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Original Article

Comparing the effectiveness of flexi-bar and stability exercises on postural control in chronic nonspecific low back pain: A randomized controlled study

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ABSTRACT

Objectives: This study aimed to compare the effect of flexi-bar and stabilization exercises on static and dynamic postural control in patients with chronic nonspecific low back pain.

Patients and methods: In this randomized controlled study conducted between November 2019 and March 2020, 38 patients (19 males, 19 females; mean age: 33.8±6.2 years; range, 20 to 45 years) were randomly assigned into flexi-bar (n=19) and stabilization (n=19) groups. Both groups received general physiotherapy for three sessions per week, a total of 10 sessions. Besides, the flexi-bar group received flexi-bar exercises, and the stabilization group received stabilization exercises. Postural sway was assessed with a force platform in three difficult conditions, including open eye, close eye, and one-leg standing and dynamic posture with the modified Star Excursion Balance Test.

Results: After the intervention, both groups showed a significant improvement in static and dynamic postural control ($p<0.05$). However, no significant differences were found between groups after treatment, while only the phase-plane portrait of opened eyes condition was significantly improved ($p=0.03$), in the flexi-bar group compared to the stabilization group.

Conclusion: Both flexi-bar and stabilization exercises effectively improved static and dynamic postural control, but none of the exercises was superior to the other. Flexi-bar is recommended as an effective tool in low back pain rehabilitation.

Keywords: Neuromuscular training, non-specific chronic low back pain, postural control, stabilization exercise, vibratory stimulation.

It is well known that low back pain (LBP) put a heavy burden on patients budgets and health systems.[1-5] Studies show that 85% of LBP cases are nonspecific, which means that there is no structural problem in the spine.[2,3,6,7] Nonspecific chronic LBP (NCLBP) has more adverse effects on the social and individual life of patients due to pain and functional disability.[8] Patients with LBP have instability in the spine due to pain and muscle weakness. These patients use rigid strategies for postural control.[6,9,10] During different daily activities, suitable trunk muscle activation is necessary for spinal stability.[6] Among physical therapy methods, exercises are more effective.[11-14] The advantages of stabilization exercises are muscular coordination and cocontraction, in addition to muscle strengthening.[13,15-17] Gomes-Neto et al.[18] demonstrated that stabilization exercises are as efficient as manual therapy in reducing pain and disability. Recently,

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vibratory stimulation has been recommended for neuromuscular training. Applying vibrations on an active muscle can lead to altering the excitation level of the primary afferent (Ia) terminals of muscle spindles. They change neuromuscular patterns and result in the activation of alpha-motoneurons.[19-21] Vibration stimulations are perceived by muscle spindles, skin, joints, and secondary terminals. These structures facilitate the gamma system due to the increasing sensitivity of Ia terminals.[19,22] Flexi-bar is a new vibratory device that is currently receiving attention. It is an adjustable elastic bar with two oscillatory poles beside a diameter of about 0.7 mm and a length of 1.5 m, which can produce vibrational excitations at a low frequency of 5 Hz. While shaking the flexi-bar, the active motion of the elbow transfers oscillatory forces through the body. The prerequisite of upper extremity movement is trunk stability;[23] with this aim, global and local muscles act automatically to control the trunk.[10,24] Therefore, this portable and economical device is useful in LBP rehabilitation. However, it is unclear which therapeutic exercise is more effective in the postural control rehabilitation of patients with NCLBP. We hypothesized that both exercise programs lead to functional changes in postural control. Therefore, this study aimed to compare the effect of flexi-bar and stabilization exercises on static and dynamic postural control in patients with NCLBP.

