Clinical Trial/Experimental Study

Medicine

OPEN

Effect of stabilization exercise combined with respiratory resistance and whole body vibration on patients with lumbar instability: A randomized controlled trial

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Abstract

Background: Lumbar stability exercise promotes deep muscle functions, and it is an effective intervention method for increasing proprioceptive sensation. This study aims to explore and compare the effects of lumbar stability exercise with respiratory resistance and whole body vibration on patients with lumbar instability.

Methods: This study is a 3-group randomized control trial. Through screening tests, 48 patients with lumbar instability were selected and randomly assigned to SE group (n = 16), stabilization exercise program using respiratory resistance (SER) group (n = 16), and stabilization exercise program using respiratory resistance and whole body vibration (SERW) group (n = 16). In order to compare the effects depending on the intervention methods, quadruple visual analogue scale (QVAS), Functional Ability Roland-Morris low back pain and disability questionnaire ([RMDQ], center of pressure path length, velocity, and area), Korean version of fear-avoidance beliefs questionnaire, and Pulmonary Function were used for measurement.

Results: All of the groups showed significant improvements in QVAS, RMDQ, Korean version of fear-avoidance beliefs questionnaire, and balance abilities before and after the interventions. The SER group and SERW group showed a significant difference in QVAS and RMDQ than the SE group ($P < .05$). In addition, balance ability showed a significant difference in SERW group ($P < .05$), where only the SER group showed a significant difference in pulmonary function indexes including forced vital capacity, forced expiratory volume in 1 second, maximum inspiratory pressure, and maximum expiratory pressure ($P < .05$).

Conclusion: Stabilization exercise program using respiratory resistance and whole-body vibration administered according to the purpose of intervention methods may be effective exercise programs for people with lumbar instability.

Abbreviations: FABQ = Korean version of fear-avoidance beliefs questionnaire, FEV1 = forced expiratory volume in 1 second, FVC = forced vital capacity, MEP = maximum expiratory pressure, MIP = maximum inspiratory pressure, QVAS = quadruple visual analogue scale, RMDQ = Roland-Morris low back pain and disability questionnaire, SE = stabilization exercise group, SER = stabilization exercise program using respiratory resistance group, SERW = stabilization exercise program using respiratory resistance and whole body vibration.

Keywords: back pain, breathing exercises, progressive patient care, proprioception, respiratory therapy

1. Introduction

Low back pain (LBP) is a common muscular disorder in which approximately 60% to 80% of the population experience at least once in their lifetime.[1] LBP is a syndrome that occurs in the area between second lumbar spine to sacroiliac joint, where there is an abnormal overload in the area due to weakening of the soft tissues and muscles.[2] As a result, issues including physical dysfunctions such as activities of daily living (ADL) and psychological factors are reported due to LBP.[3]

Sensitivity of body tissues increases from the area of LBP.[4] This makes hardening of muscles around the spine, decreased range of motion of spinal joints, and ultimately difficulties in the performance of ADLs. Patients with LBP usually show kinesiophobia due to the functional issues.[5] In addition, patients also develop negative psychosocial effects such as low self-confidence and apathy due to fear of pain, decreased quality of life, and depression.[6]

Many intervention methods are introduced to address alleviation of LBP and functional recovery, but exercise therapy

The authors have no funding and conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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How to cite this article: Park S-H, Oh Y-J, Seo J-H, Lee M-M. Effect of stabilization exercise combined with respiratory resistance and whole body vibration on patients with lumbar instability: A randomized controlled trial. Medicine 2022;101:46(e31843).

Received: 21 March 2022 / Received in final form: 30 August 2022 / Accepted: 31 August 2022

http://dx.doi.org/10.1097/MD.0000000000031843

is recommended to improve muscle instability. Stabilization exercise allows prioritized collaborative contraction of deep muscles such as transverse abdominalis and multifidus, and greatly contributes to dynamic lumbar stabilization and static stabilization of spinal segments.[7] The stabilization exercise activates sensory-motor control to modify muscle asymmetry and decrease LBP relapse, and demonstrates positive effects in improving signs of LBP through increased motor performance.[8–10]

In order to provide lumbar stabilization to patients with lumbar pain, deep muscle contractions are essential.[11] To enhance the effects during lumbar stabilization exercises, exercise interventions with respiratory methods that promote diaphragm contraction and stabilization exercises that come with respiratory resistance to induce strengthening of deep muscles in abdominals, spine, and pelvis by holding respiratory resistance apparatus with the mouth to facilitate resistance during respiration are introduced. Stabilization exercises with respiratory resistance demonstrates decreased pain, increased motor functions, and sense of psychosocial stability, and it is reported to be more effective in increasing pulmonary functions that the conventional stabilization exercises.[12]

