Spinal Stabilization Exercise with and without Whole–Body Vibration: A Randomized Controlled Clinical Trial

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Introduction: The present study aimed to compare the impacts of core stability exercises with and without Whole Body Vibration (WBV) training sessions lasting two weeks on trunk muscle endurance in patients with non-specific chronic low back. **Methods and Materials:** Thirty participants were randomly placed into either a WBV group or a spinal stabilization group at Shahid Beheshti University of Medical Sciences, Tehran, Iran, in 2013. The dependent variables manipulated included the abdominal and spinal muscular endurance, assessed prior to, midway through, and after two weeks and the WBV or spinal stabilization intervention program implemented using stabilizer pressure biofeedback unit and Biering Sorensen test. **Results:** Changes in transverse abdominal and internal oblique muscle endurance in prone position were statistically significant among the participants in both groups ($P<0.05$). However, changes in transverse abdominal muscle endurance in supine position and multifidus muscle endurance were not observed to be statistically significant in both groups. In addition, inter-group analysis showed that except for the percentage of changes of multifidus muscle endurance, the vibration group demonstrated significant improvement over the non-vibration group. **Conclusion:** As no significant difference was observed between the two treatment methods, none of treatment methods was more effective comparatively in terms of improving mid-term trunk muscle endurance.

Keywords: Whole body vibration, Trunk muscle endurance, Non-specific chronic low back pain, Core stability

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Introduction

The financial costs and disability caused by low back pain (LBP) are among growing clinical and socioeconomic problems (1). Although 5%-10% of patients suffer from chronic pain and disability, higher rates have been reported for chronic back pain as 42%-75% and recurrence of back pain episodes (24%-84%) (2).

After developing LBP, patients often remain sedentary because of the fear of the pain caused by movement. Such behavior is harmful in particular as the decreased amusement activity results in deconditioning (3). Fatigue caused by low endurance in trunk muscles may affect the ability of people with LBP in responding to the demands of an unexpected load. After repetitive loadings, fatigue may also lead to control and precision loss; prejudice the individual to develop the LBP. Therefore, trunk muscle endurance training has been recommended to elevate fatigue threshold and improve performance, and consequently, to reduce lumbar spine disability (4).

Trunk muscles mainly function as support to the vertebrae (5). Lower back extensor muscles play an important role in dynamically controlling the moving segments (5). While each of the local paraspinal muscles promote spinal stability, the multifidus alone is the cause of more than two-thirds of the stiffness with sagittal plane movements when the local paraspinal muscles are contracted (4). The synergistic contractions of the multifidus and deep abdominal muscles function as a dynamic corset for the lumbar vertebrae (3). These muscles increase spinal stiffness via elevated intra-abdominal pressure because of tensioning the lumbar spine, generating a posterior shear force against the lumbar spine, decreasing the compliance of abdominal contents, or indirectly increasing the thoracolumbar fascia tension (6). Intra-abdominal pressure impresses spinal stability by producing an extensor moment and applying force down on the pelvic floor as well as up on the diaphragm (7).

Poor spinal and abdominal muscle control can be seen among individuals with chronic LBP (8-10). Supporting such view, individuals with chronic LBP showed delayed timing of onset as well as the loss of continuous muscle contraction as the spinal stabilizing muscles are activated (11, 12). The finding that individuals with LBP appear to have altered timing of feed-forward onset of transverse abdominal gives support to the presence of a motor control dysfunction (11, 13). Such a dysfunctional pattern can be inferred to correspond to less than optimal core stability (14). Furthermore, the multifidus inhibition and atrophy have been found in patients with LBP (5, 15, 16). In such individuals, trunk muscle strength and endurance are frequently diminished (17). The lumbar multifidus and the transverse abdominal were impaired in patients with chronic LBP (1). The lumbar multifidus showed greater fatigability than other parts of the erector spinal muscle in these patients compared with that in normal people (18). Mannion *et al.*, attributed the paraspinal muscles weakness to histo-morphological and structural changes caused by type II muscle fiber atrophy as a result of disuse and deconditioning (19).

Despite the seriousness of the problem, how to treat chronic LBP is one of the most difficult concerns in clinical medicine, as no approach to diagnose nor any form of treatment has been proved to be clearly definitive or effective (20).