PATIENTS AND METHODS

This randomized controlled study was conducted at the physical therapy and rehabilitation clinic of Shahid Beheshti University of Medical Sciences between November 2019 and March 2020. Inclusion criteria were as follows: local pain in the lumbar spine (between the first lumbar vertebra and gluteal fold), chronic or repeated pain for more than three months, and age between 20 and 45 years. Patients who had undergone spinal, upper, or lower extremities surgeries and those who had neurological, orthopedic, and vestibular disorders, cardiovascular or respiratory diseases, diabetic neuropathy, and a body mass index >25 were excluded. Of 42 eligible patients, two patients were excluded from the study due to lack of inclusion criteria, and two patients were excluded from the study due to unwillingness to continue treatment. Finally, 38 patients (19 males, 19 females; mean age: 33.8±6.2 years; range, 20 to 45 years) with NCLBP were randomly assigned into two groups (flexi-bar group [n=19] and stabilization group [n=19]). The allocation was achieved using numbered sheets (1=flexi-bar group, 2=stabilization group) inside sealed envelopes picked up by the participants before baseline data collection.

Static postural control

Static postural control of the participants was assessed by a physiotherapist before and after 10 physiotherapy sessions. Postural sway was assessed with a 600×400 mm force plate (Bertec, Leeds, UK). A foam (60×40×10 cm; density: 35 kg/m^3) was used on the force plate. Postural sways were examined in three difficult situations, including standing on the foam with the eyes open (EO) and closed (EC) and standing on the foam with the EO on the preferred leg (the leg that the patient prefers to shoot a ball). The duration of each evaluation was 20 sec with a 1-min rest interval. If the participant remained in the position for the entire time, the test was considered valid. Each trial was repeated three times. Finally, their average was calculated. All patients were trained to familiarize themselves with the test conditions before the preliminary test. Participants stand with their legs separated by their hip width, the arms at the side, and shoulders relaxed. For the EO condition, we placed a point approximately 5 m ahead on the wall, and the participant had to look at this point. For the EC condition, the participant closed their eyes. Postural sway data were sampled at 1000 Hz and a low-pass filter with a frequency cut-off range of 10 Hz. A custom MATLAB program was used for data reduction.

Dynamic postural control

Dynamic postural control of the participants was assessed by a physiotherapist before and after 10 physiotherapy sessions. The dynamic postural control was evaluated using the modified Star Excursion Balance Test (mSEBT). The mSEBT includes three directions: anterior, posteromedial, and posterolateral directions. First, the test was explained through demonstrative instruction. In this way, the participant should place the preferred foot in the center of the "star," then reach as far as possible with the nonstance leg, place the big toe to the marked tape, and return to the starting position. During the test, the arms should be at the side, and the heel of the preferred foot should be in full contact with the ground. The amount that the participant could touch without disturbing the balance was measured with a meter. Each direction was repeated three times, and the average was calculated.

Intervention

First, both groups received 20 min of general physiotherapy by a physiotherapist, including

transcutaneous nerve electrical stimulation, infrared, and ultrasound. Afterward, both groups performed a warm-up period (four stretching exercises) at the beginning of every session. The participants commenced their exercises with simple movements and progressed to more challenging exercises. The participant was allowed to go to the next stage if the previous stage was fully performed and according to the relevant protocol. Finally, both groups performed a cool-down period (four stretching exercises) at the end of every session. Exercises were performed under the supervision of a physiotherapist in the clinic. The frequency of exercise for both groups was three sessions per week for a total of 10 sessions. The participants were instructed to perform their exercises as much as they could. However, the net exercise time was defined as 20 min for each group, with variances depending on the participant's ability.

Flexi-bar exercise program

Before the main experiment to familiarize participants with the flexi-bar device, a practice was conducted. Participants should always hold the flexi-bar from its center with a relaxed grip. In other words, they should not squeeze it. The flexi-bar exercises should be done with as little trunk movement as possible. Participants performed each flexi-bar exercise for 30 to 60 sec and rested for 90 sec, but the swing duration was dependent on the fitness level of the participants. The flexi-bar exercises comprise eight programs (Table 1).