Vibration stimulations are reported to have positive effects by enhancing motor functions and increasing energy metabolization and blood circulation.[13] When vibration is applied to muscles, sensory stimuli are provided to activate muscle spindles, and thereby strengthening deep muscles that are critical for postrural stabilization. In addition, whole body vibration (WBV) exercise activates proprioceptors and Golgi tendons, inducing reflective contraction of muscles to affect kinaesthesis. Stabilization exercise with whole body vibration is effective for pain, balance ability, and deep muscle activation in LBP patients.[14] Additionally, stabilization exercise with respiratory resistance is reported to be an effective intervention for LBP, dysfunction, and psychosocial stability.[15]

Respiratory resistance and whole body vibration given with stabilization exercises are both suggested as important factors for the recovery of LBP, but comparisons in exercise intensity or effects depending on the functional levels of patients with lumbar Tinstability are not yet recommended. Therefore, this study aims to investigate the effects of stabilization exercises with respiratory resistance and whole body vibration on pain, functional level, psychosocial level, and pulmonary functions and to suggest effective stabilization exercise method and clinical feasibility.

2. Methods

2.1. Participants

This study recruited 82 patients who were receiving therapy for lumbar pain as either outpatient or inpatient in P hospital in D city. The study took place between November 2020 and January 2021. Due to the COVID-19 pandemic, preventive measures against the pandemic such as taking body temperatures were taken into consideration prior to the recruitment. The inclusion criteria were: persons who experienced LBP within 6 weeks, mean score of 3 or higher in quadruple visual analogue scale (QVAS), more than, positives in lumbar instability test,[16] and persons who are able to stand on 1 leg for more than 30 seconds. The exclusion criteria were: persons who have difficulty in participating in the intervention due to vestibular disorders, persons who have respiratory disorders, persons with the history of spinal surgery, who are pregnant, and persons with the study participation rate less than 80%. All participants signed the agreement ensuring that they fully understood the purpose and process of the study and are voluntarily participating.

2.2. Study design

This study is a 3-group randomized control trial (3-group RCT study design). G*power program was used to determine the size of the participants. Medium effect size was set to .25 according to Cohen's f, significance level (α) as .05, and Power($1-\beta$) = .8, 42 participants were needed for this study. However, 15% of drop out rate was considered, therefore 48 participants were ultimately selected.

The selected 82 participants were given a lumbar instability test to screen appropriateness for inclusion in the study. The lumbar instability test considered the participant to have lumbar instability when 3 or more items out of the 5 items resulted in positive.[16] The items tested were: instability test prone (positive when pain disappears with manual pressure), passive extension test of lumbar area (positive when there is pain or not able to maintain position), lumbar segment posterior/anterior movement test (positive when there is abnormal movement), direct lift of lower extremity test (positive if greater than 90 degrees), and age (positive when over 41). Through the screening test 34 total participants were excluded for the study. There were participants who did not satisfy the lumbar instability test (n = 30) and who scored below 2 in pain level (QVAS) (n = 4).

After conducting screening test for the 48 participants, a random number production program was used[17] to randomly assign the participants to stabilization exercise group (SE) (n = 16), stabilization exercise program using respiratory resistance group (SER) (n = 16), and stabilization exercise program using respiratory resistance and whole body vibration (SERW) (n = 16). The participants were not given information about the group to which they had been assigned. Pain level, functional ability, Korean version of fear-avoidance beliefs questionnaire (FABQ), and pulmonary functions were conducted before and after the interventions for all 3 groups. All participants received stabilization exercises, and therefore, the participants were not able to determine which group they were assigned to. All assessments were made by a physiotherapist with 8 years of clinical experience and specialization in musculoskeletal system. This study was approved by the Ethics Committee, and is registered in the WHO International Clinical Trials Registry Platform: KCT0005773. The study process is shown in Figure 1.

2.3. Intervention

2.3.1. Stabilization exercise program. The stabilization exercise that all 3 groups received were modified from the exercise program method suggested by Zheng, et al[18] This exercise program induces lumbar stability through contraction of the abdominal muscles and strengthening of lumbar area and lower extremity muscles. The exercise program consisted 6 exercises that include squat, lunge, flank, curl up, bridge, and bridge with knee extension. Stretching for 10 minutes is provided with the purpose of warm up and cool down before and after each interventions. Each exercises were performed for 5 repetitions in a set, 10 seconds for each set, and 5 sets total. Break time of 20 seconds were given between each sets. The intervention was provided for 60 minutes per session, 3 sessions per week, and a total period of 5 weeks.