Active rehabilitation should include a problem management approach to deal with chronic LBP (21). Core strengthening has become a major trend in rehabilitation of chronic LBP. Core stability muscle training on the vibration/acceleration programs must be investigated as a means to improve overall patient management for this condition via rehabilitating the abdominal 'corset' and stabilizing symptomatic hyper mobile segments of the lumbar spine in people suffering from LBP (21).

The whole body vibration (WBV) as a form of vibration therapy is a relatively new mode of training. Nevertheless, little research has been done concerning the impact of WBV training on selected dependent variables, such as spinal and abdominal muscle endurance among chronic LBP patients. Part of the significance of the present study is in bridging the gap in documented evidence.

The aim of the present study was to investigate whether core stability exercise with dynamic WBV can be used as a more effective form of core muscle stabilization in chronic LBP sufferers with regard to core muscle endurance and activation. Thus, the study aims at testing the main hypothesis that the core stability exercise with WBV would be more efficient than conventional stabilization exercise in improving the trunk muscle endurance in chronic LBP patients.

Methods and Materials

The present randomized controlled clinical study was conducted at Shahid Beheshti University of Medical Sciences, Tehran, Iran, in 2013. The research sample included a total of 30 patients (18 males and 12 females) who had been diagnosed with non-specific chronic LBP. The participants were randomly divided into two groups of 15, an exercise group and an exercise plus WBV group.

Both groups were exercised three times a week, for two weeks with at least 1-day break between any 2 consecutive sessions. The participants were asked to report any adverse events.

The present study was a randomized, clinical trial conducted at the Physical Therapy Research Center (PTRS) of Shahid Beheshti University of Medical Sciences, Tehran, Iran. Approval for the study was obtained from the PTRS Research Ethics Sub-Committee (SBMU.REC.1392.545).

The inclusion criteria required that all the participants should have been diagnosed with symptoms of nonspecific LBP and should have been experienced continuous or intermittent symptoms of LBP for at least three months prior to the study. They were selected from the patients aged between 20-45 years of with a 3-5 score on visual analog scale. Besides, they should not have shown any signs of spinal tumors or metastases, recent fractures of the axial skeleton, inflammatory disease of the spine, progressive neurological defects, heart disease, recent abdominal surgery during the past two years, hip or knee endoprothesis or metal implants, recent venous thrombosis, pregnancy, epilepsy, diabetes, chronic migraine, gallstone, renal stone, and balance problem. They should not have been athletes, either.

The exclusion criteria were vertigo, paresthesia, heart rate increase, pain severity increase, nausea, anxiety, and blurred vision during the treatment period, inability to tolerate the vibration, and unwillingness to cooperate. Patients who undertook any type of medication during the study and those with a body mass index (BMI) of greater than 25 kg/m^2 were excluded.

Both groups received assessment screening prior to, midway, and two weeks after the intervention.

The participants' abdominal muscle endurance was evaluated using the Stabilizer Pressure Biofeedback Unit (PBU, Chattanooga Group INC. Alixon TN 37343. USA). The pressure biofeedback unit was a simple pressure transducer with a three-chamber air-filled pressure bag allowing body movement, especially spinal movement, to be detected during exercise, a catheter, and a sphygmomanometer gauge. The pressure bag was 16.7-24 cm in size and made from inelastic material. The sphygmomanometer had a range of 0-200 mmHg, with 2-mmHg intervals on the scale. Changes in the body position alter the pressure, and was measured and recorded by the sphygmomanometer (10).

To measure transverse abdominal and internal oblique muscle endurance, the pressure cell was positioned centrally below the abdomen, while the umbilicus was in the center of the inflatable sleeve and the distal edge at the anterior superior iliac spine of the participants, who were in prone position. The pressure cell was inflated to 70 mmHg. Then, the patient was asked to draw the abdominal wall up and in without any movement in the spine or pelvis. The pressure decreased by 4-10 mmHg and contraction time was measured by a stopwatch (10).