Stabilization exercise program

First, low-intensity isometric contraction of transverse abdominis in simple positions was explained to participants. Then, dynamic activities were combined with the contraction of the transverse abdominis muscle. Each exercise was held 10 times for 10 sets to make the number of times and sets identical. The stabilization exercises comprise six programs (Table 1).

Outcome measures

In this study, phase plane portrait related to static postural control was considered as the primary outcome measure. The amount of displacement in anterior, posteromedial, and posterolateral directions related to dynamic postural control were considered secondary outcome measures.

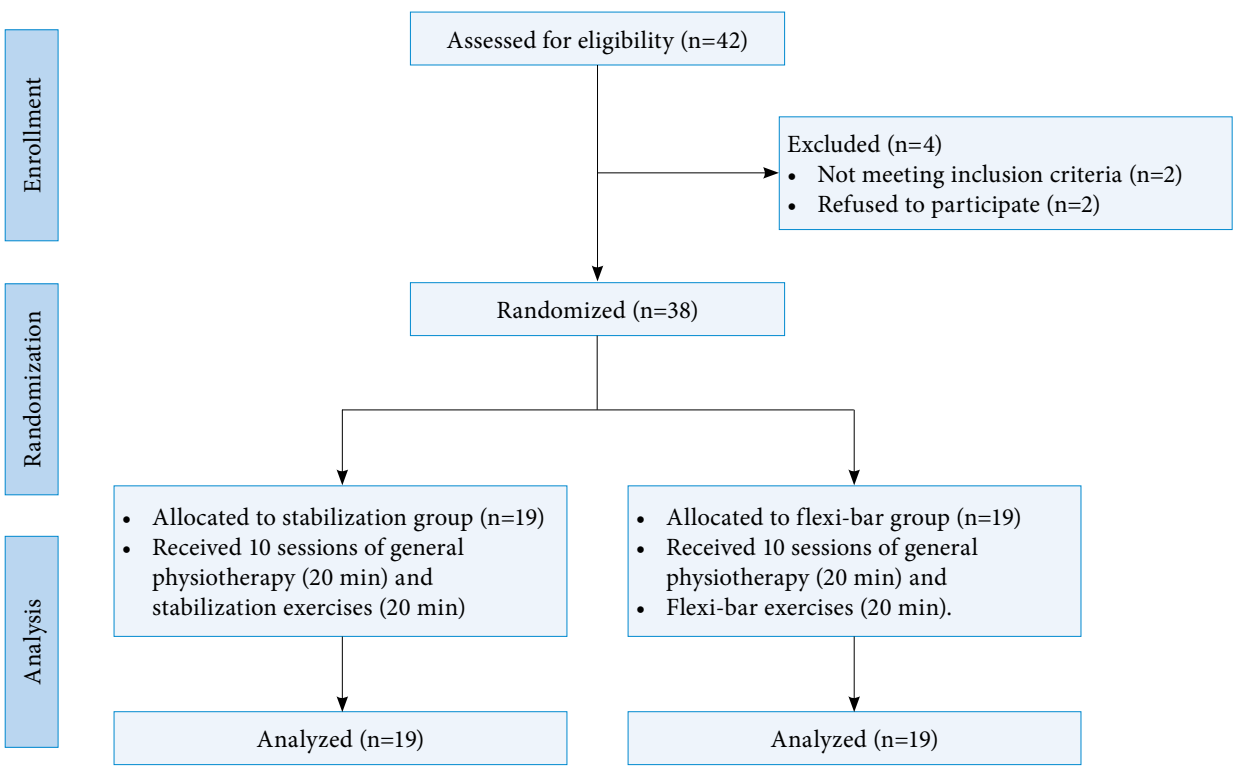


Figure 1. Study flowchart.