2.3.2. Stabilization exercise program using respiratory resistance. The SER group performed the exercise program using a respiratory resistance apparatus (Expand a Lung, Miami, USA). Ventilation during respiration may be controlled using the respiratory resistance apparatus, and it is also used to strengthen respiratory muscles. In addition, a reliable index Rating of Perceived Exertion (RPE) was used to measure the level of exercise fatigue to observe motion resistance during the exercise. This study controlled the RPE between 13 to 14 to maintain the level between " difficult" and "slightly difficult."[19] After attaching the respiratory resistance apparatus, explanation

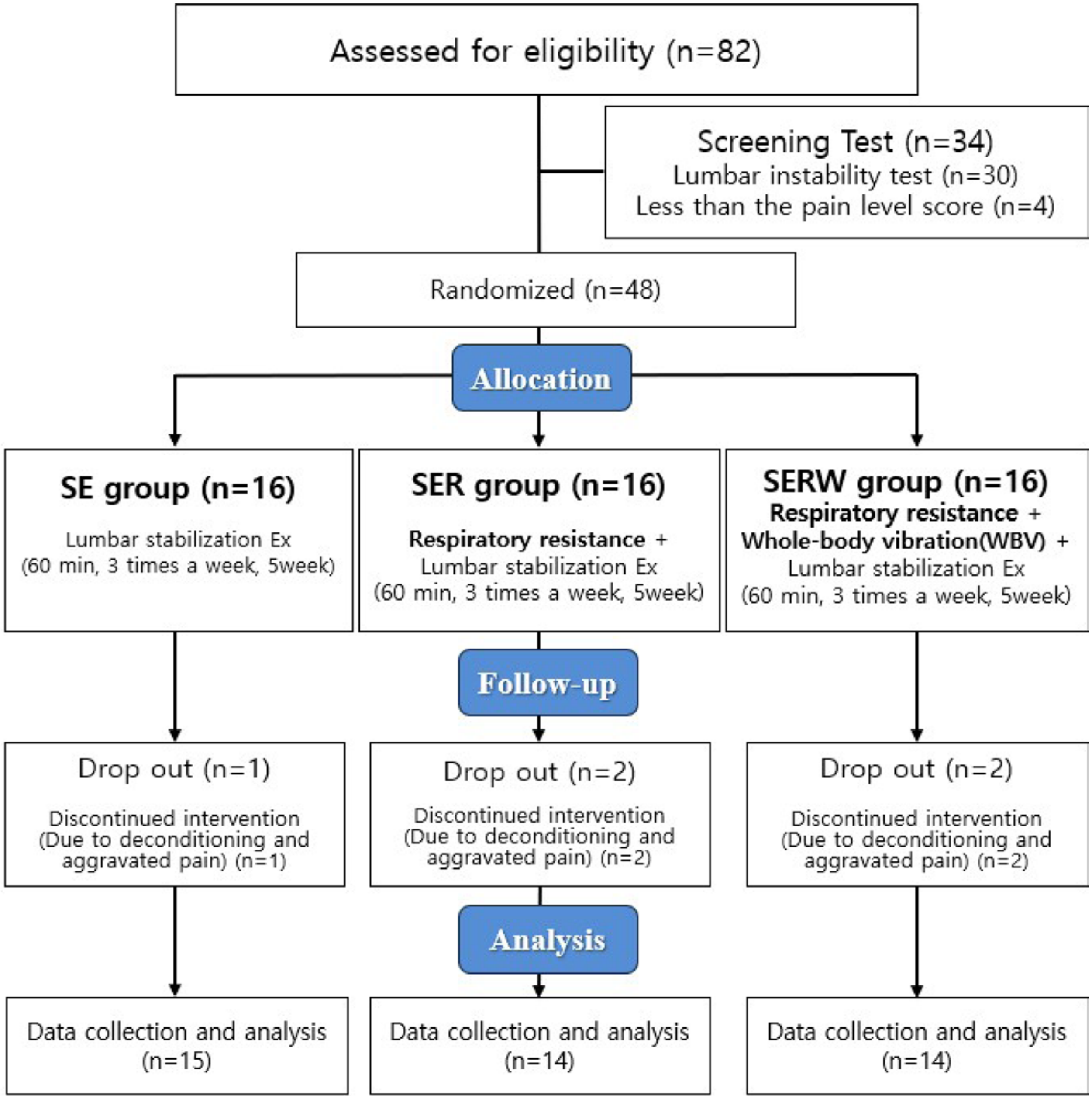

Figure 1. CONSORT flow diagram.

confirming that interventions may be discontinued in situations of abnormal situations, dizziness, and breathing difficulties.

2.3.3. SERW. The SERW group performed the exercise program using a respiratory resistor apparatus and vibrator (SW-VH11, Wonju, Korea) (Fig. 2). Vibration stimulation is administered as an exercise method that contributes stabilization by delivering the stimulus to lumbopelvic area or proximal part of the lower extremities. In the intervention, the frequency followed the study methods suggested by Di Giminiani, et al[20] and the sound wave intensity was set to 30 and the frequency was set to 30 Hz, which is reported to be appropriate from muscle activation.

