved by the Ministry of Health and Welfare Institutional Review Board, and informed consent was obtained from all patients. The sample size was estimated based on a power of 80% with large differences (.8) in effect size. patients were recruited from Korean spine rehabilitation hospitals. Inclusion criteria were as follows: (1) consistently diagnosed with mechanical LBP by physiatrists, (2) chronic low back pain (>3 months), and (3) LBP at L4-L5 and lumbosacral segments associated with PDS with or without radiating pain toward the buttock/lower leg. The PDS was classified

Table 1. Demographic and clinical characteristics of patients (N=40)

Characteristic	Experimental group (n_1=20)	Control group (n_2=20)	p
Gender (male/female)	2/18	4/16	
Age (years)	35.4±7.3[a]	34.9±8	.719
Height (㎝)	162.4±6.2	193.1±6.1	.841
Weight (㎏)	56.4±8.8	57.4±9.5	.387

[a]mean±standard deviation.

based on the directional preference for lumbar extension, not requiring any lateral compartment procedures (Clare et al, 2007; Mckenzie and May, 2003). Exclusion criteria were a history of low back surgery, spondylolisthesis, increased peripheral pain with repeated lumbar extension, and neurological or musculoskeletal impairments that could affect the experimental tests (Van et al, 2003). patients were randomly assigned to either the experimental group (n_1=20) or the control group (n_2=20). The experimental group received a combination of ADIM and LE, whereas the control group received LE alone. Demographic and clinical characteristics of patients are presented in Table 1.

Study design

This study was based on a longitudinal single-blind randomized controlled study. visual analog scale, the modified Oswestry disability index were used to measure the pain and function. Trunk muscle strength, and radiographic imaging, lumbar intervertebral displacement (LID), IV and TLE angles were calculated to evaluate the lumbar segmental instability in patients with mechanical LBP.

Procedure

This study is a single-blind randomized controlled design in which the two investigators who performed the radiographic examinations and the patients were blinded to group allocation and the intervention provided. All experimental procedures were implemented by the same investigator. A randomization sequence was created with Microsoft Excel (Microsoft corp., Roselle, IL, USA) to assign patients randomly to either the experimental group or the control group for a 2-week course of treatment. To standardize tests and interventions, the certified and experienced physical therapists were trained in the standardized clinical tests, ADIM training and/or lumbar extension technique (Clare et al, 2007; Mckenzie and May, 2003).

Clinical radiographic imaging was performed with AccuRay-525R (Dong Kang Medical Systems Co., Ltd., Seoul, Korea) to determine lumbar spine movement characteristics. Each participant was instructed to lie prone with the pelvis stabilized and to extend his or her lumbar spine within pain-free maximal extension for 5 seconds. The risks are minimal; but the examiner be requested to be present if there is serious concern about the risks involved. The radiographic images were acquired at the end of the expiration phase. The baseline or pretest radiographic imaging was obtained under the LE condition for both groups. However, to evaluate intervention-related changes in lumbar spine kinematics, post-test imaging was performed under the LE condition for the control group as well as under the ADIM + LE condition for the experimental group. Ultrasound imaging and a pressure biofeedback unit (PBU) were used to monitor core stabilization performance during ADIM to ensure consistency in the implementation of experimental procedures.

Clinical radiographic measures included the TLE angle (the angle between the inferior endplate of T12 and the superior endplate of S1) (Powers et al, 2008), IV angles (Hodges and Richardson, 1999) [the angles between the inferior and superior endplates of contiguous vertebrae from L1 to S1 (Figure 1)], and the LID [the vertical distance from the inferior-posterior edge of the superior vertebral body to the posterior surface of the inferior vertebral body (Figure 2)] (Dupuis et al, 1985; Kong et al, 2009). LID is recognized as an important indicator of lumbar spinal instability (Kong et al, 2009). Interspinal instability was determined by computing the LID and IV angles. Excessive or abnormal spinal instability was defined as >2-3 ㎜ of LID and a >10° IV angle (Berlemann et al, 1999).