Statistical analysis

The sample size was calculated using G power 3.1.4 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) based on a pilot study that included 10 participants (five participants in the flexi-bar group and five participants in the

TABLE 1
Exercise programs

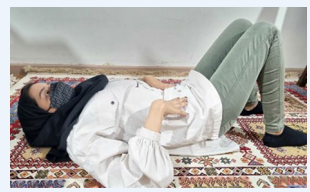
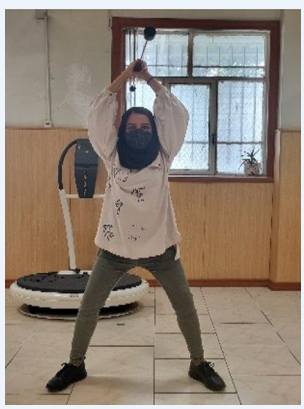
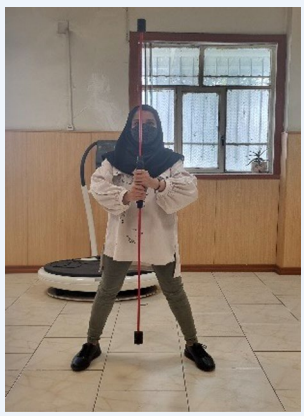
Flexi-bar exercises		Stabilization exercises	
Chest & back: Stand with your legs separated by your shoulder width. Grasp the handle from above, in front of your body; then, swing it forward and backward (30-60 sec).		**Abdominal drawing-in at the supine position:** Lie on your back with your knees bent. Squeeze your stomach muscles without pressing your back flat to the floor. Hold for 10 sec, counting aloud to avoid holding your breath. Ten repetitions.	
Lower back & chest: Stand in a squat position with your knees and toes pointing outward, lean your upper body forward, and keep your back straight. Grasp the handle from above; then, swing it up and down in the direction of the floor (30-60 sec).		**Abdominal drawing-in with heel slides:** Lie on your back with your knees bent as in the previous exercise. While tightening your stomach muscles (abdominal drawing-in), slide the heel of one foot away from you until your knee is straight (3 sec count). Then, slide your heel back until your knee is in its original bent position (3 sec count). Relax and repeat on the opposite leg. Ten repetitions for both legs.	
Deep back extensors: Stand in a squat position with wide legs and hold the flexi-bar above your head with extended arms; then, swing it up and down (30-60 sec).		**Abdominal drawing-in with bridging:** Lie on your back with knees bent. While tightening your stomach muscles (abdominal drawing-in), tighten your buttocks and slowly lift them off the floor. Do not allow your back to arch. Hold for 10 sec. Ten repetitions.	
Bottom: Stand in a deep squat position and grasp the flexi-bar with both hands from above; then, raise both arms to head height and swing it forward and backward (30-60 sec).		**Abdominal drawing-in with single leg bridging:** Lie on your back with knees bent. While tightening your stomach muscles (abdominal drawing-in), tighten your buttocks and slowly lift your buttocks off the floor; then, straighten one knee so that only one foot is on the floor. Hold for 10 sec. Ten repetitions.	

TABLE 1
Continued

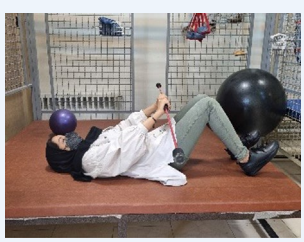
Flexi-bar exercises

Core muscles:
Stand with your legs more than your shoulder-width apart, hold the flexi-bar vertically and in front of your body; then, swing it from left to right (30-60 sec).

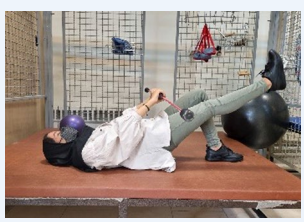


Multifidi (deep vertebral stabilizing muscles):
Stand in the wide-leg squat position, hold the flexi-bar from above and bring your extended arms up to chest height; then, swing it up and down (30-60 sec).

Torso musculature:
Lie on your back with your knees bent and place your heels on the floor. Hold the flexi-bar with extended arms; then, swing it forward and backward, parallel to your thighs (30-60 sec).