2.4. Assessment methods

2.4..1. Pain level. In order to determine the pain level depending on the intervention programs, 4-item visual analogue scale (QVAS) was used. This scale consists 4 items that ask for: current pain level, average pain level experienced, pain level when it is least severe, and pain level when it is most severe. Each questions are scored from 0 to 10 where 0 means no pain at all and 10 with the most severe pain. This test has a high reliability of r = .76–.84.[21]

2.4.2. Functional ability. In order to determine the lumbar functional ability of the participants, Roland-Morris Low Back Pain and Disability Questionnaire (RMQD) was used. This assessment is a self reported questionnaire that has 24 items, where each items are scored wither 0 or 1, and the highest possible score is 24. Higher score means greater functional disability. RMQD is useful in explaining the levels of functional limitations. This assessment has a high reliability of r = .92.[22]

Wii Balance Board (WBB) (Nintendo, Kyoto, Japan) was used to measure static balance ability of the participants of different intervention groups. On top of the platform shaped WBB, the participants' change in center of pressure is traced to calculate path length, velocity, and area. The data measured with WBB were collected using Balancia software (Balancia software,

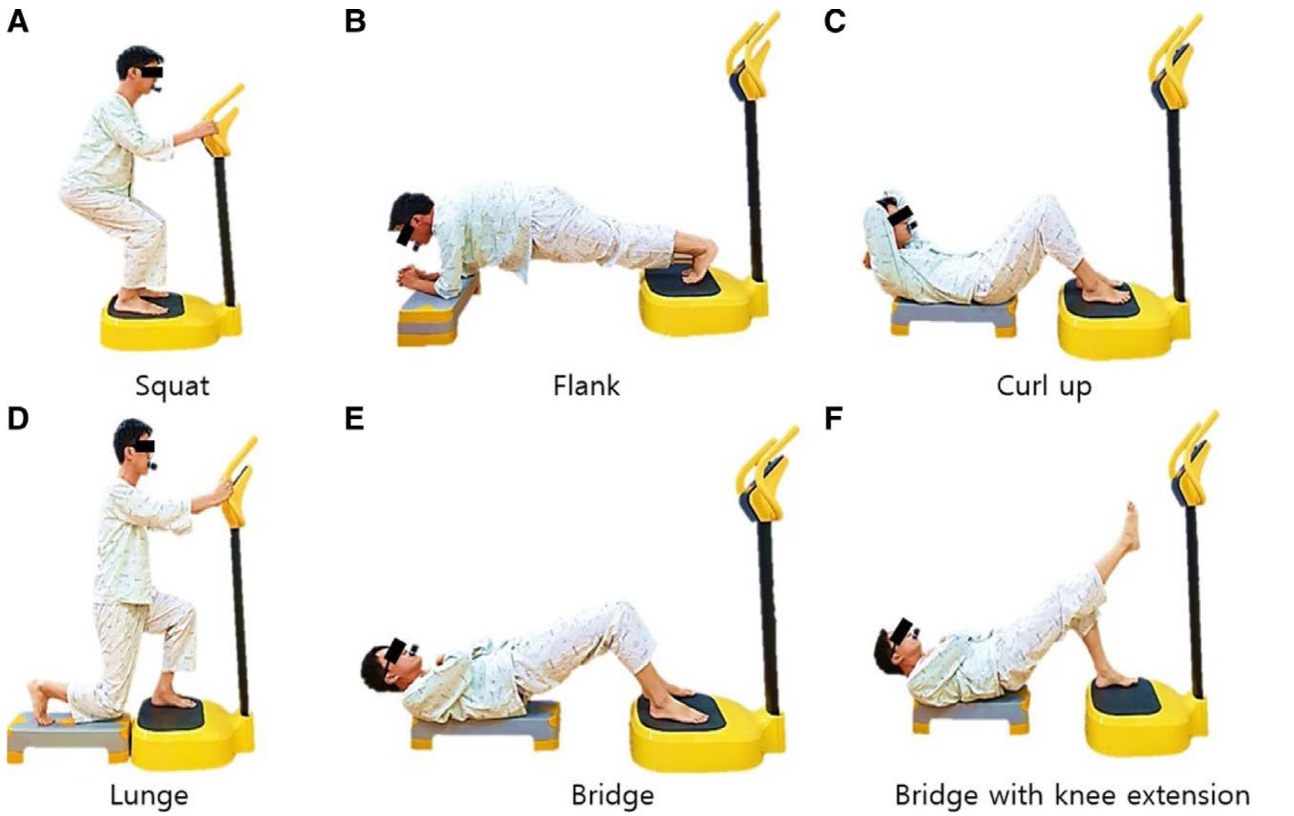

Figure 2. Stabilization exercise program using respiratory resistance and whole body vibration.