A visual analog scale (VAS) was used to determine the severity of LBP (Shaffer et al, 1990). The VAS ranged from 0 (“no pain”) to 10 (“worst pain”). The modified Oswestry disability index (MODI) was used to determine the pain and physical and social disabilities related to LBP (Marshall and Murphy, 2010). The MODI consists of 10 items (pain intensity,

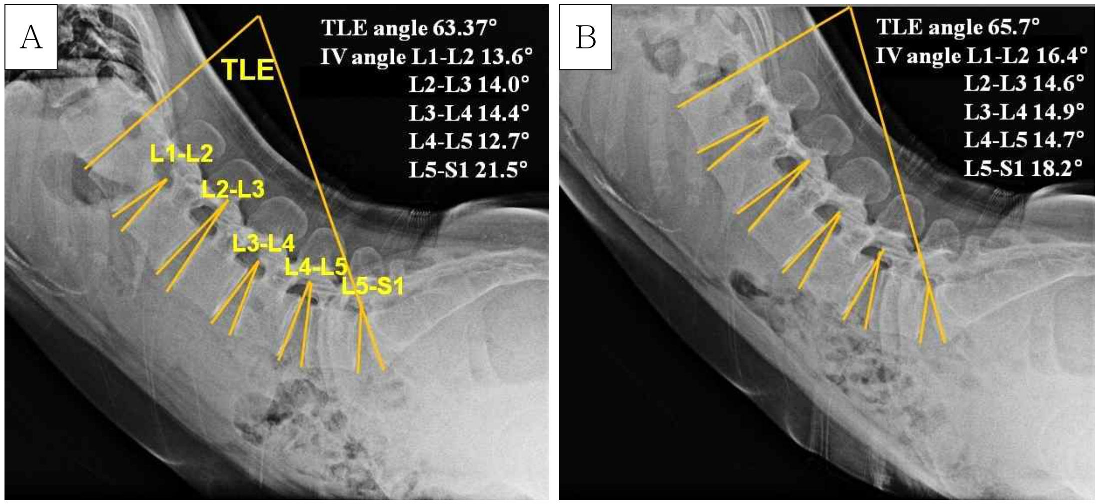

Figure 1. The X-ray images of the LE assessment; the total LE angle and the intervertebral angles were measured in lumbar extension position (A : LE position without ADIM, B : LE position with ADIM) (LE : lumbar extension, ADIM : abdominal drawing-in maneuver).

personal care-washing and dressing, lifting, walking, sitting, standing, sleeping, sex life-if applicable, social life, and traveling) on a scoring scale ranging from 0 (“no pain”) to 5 (“worst pain”). The reliability and validity of the VAS and MODI measures ranged from r=.60 to r=.92, suggesting good to excellent correlations (Boonstra et al, 2008; Kim et al, 2005).

MSI ratio was determined by measuring maximal voluntary isometric muscle contraction (MVIC) for the abdominal and erector spinae muscles using hand-held dynamometry (HHD) (JTech Medical, Salt Lake City, USA) measurements. The MSI ratio was expressed as erector spinae MVIC/abdominal MVIC. To assess the abdominal muscles, each participant was positioned supine with the hip and knee at 90° of flexion and asked to raise his or her trunk from the table (off of the inferior scapula border) and push against a hand-held dynamometer applied at the sternum (Kendall et al, 1973). For the erector spinae muscle test, the participant was asked to lie prone with hands resting on the buttocks while the pelvis was stabilized with a strap and then asked to extend the trunk (off of the umbilicus) and push against a dynamometer applied at the thoracic spine (T6-8). All patients performed 3 consecutive trials, with each test lasting for 5 seconds and a resting interval of 3 minutes between tests. The reliability and validity of the strength test used in this study is considered good to excellent (Abizanda et al, 2012).

Intervention

The experimental group underwent ADIM exercises during LE intervention while the control group underwent LE intervention alone. The interventions were consistently provided 30 minutes per day, 3 times per week, over a 2-week period.