Bottom (glutes):
Lie on your back with your knees bent. Tighten your buttocks and slowly lift your buttocks off the floor; then, straighten one knee so that only one foot is on the floor. Grasp the handle from above, extend your arms completely; then, swing it forward and backward, parallel to your thigh (30-60 sec).



Stabilization exercises

Bird-dog exercise:
Start on your hands and knees. Tighten your stomach muscles. First, lift your right arm from the table. Hold for 10 sec. Return to the starting position and repeat it for the left arm. Second, tighten your stomach muscles and then extend your right leg so that your knee is lifted from the table. As you do this, keep your hips level with the table. Hold for 10 sec. Return to the starting position and repeat for the left leg. After that, tighten your stomach muscles and extend your right leg so that your knee is lifted from the table, and lift your left arm from the table at the same time as you do this; keep your hips level with the table. Hold for 10 sec. Return to the starting position and repeat with the left leg and the right arm. Ten repetitions.

Supine dead bug:
Lie on your back with the hips and knees at 90 degrees flexion and the arms at 90 degrees flexion. First, perform an abdominal drawing-in maneuver and maintain it throughout the exercise. Then raise the right arm above the head and flatten it completely. At the same time, raise and flatten the left leg to the ground, then return to the starting position and repeat this exercise for the left arm and the right leg. Ten repetitions.

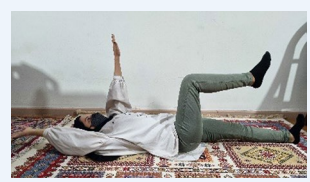


TABLE 2
Baseline demographic characteristics of study population

Variables	Stabilization group (n=19) Mean±SD	Flexi-bar group (n=19) Mean±SD	*p*
Age (year)	32.4±7.6	35.2±5.6	0.18
Height (cm)	174.3±12.4	171±7.04	0.32
Weight (kg)	72.4±11.4	68.5±7.7	0.23
Body mass index (kg/m^2)	23.7±0.9	23.4±1.6	0.48

SD: Standard deviation.

stabilization group) with the same inclusion and exclusion criteria. In this pilot study, phase plane portrait in the anteroposterior–mediolateral position was considered the primary outcome measure, which assessed static postural control. Accordingly, with an effect size of 0.89, the statistical power and statistical level of significance for the present study were set at 0.9 and 0.05, respectively. The sample size for each group was determined as 19 with a power of 90%.

Data were analyzed using IBM SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to report the baseline demographics and characteristics (Table 2). For analytical statistics, first, the normality of the data was confirmed using the nonparametric Kolmogorov-Smirnov test. Second, an independent-sample t-test was used to assess any significant differences between the two study groups in demographic characteristics and baseline values of dynamic and static postural control (Table 3). Third, a paired t-test was used to assess static and dynamic postural control in the flexi-bar and stabilization groups before and after treatment (intragroup study). Finally, based on the comparison of the baselines, some variables were different in the two groups, and in those that did not differ, the difference in the mean was large. The analysis of covariance was used to adjust primary differences and more accurately compare the two groups and examine the effect of the intervention (intergroup study; Table 3). The significance level was considered $p<0.05$ for all comparisons.

RESULTS

There was no statistically significant difference between the groups for age, height, weight, and body mass index ($p>0.05$, Table 2). There were no significant statistical differences in demographic characteristics between groups on entry to the trial except for the mean total velocity of EO ($p=0.005$) and phase plane portrait of EO ($p=0.02$, Table 3).

After the intervention period, the paired t-test analysis showed a significant reduction in mean total velocity ($p<0.05$) and phase plane portrait ($p<0.05$) of all conditions (EO, EC, and one-leg standing) and significant increases in mean reach distances of the anterior, posteromedial, and posterolateral directions ($p<0.05$) within each group (Table 3).