Mintosys, Korea). The interrater reliability of WBB is ICC = .92–.98 (Holmes et al, 2013), and Balancia program has high interrater reliability (r = .79–.96) and validity (r = .85–.96).[23]

2.4.3. Psychosocial factor. To determine the psychisocial factors of the participants, Korean Version of FABQ was used. This questionnaire has 16 items that are categorized into physical activity (PA) and work (W). In fear-avoidance response, FABQ-PA consists of 5 items with the score range from 0 to 24. FABQ-W has 11 items and the score ranges from 0 to 42. The reliability of this test is .95.[24]

2.4.4. Pulmonary function. Pulmonary function test was conducted using Microquark (COSMED, Roma, Italy) after entering sex, age, height, and weight of the participants. The pulmonary function test measured forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), forced expiratory volume in 1 second/forced vital capacity (FEV1/FVC), and maximum voluntary ventilation (MVV). In addition, Pony FX MIP/MEP (COSMED, Roma, Italy) was used to measure the changes in respiratory muscles. In a standing position, the participants positioned their legs shoulder width, holding the mouth piece with the mouth and nose closed with a clip. Maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) were measured in this position. After 3 light respirations, a total of 3 MIP and MEP were measured, and the highest values of each were used for analyzation. The measurement was performed 3 times by a skilled physiotherapists with many years of experience in pulmonary function test. Between each tests, 10-minute vreaks were given. Interrater reliability of pulmonary function test using Pony FX MIP/MEP is r = .99.[25]

2.5. Statistical analysis

All data collected through the interventions were analyzed using SPSS version 25.0 (IBM, Chicago, IL). General characteristics of the participants were determined with test of normality through Shapiro–Wilk test, and mean and standard deviations were analyzed through 1-way ANOVA and $\chi 2$ test. In order to investigate the amount of changes of the intervention effects before and after the intervention for each groups, paired t test was made and 1-way ANOVA was used to compared each groups. Statistical significance level (α) was set to .5.

3. Results

Among the participants, a total of 5 participants were excluded from the study where 2 participants dropped out due to pain aggrevation and 3 participants dropped out due to decondition. Ultimately, data were collected from 15 participants in the SE group, 14 from the SER group, and 14 from the SERW group. There was no statistically significant difference in the general characteristics of the 3 groups (Table 1), and the pretest outcome values of the 3 groups were homogeneous.

3.1. QVAS

Pain levels of the 3 groups showed significant decrease before and after the intervention, and SER and SERW groups showed significant decrease compared to the SE group ($P < .05$) (Table 2).

3.2. Functional ability

Roland-Morris low back pain and disability questionnaire and balance ability of the participants showed significant increase before and after the intervention for all 3 groups ($P < .05$). When the 3 groups were compared, SERW and SER group showed a significant increase that the SE group in Roland-Morris low back pain and disability questionnaire ($P < .05$), and only

Table 1

General characteristics.

	SE group (n = 15)	SER group (n = 14)	SERW group (n = 14)	F(p)
Sex (M/F)	6/8	9/5	8/6	.645 (.530)
Age (yr)	30.29 ± 5.34[a]	31.07 ± 6.82	30.93 ± 4.70	.076 (.927)
Height (cm)	170.71 ± 9.82	168.21 ± 6.41	171.14 ± 9.63	.456 (.637)
Weight (kg)	69.57 ± 18.11	72.16 ± 17.67	69.12 ± 19.18	.113 (.894)
BMI (score)	23.52 ± 3.98	25.33 ± 5.23	23.32 ± 5.10	.742 (.483)
Onset (mo)	16.64 ± 3.03	16.71 ± 3.27	16.71 ± 3.01	.007 (.993)

[a]Mean ± standard deviation.
SE = stabilization exercise, SER = stabilization exercise program using respiratory resistance, SERW = stabilization exercise program using respiratory resistance and whole body vibration.

Table 2

Comparison of pain level, functional ability before and after intervention between groups.