The same procedure was repeated to assess transverse abdominal muscle endurance with the difference that the

Table 1. Demographic characteristics of patients

	WBV Group			NWBV Group		
	Mean (SD)	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**
Age (yr)	27.13 (4.94)	20	37	28.13 (5.64)	20	40
Height (cm)	166.47 (4.94)	153	188	167.53 (7.20)	155	180
Weight (kg)	61.53 (11.12)	50	85	62.47 (8.71)	49	76
BMI(kg/m^{2})	22.07 (1.80)	17.30	24.38	22.14 (1.76)	17.73	24.18

Table 2. Descriptive indices: The percentages of the changes of multifidus muscle endurance in the two groups

	WBV Group		NWBV Group	
	Mid. test-Pre test	**Post. test-Pre test**	**Mid test-Pre test**	**Post. test-Pre test**
Mean (SD)	178.48 (58.39)	475.28 (160.45)	173.04(81.19)	335.97 (173.54)
Min	73.33	246.15	68.97	130.61
Max	256.41	800.00	354.17	680.00

Table 3. Descriptive indices: The percentages of the changes of abdominal muscle endurance in prone and supine positions in the two groups

	Transverse abdominal				Transverse abdominal & internal oblique			
	WBV group		**NWBV group**		**WBV group**		**NWBV group**	
	Mid-pre	Post-pre	Mid-pre	Post-pre	Mid-pre	Post-pre	Mid-pre	Post-pre
Mean (SD)	85.64 (49.22)	182.9 (124.25)	94.59 (142.31)	159.47 (223.41)	60.85 (65.94)	130.66 (107.26)	57.69 (65.72)	108.28 (121.40)
Min	24.47	50.36	16.28	48.24	9.38	24.29	17.69	26.16
Max	168.70	466.96	506.06	875.76	280.36	421.43	223.26	402.33

pressure biofeedback unit was placed below their lumbar region, with the distal edge at the posterior superior iliac spine while the patient was in supine position. The depression of the abdominal muscles over the device decreased the pressure by 2 mmHg. The time was recorded using a stopwatch [11].

The Sorensen test was run to measure multifidus muscles endurance. To this end, the patient lied prone on plint, keeping upper half body (from anterior superior iliac spine) out of the mat. The patient was requested to keep the upper body in a horizontal alignment while firmly strapping to the table over the pelvis, thigh, and lower leg. The participant's maintenance time in this position was measured. Postural awareness and correct technique were controlled during every exercise session (22).

Whole Body Vibration Group:

To implement the treatment program, the vibration frequency was kept constant at 25 HZ per exercise and the exercise intensity was increased for every two sessions by increasing the time. The vibration time was set at 30 s initially and then increased 15 s per two sessions. Cooling down through stretching exercises was performed at the end of each session. The power plate set out to peak-to-peak amplitude of 1-3 mm (low amplitude) of vertical vibration. The exercises were supervised closely by a physiotherapist. Besides, the positions were (1) abdominal crunch, (2) bridging, (3) modified side bridge, (4) all fours superman, (5) modified superman, (6) one arm superman, and (7) lower abdominal.

Spinal Stabilization Group:

All the exercises were the same as those performed by the WBV Group, but they were performed without the vibration. Progression was applied by increasing the number of sets and repetitions for every two sessions. During the first two sessions, all exercises were carried out with 8 repetitions, in the second session, all exercises were done at 2 sets with 8 repetitions, and in the last two sessions all the exercises were performed at 3 sets with 10 repetitions.

Statistics

The collected data was entered into and analyzed by SPSS (v. 20) (Chicago, IL, USA). After checking the normal distribution of data by Shapiro-Wilk test, the baseline demographics and measures were compared for two treatments using independent samples t-test to ensure that they were equivalent prior to the intervention. Repeated measures ANOVA was also run to measure the treatment effect in each group and to compare the treatment effects for the two groups. A P-value of $P<0.05$ was considered as statistically significant.

Results

The demographic variables of the patients are shown in Table 1. The percentages of the changes of multifidus muscle endurance showed that there was a statistically significant difference between the two treatment groups ($P<0.05$). The vibration group showed a greater rate of increase than the non-vibration group in comparison to the baseline. A significant multifidus * group interaction effect ($P=0.017$) signified a statistically significant treatment effect of WBV in comparison with the baseline. Descriptive data of percentages of the changes of multifidus endurance is given in Table 2.

The percentages of the changes of prone and supine time, showed no statistically significant difference between the two treatment groups in comparison to the baseline. Although the values calculated were not statistically significant, the graphical representations in Table 3 illustrate the observable increase in abdominal endurance between the mid and pre-test as well as between the post and pre-test in WBV group in comparison with that in the non-WBV group.