However, no significant differences were found between the flexi-bar and stabilization groups in mean reach distances of mSEBT ($p>0.05$), mean total velocity of all conditions ($p>0.05$), and phase plane portrait of EC and one-leg standing ($p>0.05$). However, the flexi-bar group did significantly better in phase plane portrait of EO condition compared to the stabilization group ($p=0.03$, Table 3).

DISCUSSION

The purpose of the study was to compare the efficacy of flexi-bar and stabilization exercises on postural control in NCLBP. To our knowledge, this is the first study to examine the efficacy of flexi-bar and stabilization exercises on static and dynamic postural control in people with NCLBP.

In comparison with healthy subjects, people with NCLBP showed a poor mSEBT performance due to limited anterior pelvic tilt and pain.[25] Suitable activation of core muscles is required before limb movement to perform a good mSEBT. This anticipatory activation is reduced in individuals with NCLBP and results in poor mSEBT performance.[26-28] Therefore, in a therapeutic exercise regime, preventive contraction of the transverse abdominis and multifidus muscles can improve the prediction of lower limb movement in mSEBT.[29,30] Additionally, therapeutic exercise can reduce pain due to a synergistic effect of improving

the strength of the muscles.[31] In the present study, the dynamic postural control was significantly improved in both groups after 10 treatment sessions. However, there was no significant difference between the flexi-bar and stabilization groups. Our results support those of Yalfani et al.,[29] Park et al.,[31] and Sierra-Guzma´n et al.[32] Sierra-Guzma´n et al.[32] reported that whole body vibration training displayed better performance on the mSEBT in athletes with chronic ankle instability after six weeks. Vibratory exercises can be effective in neuromuscular control in addition to muscles strengthening.[33] Park et al.[31] reported that flexi-bar exercises were more effective than sling and ball exercises in improving dynamic posture in patients with CLBP.

Another purpose of the present study was to examine the efficacy of flexi-bar and stabilization exercises on static postural control of people with NCLBP. According to our results, static postural control of both groups significantly improved after 10 treatment sessions. However, no significant differences were found between groups after treatment, while only the phase-plane portrait of the EO condition was significantly improved in the flexi-bar group compared to the stabilization group.

Postural disorders may be due to poor coordination of the back muscles and disturbances in the peripheral proprioceptive system.[30] In this connection, it was reported that inputs from muscle afferents lead to adaptive changes in postural control. One interesting finding of the present study was that the flexi-bar exercises had higher improvement in phase plane portrait of EO condition than stabilization exercises. This improvement is more likely since flexi-bar vibrations destabilize the support surface, increasing the activity of the muscles around the spine and the abdominal muscles to maintain posture.[34] The results are in agreement with those of Lee et al.,[35] who reported the effectiveness of flexi-bar exercises on the improvement of center of pressure displacement in healthy individuals.

According to Bogaerts et al.,[36] vibratory stimulation excites the muscle spindles and strengthens the muscles through proprioception improvement. Additionally, Moreside et al.[24] state that flexi-bar exercises improve torso stability by activating deep muscles. It is noteworthy that Stevens et al.[37] concluded that the contraction of the external trunk muscles occurs to maintain the stability of the trunk and block the displacement of the spine and pelvis on an unstable surface. This block dramatically