		SE group (n = 15)	SER group (n = 14)	SERW group (n = 14)	F(p) post hoc	
QVAS (point)	Pre	6.46 ± .46a	6.45 ± .44	6.41 ± .43	.053 (.949)	AIB,AIC
	Post	5.96 ± .87	4.66 ± .40	4.59 ± .39		
	Post-pre	−.50 ± .79	−1.79 ± .43	−1.82 ± .58	20.581 (.000)*	
	t(p)	−2.348 (.035)*	−15.691 (.000)*	−11.677 (.000)*		
RMDQ (score)	Pre	21.14 ± 1.61	21.43 ± 1.60	21.29 ± 1.59	.111 (.895)	AIB,AIC
	Post	13.07 ± 1.44	10.14 ± 1.17	10.29 ± 1.27		
	Post-pre	−8.07 ± 1.86	−11.29 ± 1.14	−11 ± .96	23.420 (.000)*	
	t(p)	−16.245 (.000)*	−37.083 (.000)*	−42.839 (.000)*		
CoP velocity (cm/s)	Pre	4.81 ± .69	4.78 ± .71	4.69 ± .69	.202 (.818)	AIC, BIC
	Post	4.35 ± .57	4.02 ± .79	3.50 ± .65		
	Post-pre	−.46 ± .57	−.76 ± .75	−1.19 ± .86	3.519 (.039)*	
	t(p)	-3.019 (.010)*	−3.793 (.002)*	−5.212 (.000)*		
CoP length (cm)	Pre	144.95 ± 22.37	142.69 ± 22.12	142.61 ± 20.19	.053 (.949)	AIC, BIC
	Post	136.86 ± 16.13	128.83 ± 16.32	108.41 ± 4.99		
	Post-pre	−8.09 ± 12.57	−15.29 ± 23.02	−34.20 ± 20.34	6.931 (.003)*	
	t(p)	−2.409 (.032)*	−2.485 (.027)*	−6.291 (.000)*		
CoP area (cm2)	Pre	9.29 ± 2.70	8.89 ± 2.60	9.79 ± 2.33	.434 (.651)	AIC, BIC
	Post	7.87 ± 2.24	6.58 ± 2.65	6.01 ± 2.79		
	Post-pre	−1.42 ± 2.29	−2.31 ± 2.45	−3.78 ± 2.61	3.290 (.048)*	
	t(p)	−2.317 (.037)*	−3.530 (.004)*	−5.417 (.000)*		

[a]Mean ± standard deviation.
CoP = center of pressure, QVAS = quadruple visual analogue scale, RMDQ = Roland-Morris low back pain and disability questionnaire, SE = stabilization exercise, SER = stabilization exercise program using respiratory resistance, SERW = stabilization exercise program using respiratory resistance and whole body vibration.
*$P < .05$.

the SERW group showed significant increase in balance ability($P < .05$) (Table 2).

3.3. FABQ

FABQ that shows the psychosocial level of the participants showed significant increase in all 3 groups ($P < .05$), but there was no significant increase in the amount of changes among the groups (Table 3).

3.4. Pulmonary function

FVC, FEV1, MVV, MIP, and MEP of the participants showed significant increase before and after the intervention in the SER and SERW group ($P < .05$), and in the differences among the groups, the SER group showed a significant increase in FVC, FEV1, MIP, and MEP ($P < .05$) (Table 4).

4. Discussion

This study aimed to explore the effects of stabilization exercise programs depending on intervention methods on LBP patients with lumbar instability. The results demonstrate that all participants showed statistically significant differences ($P < .05$) in pain level, functional level, and psychosocial level. Additionally the SER group showed significant improvement in pain level, functional level and lung function ($P < .05$), and the SERW group showed improvement in pain level, functional level, and balance ability.

Lumbar stabilization exercise controls the pressure applied to the lumbar area through dynamic movements, and ultimately improves pain and increases functional activities.[26] Park and Lee[11] studied the effects of stabilization exercise with respiratory resistance in patients with LBP, and demonstrated that there was a significant difference in pain level ($P < .05$, $d = 2.74$). When Zheng et al[18] provided stabilization exercise with whole body vibration, there was a significant difference in maintaining postures and pain level ($P < .05$, $d = .52$). This study also demonstrated significant increase ($P < .05$) in pain level before and after the intervention in all 3 groups (SE group ($d = .33$), SER group ($d = .90$), and SERW group ($d = .91$)) and it was consistent with the existing studies. There was no significant difference among the 3 groups, but SER and SERW groups showed a greater effect size compared to the SE group. Stabilization exercise with whole body vibration may have reduced pain from the increased control ability of the deep muscles by increasing proprioception during whole body vibration. When respiratory resistance was added to the stabilization exercise, increase in abdominal pressure from strong contraction in the abdominals may have contributed to pain reduction.

As LBP is a general health issue, it limits many activity performances due to pain and dysfunction, thereby resulting in poor quality of life.[27] Yang et al[28] argued that pain and dysfunction

Table 3

Comparison of psychosocial level before and after intervention between groups.