For the ADIM exercise, the participant was asked to lie in the prone position, and a PBU was placed under the anterior superior iliac spine (ASIS) and inflated to 70 ㎜Hg. The participant was then asked to inhale and stabilize the lumbar spine by coordinated and balanced co-activation of deep and superficial core muscles while maintaining pressure within the target pressure range of 4-10 ㎜Hg (Figure 3). The coordinated co-activation of deep and superficial core muscles and lumbar core stability were concurrently monitored by real-time ultrasound imaging and PBU, respectively. Specifically, ultrasound imaging was used to guide accurate activation of the deep core muscles in coordination with overactive external oblique muscle or rectus abdominus to improve muscle balance between the overactive super-

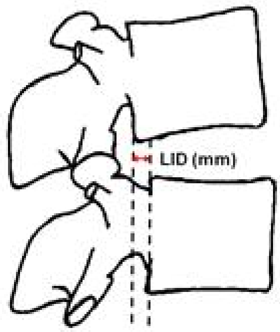

Figure 2. Measurement of relative lumbar spinal intersegmental displacement.

ficial and underactive deep core muscles (Frank et al, 2013; Janda et al, 1996). A linear transducer was transversely placed 2.5 ㎝ anteromedial to the point midway between the iliac crest and the 12th rib (Whittaker, 2008).

For the LE method, once core stabilization was achieved from the ADIM training, LE exercise was implemented according to the specific procedure: 1. The participant was asked to lie prone with hands palms down and aligned under the shoulders while maintaining the core stabilization. 2. The participant then raised the upper body using the arms, but the pelvis and lower legs remained stable. 3. The participant maintained this position for one to two seconds and then returned to the neutral prone position. 4. The participant rhythmically repeated this movement to move further towards the end range of motion with each repetition. 5. The movement was repeated up to 10 times. The use of the “force progressions” concept in the LE method was applied via dynamic patient-generated force progression to improve the centralization of the symptoms and lumbar extension movement. After the participant successfully performed repeated LE, patients progressed to end-range with patient overpressure, which involved the patient locking the elbows straight and exhaling while allowing the pelvis to sag. Applications of force progressions and force alternatives were conducted according to the clinical reasoning and attentive interpretation of symptomatic and mechanical responses described in the LE method (Clare et al, 2007; Mckenzie and May, 2003).

Figure3. Core stability test using a pressure biofeedback unit.

Statistical analysis

Descriptive and standard statistical analyses included mean, standard deviation, and computations of the independent t-test was used to determine group difference of age, height, and weight, χ^2 test was used to determine whether there were between group differences of gender. A independent t-test was used to compare intervention-related changes in VAS, MODI, trunk strength, LID, IV, and TLE angles within and between groups. A paired t-test was used to investigate pre-posttest within group. The level of significance was set at $p<.05$. All statistical analyses were performed with SPSS ver. 18.0 (IBM corp., Armonk, NY, USA).

Results

Demographic and clinical data: Independent t-tests showed no significant differences in baseline demographic or clinical variables between groups, indicating that the groups were homogenous (Table 1).

Pain and function data

Independent t-tests revealed a significant within-group differences ($p<.001$) but not between-group differences in the VAS ($p=.17$) or MODI ($p=.16$), although some results approached statistical significance (Table 2).

Muscle strength imbalance ratio

The muscle strength imbalance ratio at pretest was not significantly different between groups

Table 2. Clinical outcome data in pain, lumbar function, and trunk muscle strength

Variable		Experimental group (n_1=20)			Control group (n_2=20)		
		Pretest	Posttest	Changes	Pretest	Posttest	Changes
VAS[a]		5.7±1.7[b]	2.2±1.4	-3.5±1.4	5.5±1.3	2.6±1.5*	-2.9±1.3
MODI[c]		11.2±6.2	6.3±6.7*	-4.8±3.6	11.6±4.3	8.1±4.1*	-3.5±2.1
Strength measure (N)	Abdominal muscle	82.5±13.2	86.9±13.2	4.4±12.4	83.5±29.2	84.5±21.3	1.0±15.3
	Erector spinae muscle	80.7±16.2	100.8±17.5*†	20.0±11.0	80.1±19.7	83.2±10.6	3.1±17.3
	E[d]/A[e] Ratio	.9±.1	1.1±.1	.1±.1†	.9±.1	1.0±.2	.0±.1