Table 3 shows that the direction of this change increased in both groups. However, there was no difference between the two treatments over time in comparison with the baseline, as they both increased at the same rate. No statistically significant prone*group (P=0.955) and supine*group (P=0.372) interaction effect were observed. The vibration group showed a greater rate of increase in supine time compared with that in the non-vibration group in comparison to the baseline; however, this difference was not statistically significant (Table 3).

Discussion

Chronic LBP is viewed internationally as a main issue in the field of rehabilitation due to its high prevalence rates (17). Evidence from the literature suggests that individuals with chronic LBP come up frequently with impaired trunk muscle strength and endurance resulting in functional disability in their daily activities (23).

As such, the aim of the present study was to investigate and compare the potential effects of core stability exercise with WBV versus core stability exercises on trunk muscle endurance in patients suffering from non-specific chronic LBP over a two-week period.

Clinicians often prescribe stabilization exercises for patients with LBP under the assumption that these exercises reduce transverse abdominal and lumbar multifidus muscle impairments. Therefore, the clinical improvements after the application of this therapy are often attributed to enhanced muscle function (24). In the present study, inter-group analysis indicated that except for significant improvements concerning changes in multifidus muscle endurance for the vibration group over the non-vibration group, other outcome measures such as changes in the abdominal muscle endurance in supine and prone positions did not show any statistically significant differences. These findings are in line with Torabi *et al.*'s, who found that multifidus muscle endurance showed a statistically significant difference between the two treatments (23). It was also noted that the vibration group showed more improvements than the non-vibration group. Support for multifidus musculature endurance gains was also found in various studies, due to the participation in WBV intervention program (17, 23). The authors showed that vibratory waves irritated the primary endings of the muscle spindle that activated a larger fraction of the motor neuron pool and recruit previously inactive motor units into contraction, thus leading to the more efficient use of the force production potential of the muscle groups involved. The motor neuron pool activation mechanism was further reinforced during WBV by recruitment of previously inactive motor neurons, together with their activity synchronization, and increased discharge of the neutral drive leading to greater improvements in neuro-motor control during voluntary muscle contraction (17, 20). Most researchers argue that vibration can improve strength, muscle endurance, power, and flexibility, but they agree that these changes are likely to result from the vibration on the proprioceptive receptors in the muscles (25). In addition, a close relationship was found in a study between activation of joint mechanoreceptors and stimulation of the gamma efferents (to sensitize the spindles), resulting in the increased muscle 'stiffness' and joint stability. This may also be of great help in understanding the complex way that WBV may enhance proprioception (25).

Direct muscle vibration has been proved to have interesting effects on the proprioceptive system and stability [4, 20]. Lamis and Wilson showed vibration-triggered changes in proprioception in the LBP during exposure to direct paraspinal muscle vibration (26). The performance of proprioception and kinesthetic sense exercises is needed to stimulate joint receptors and to re-establish normal muscular firing patterns imperative for functional activity (27).

The reason why WBV showed a statistically significant difference in multifidus endurance over spinal stabilization alone can be attributed to the WBV effects on proprioception. Smaller cross-sectional area and moment arm of lumbar multifidus muscle in comparison to transverse abdominal play a more proprioceptive role for these muscles. Furthermore, the multifidus muscle alone is responsible for more than two-thirds of the increased stiffness with sagittal plane movements, which accentuate this role (4).

Previous studies also demonstrated improvements in motor control and physical condition (e.g., strength, endurance, power, and balance) because of proprioceptive effect of vibration (28). To sum up, the WBV affects multifidus muscle endurance more effectively than abdominal muscle because of its greater proprioceptors amount indirectly affecting muscle endurance.

These results were reported in our previous study published in the Journal of Paramedical Science in 2013 which showed a statistically significant difference between the two treatments in terms of multifidus muscle endurance.

Conclusion

Except for the significant increase in the multifidus muscle endurance in the vibration group over the non-vibration group, a slight difference was noticed regarding the vibration-training group. However, it was not adequate to conclude that vibration training was more effective than core muscle exercises alone.

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All authors made substantial contributions to conception, design, acquisition, analysis and interpretation of data.

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