		SE group (n = 15)	SER group (n = 14)	SERW group (n = 14)	F(p)	post hoc
FABQ-PA (score)	Pre	20.14 ± 2.48[a]	20.21 ± 2.46	20.29 ± 2.43	.012 (.988)	A, B, C
	Post	10.00 ± 1.57	9.64 ± 1.55	9.93 ± 1.54		
	Post-pre	−10.14 ± 3.63	−10.57 ± 3.2	−10.35 ± 2.53	.065 (.938)	
	t(p)	−10.442 (.000)*	−12.347 (.000)*	−15.317 (.000)*		
FABQ-W (score)	Pre	37.79 ± 2.94	38.36 ± 3.03	37.43 ± 3.01	.343 (.712)	A, B, C
	Post	20.57 ± 2.87	20.14 ± 2.51	20.36 ± 2.50		
	Post-pre	−17.21 ± 4.37	−18.21 ± 2.83	−17.07 ± 4.65	.334 (.718)	
	t(p)	−14.736 (.000)*	−24.054 (.000)*	−13.741 (.000)*		
FABQ-total (score)	Pre	57.93 ± 3.95	58.57 ± 4.03	57.71 ± 3.93	.177 (.839)	A, B, C
	Post	30.57 ± 2.28	29.79 ± 2.36	30.29 ± 1.98		
	Post-pre	−27.36 ± 5.03	−28.79 ± 2.61	−27.43 ± 5.03	.474 (.626)	
	t(p)	−20.341 (.000)*	−41.313 (.000)*	−20.387 (.000)*		

[a]Mean ± standard deviation

FABQ = Korean version of fear-avoidance beliefs questionnaire, PA = physical activity, SE = stabilization exercise, SER = stabilization exercise program using respiratory resistance, SERW = stabilization exercise program using respiratory resistance and whole body vibration, W = work.

*$P < .05$.

Table 4

Comparison of pulmonary function before and after intervention between groups.

		SE group (n = 15)	SER group (n = 14)	SERW group (n = 14)	F(p)	post hoc
FVC (L)	Pre	4.05 ± .90[a]	4.07 ± .88	4.02 ± .89	.162 (.851)	A|B, B|C
	Post	4.10 ± .89	4.41 ± .85	4.20 ± .86		
	Post-pre	.04 ± .13	.34 ± .24	0.18 ± 0.28	6.251 (.004)*	
	t(p)	1.216 (.245)	5.433 (.000)*	2.476 (.028)*		
FEV1 (L)	Pre	3.43 ± 1.05	3.21 ± 1.04	3.33 ± 1.05	.304 (.739)	A|B, B|C
	Post	3.56 ± .99	4.51 ± 1.01	3.96 ± .98		
	Post-pre	.13 ± 1.21	1.30 ± 1.09	0.63 ± 1.09	3.760 (.032)*	
	t(p)	.395 (.699)	4.449 (.001)*	2.171 (.049)*		
FEV1/FVC (%)	Pre	84.73 ± 10.06	87.73 ± 10.25	86.41 ± 10.28	.162 (.851)	A,B,C
	Post	88.16 ± 5.91	86.33 ± 10.38	86.36 ± 10.41		
	Post-pre	3.43 ± 11.96	−1.40 ± 3.00	−.057 ± .25	1.715 (.193)	
	t(p)	1.073 (.303)	−1.745 (.105)	−.865 (.403)		
MVV (L/min)	Pre	105.03 ± 24.64	104.34 ± 24.66	106.13 ± 24.96	.019 (.982)	A,B,C
	Post	112.04 ± 23.77	121.76 ± 22.77	113.36 ± 23.83		
	Post-pre	7.01 ± 13.97	17.43 ± 14.72	7.23 ± 12.48	2.623 (.085)	
	t(p)	1.876 (.083)	4.431 (.001)*	2.168 (.049)*		
MIP (cmH_2O)	Pre	56.46 ± 5.99	56.94 ± 5.97	57.33 ± 5.83	.076 (.927)	A|B, B|C
	Post	56.98 ± 5.86	66.51 ± 3.00	60.35 ± 6.29		
	Post-pre	.52 ± 1.05	9.57 ± 5.34	3.02 ± 2.92	24.030 (.000)*	
	t(p)	1.864 (.085)	6.702 (.000)*	3.866 (.002)*		
MEP (cmH_2O)	Pre	50.76 ± 5.65	50.86 ± 5.62	51.26 ± 5.72	.031 (.970)	A|B, B|C
	Post	51.61 ± 5.84	59.52 ± 3.48	53.76 ± 6.36		
	Post-pre	.84 ± 1.77	8.66 ± 3.83	2.50 ± 3.09	26.042 (.000)*	
	t(p)	1.777 (.099)	8.457 (.000)*	3.024 (.010)*		

[a]Mean ± standard deviation.

FEV1 = forced expiratory volume in 1 s, FEV1/FVC = forced expiratory volume in 1 s/forced vital capacity, FVC = forced vital capacity, MEP = maximum expiratory pressure, MIP = maximum inspiratory pressure, MVV = maximum voluntary ventilation, SE = stabilization exercise, SER = stabilization exercise program using respiratory resistance, SERW = stabilization exercise program using respiratory resistance and whole body vibration.