[a]visual analog scale, [b]mean±standard deviation, [c]the modified Oswestry disability Index, [d]erector spinae muscle, [e]abdominal muscle, *significant difference between pretest and posttest for each group (p<.05), † significant difference in the intervention-related changes of variables between the two group (p<.05).

Table 3. Comparative radiological imagining data in the lumbar intersegmental displacements, intervertebral, and total lumbar extension angles between groups

Variable		Experimental group			Control group		
		pretest	posttest	changes	pretest	posttest	changes
LID[a] (㎜)	L1-L2	1.7±.6	1.7±.7	.0±.6	1.6±.4	1.6±.6	-.3±.4
	L2-L3	1.6±1.5	1.7±1.6	.1±.6	1.8±.8	1.8±.7	.0±.6
	L3-L4	2.8±1.3	2.4±1.3*	-.4±.7†	2.6±1.0	3.1±1.4*	.5±.7
	L4-L5	2.1±1.3	1.7±1.1	-.3±1.0	1.9±.5	1.8±.6	-.1±.4
	L5-S1	2.3±.9	1.2±.6*†	-1.1±.8†	1.9±.9	2.2±.9*	.2±.4
IV[b] angle (°)	L1-L2	8.5±2.9	10.8±2.5*	2.2±2.2	8.1±3.5	9.1±3.0*	1.0±1.6
	L2-L3	9.4±2.1	12.4±2.7*	3.0±2.0	8.4±3.6	10.2±2.8*	1.8±1.7
	L3-L4	.5±3.3	12.8±3.1*	2.3±1.9	10.1±2.9	11.3±2.6*	1.2±1.8
	L4-L5	1.4±3.4	14.5±3.2*	3.1±1.9†	12.7±4.0	13.4±2.7	.6±3.4
	L5-S1	18.1±3.6	15.2±3.2*	-2.9±1.4†	15.6±4.4	17.5±4.4*	1.9±1.9
TLE[c] (°)		60.2±8.6	69.1±9.3*	8.9±6.3†	57.3±8.9	60.8±8.0*	3.5±5.3

[a]lumbar intervertebral displacement, [b]intervertebral, [c]total lumbar extension, *significant within-group difference (p<.05), † significant between-group difference (p<.05).

(p=.948), but the ratio was significantly increased in the experimental group following the intervention at the posttest (p=.041) (Table 2).

Clinical radiographic data

There were significant differences between groups in LIDs (posttest-pretest) for the L3-L4 (p<.001) and L5-S1 (p<.001) segments, indicating greater spinal stability after the combination of LE and ADIM than after LE intervention alone. Similarly, the combined intervention group showed greater improvement in the TLE angle (p=.006) and IV angles at L4-L5 (p=.008) and L5-S1 (p<.001) than did the control group. Both groups showed significant improvements in IVs at L1-S1, with the exception of the IV angle at L4-L5 in the control group (Table 3).

Test-retest reliability of the radiographic measurements: Test-retest reliability of the radiographic measurements for the TLE angle, IV angles, and LID was determined by intraclass correlation coefficients (ICC) [3, 1] analysis. The correlations were .91 (.53 to .98) for the TLE angle, .96 (.83 to .99) for the IV angles, and .86 (.41 to .97) for the LID, suggesting good to excellent consistency.

Discussion

This is the first study to demonstrate the effects of lumbar stabilization with an ADIM technique during LE in individuals with chronic LBP. As hypothesized, the experimental group, which received a combination of LE and ADIM, showed greater reduction in LIDs (L3-L4 and L5-S1) and IV angles of the lumbosacral segment (L5-S1) than did patients in the control group who received only LE exercise. These results suggest that the addition of ADIM significantly increased lumbar spinal stabilization in individuals with LBP, thereby reducing pain associated with functional lumbar flexion during daily activities.

Importantly, radiological imaging revealed that the baseline LID (2.1 ㎜) and IV angle (10.9˚) for L1-5 instability in the present study were comparable to those identified as indicating abnormal spinal instability in previous studies (LID: >2-3 ㎜ and IV angle: >10˚) (Dupis et al, 1985; Berlemann U et al, 1999). This lumbar instability was noticeably decreased in the L3-4 and L5-S1 LID lumbar segments in the experimental group (L3-4: 14.2%, L5-S1: 47.8%, within group changes) but increased in the control group (L3-4: -19.2%, L5-S1: -15.7%, within group changes). Similarly, the L5-S1 segment IV angles were substantially more decreased in the experimental group (16.0%, within group changes) than in the control group (-12.1%, within group changes), suggesting that the combined method was more effective for lumbosacral stabilization. The total lumbar extension angle was greater in the experimental group (15%, within group changes) than the control (6%, within group changes) group, indicating that a superior stabilization effect was achieved with the combined ADIM and LE technique. Such improvements in lumbar extension movement after LE combined with ADIM were similar to ranges of improvement reported previously (15-17%) in patients with LBP who participated in press-up and other specific core stabilization exercises (O'sullivan et al, 1997; Powers et al, 2008). In addition, the one-week post-intervention test showed more rapid alleviation of LBP (65%) in the experimental group than in the control group (25%), which corroborates previous results in studies of LBP management (Franca et al, 2010; Kumar, 2011; O'sullivan et al, 1997). One important underlying mechanism by which the ADIM enhances lumbopelvic stabilization is neuromuscular activation of the TrA muscle, which synergistically contracts posterior fibers of the IO muscle. This in turn increases the posterior-lateral lumbar tension on the thoracolumbar fascia (TLF) that connects to both the spinous and transverse processes of the lumbar spine (Stanton and Kawchuk, 2008). Co-activation of the TrA and IO muscles paired with the tension on the TLF generates intra-abdominal pressure (IAP), which transforms abdominal function into mechanical stiffening of the TLF. This mechanical stiffness provides spinal lumbar stabilization and optimal lordotic lumbar alignment (Hicks et al, 2005). In the current study, such spinal stabilization appeared to improve pain and decrease physical and social disabilities in daily activities, as evidenced by the VAS and MODI data.

The MSI ratio between the erector spinae and abdominal muscle strength significantly improved after the combination of LE and ADIM exercise, but no apparent change was observed after LE alone. Given the 2-week intervention period, this result indicates that such acute and rapidly-resolving episodes can be attributed to disinhibition or release of pain-induced inhibition, rather than muscle hypertrophy (Van et al, 2003). Our results agree with recent clinical evidence that demonstrated enhancements in pelvic stabilization, pain reduction, and associated lumbar extension strength in LBP patients (Smith et al, 2011).

One potential shortcoming of the present study was that dynamic IV disc movement characteristics associated with posterior derangement were not measured. Future research on the effects of core stability interventions on IV disc movement using motion MRI is warranted. Nevertheless, our data demonstrate, for the first time, the additive effect of ADIM on lumbar spinal stability and associated reduction in low back pain and increase in functional mobility. The radiographic imaging measurement was proven to be useful and reliable to detect therapy-induced minute structural changes associated with lumbar spinal instability. And 3 times intervention in a week is not a normal clinical does in LE exercise for LBP further research should do for shorter periods and multiple times per day.

Conclusion

In this investigation, we demonstrated the superior effects of combined LE with ADIM on pain, spinal stability, and associated functional movement in patients with muscular strength imbalance and instability when compared to the conventional lumbar extension exercise alone. Most importantly, the combined intervention rapidly ameliorated pain and improved lumbar spinal stability and overall spinal mobility. These promising results suggest that the use of lumbar extension exercises alongside ADIM is beneficial for LBP patients with core instability.

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