*$P < .05$.

of LBP patients are important factors in determining the direction of therapy. This study assessed lumbar dysfunction along with pain level. Calculating the score percentage in relation to the total score of 24, the SE group showed a dysfunction decrease from 88% to 54%, the SER group from 89% to 42%, and the SERW group from 88% to 42%, suggesting that lumbar dysfunction level has decreased significantly ($P < .05$). In addition, the SER and SERW groups showed a statistically significant increase ($P < .05$) compared to the SE group. The SER group may have shown increased intramedullary and intraabdominal pressures from the strengthening of deep abdominal muscles and diaphragm through respiratory resistance training. Furthermore, it may have affected respiratory function, pain, and ADL performance, thereby affecting functional limitations in the lumbar area. In the SERW group, it may be suggested that pain and functional limitations have decreased through training on unstable surfaces with whole body vibration, where this method may have increased proprioception and neuromuscular control ability.

Park and Lee[29] reported that with the onset of LBP, psychological changes occur and this change affects physical and work-related activities. Choi, et al[2] reported that pain level and FABQ have significant correlations. Therefore this study used Korean Version of FABQ to investigate the psychosocial factors of the participants before and after the intervention. The results showed that all participants have significantly decreased phychological anxiety ($P < .05$), but there was no significant difference among the 3 groups. All participants have performed the same stabilization exercises, and with the randomized assignment to different groups, not knowing which group they were assigned to, and stabilization exercise that avoided direct movement of the lumbar area may have affected psychological factors.

In order to maintain balance stabilization exercise on unstable surface requires co-contraction of many muscles that go through body joints.[29] This study measured and compared the variables of center of pressure velocity, length and area to determine balance abilities of the participants before and after the interventions. As a result, all 3 groups showed significant increase ($P < .05$) in all variables before and after the interventions. In addition, there was difference between the 3 groups showed a significant difference only in the SERW group that combined respiratory resistance and whole-body vibration ($P < .05$). It is consistent with the results of previous studies that there was a significant improvement in balance ability by performing neuromuscular stabilization exercise using whole-body vibration for LBP patients ($P < .05$).[14] Rittweger, et al[30] reported that frequency lower than 20Hz may cause excessive relaxation of the muscles and frequency exceeding 50 Hz may cause muscle pain, thereby suggesting the frequency to be set between 20 and 50 Hz. This study used 30 Hz for the intervention as suggested by Di Giminiani, et al[20] in their study, where they reported that this frequency induces the greatest muscle activation. Since whole body vibration exercise implements a novice form of stimulation to the muscular system, it not only provides additional neural adaptation, but also improves balance abilities by giving positive effects in muscle activation when vibration is given. Many surrounding muscles are speculated to be activated in motor units rather than a single muscle activation to maintain balance against external resistance through whole body vibration.

This study showed a significant increase in FVC, FEV1, MVV, MIP, and MEP before and after the intervention in the SER and SERW group ($P < .05$), and in the differences among the groups, the SER group showed a significant difference in FVC, FEV1, MIP, and MEP ($P < .05$). It is thought that, in the SER group, high-intensity respiratory resistance training with breathing resistance in addition to stabilization exercise led to strengthening of the diaphragm, and thus focused on training for breathing. However, in the SERW group, it is thought that the whole body vibration training in parallel with respiratory resistance applied various movements along with vibration stimulation of the lower extremities, so it is thought that only the breathing resistance could not be focused. Stabilization exercise with respiratory resistance may have applied pressure on the supplementary inspiration muscles and diaphragm, enhance internal pressure of the chest and trunk muscle activation during respiratory resistance, and increase spinal stabilization to ultimately enhance pulomary function, MIP, and MEP.

While conducting this study, 1 to 2 days of preceding training was required for participants in stabilization exercise with whole body vibration group. In addition, the mouth piece of respiratory resistance apparatus is made with silicon material. The participants in SER and SERW group complained about the intervention when there was an exposure of saliva during training, creating nauseating sensations. Furethermore, this study has some limitations. First, the intervention period was not long enough to consistently compare and analyze the effects after the intervention. Secondly, the age range of the participants were limited to 30’s, making it difficult to generalize to all LBP patients of all ages. These limitations must be addressed in studies determining the long term effects of lumbar stabilization exercise in the future.

5. Conclusion

This study aimed to explore the effects of stability exercise programs depending on intervention methods for patients with lumbar instability. The results showed that pain and dysfunction decreased with increased pulmonary functions in the SER before and after the interventions, and decreased pain and dysfunction with increased balance ability in the SERW group. In current clinical settings, various methods of stabilization exercises are facilitated to patients with lumbar instability. If stabilization exercise program using respiratory resistance and whole-body vibration administered according to the purpose of intervention methods may be effective exercise programs for people with lumbar instability.

Acknowledgments

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2022R1C1C101350111).

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