TABLE 3
Comparison of outcome measures

	Stabilization group (n=19)				Flexi-bar group (n=19)						
	Before	After			Before	After					
Variables	Mean±SD	Mean±SD	p*	Difference	Mean±SD	Mean±SD	p*	Difference	p**	p***	Effect size
Mean total velocity of EO (mm/s)	46.7±11.4	36.6±6.2	<0.001	-10.06±7	37.3±7.7	33.2±6.9	0.001	-4.11±4.28	0.005	0.22	0.04
Mean total velocity of EC (mm/s)	62.6±13.9	55.4±15.04	<0.001	-7.18±5.79	65.1±24.4	58.1±18.3	0.04	-6.96±15.94	0.70	0.76	0.003
Mean total velocity of one-leg standing (mm/s)	114.3±15.01	98.8±19.6	<0.001	-15.49±6.76	108.6±23.9	95.7±23.6	<0.001	-12.92±9.03	0.39	0.33	0.03
Phase plane portrait of EO (arbitrary unit)	30.1±6.6	24.3±4.1	<0.001	-5.84±3.17	25.6±4.4	22.8±4.3	<0.001	-2.75±2	0.02	0.03	0.13
Phase plane portrait of EC (arbitrary unit)	40.8±8.7	36.1±9.8	<0.001	-4.64±3.63	43.03±14.6	37.9±10.8	0.04	-5.03±9.75	0.57	0.87	0.001
Phase plane portrait of one-leg standing (arbitrary unit)	74.7±7.8	61.3±12.9	<0.001	-13.46±8.72	69.8±11.6	61.3±11.9	<0.001	-8.50±5.88	0.13	0.06	0.10
mSEBT in the anterior direction (cm)	78.9±11.1	94.7±13.8	<0.001	15.66±9.84	84.8±12.6	93.3±11.9	0.002	8.59±10.26	0.14	0.10	0.08
mSEBT in the posteromedial direction (cm)	82.8±13.6	88.3±16.5	<0.001	5.50±5.64	84.6±13.9	89.1±13.4	0.009	4.52±6.71	0.69	0.64	0.006
mSEBT in the posterolateral direction (cm)	64.3±16.3	72.4±21.3	<0.001	8.12±7.79	71.2±8.2	81.9±9.3	<0.001	10.66±5.97	0.11	0.54	0.01

SD: Standard deviation; EO: Eyes open; EC: Eyes close; mSEBT: Modified star excursion balance test; * Based on paired sample t-test for within groups comparisons; ** Based on independent-sample t-test between groups for baseline variable comparisons; *** Based on ANCOVA for between groups comparisons.

prevents deep muscle activity, such as multifidus and erector spine. However, according to the findings of Kim et al.,[34] the combination of flexi-bar with bridging exercise makes the erector spine muscles more active than bridging exercise, which means that both superficial and deep muscles are involved in flexi-bar training. Bervis et al.[6] state that vibrations of flexi-bar are transferred to the whole body from the upper extremity to the lower extremity. In this study, muscle electromyography activity showed that the flexi-bar leads to muscle activation of the trunk, hip, and ankle for postural control. Lim[38] showed that flexi-bar exercises in quadruped and sitting positions cause more internal oblique muscle activity than rigid bar exercises in quadruped and sitting positions. The internal oblique muscle is crucial in spinal stability as this muscle is combined with the thoracolumbar fascia and located deeper than the external oblique muscle.[38] Furthermore, Chung et al.[39] reported that flexi-bar oscillations in standing, quadruped, and side-bridging positions resulted in the high activity of the internal oblique muscle. Goncalves et al.[10] also reported that the internal oblique muscle in flexi-bar exercises is 72% more active than in other exercises. Therefore, flexi-bar exercises are more effective in stabilizing trunk muscles than stabilizing exercises.

Other static postural control variables, such as phase plane portrait and mean total velocity, in EC and one-leg standing conditions did not significantly change between groups. This finding may be because we used foam to investigate changes in static postural control, and some conditions, such as EC and one-leg standing, make it much more challenging. Furthermore, the fluctuation of the surface under patients' feet reflects a dysfunction in the proprioceptive system.[40] On the other hand, in individuals with NCLBP, center of pressure displacement and velocity in challenging situation, such as EC and unstable surfaces, are increased.[26] Hence, in the future, it is recommended to use a longer course of treatment and add postural retraining exercises to the treatment program to precisely examine the effectiveness of flexi-bar and stability exercises on static postural control in NCLBP.

According to the results of this and the other studies, in brief, it can be concluded that based on the goals of treatment in different musculoskeletal disorders, a flexi-bar can be used to treat some disorders. More studies are needed to identify other indications/contraindications for use of the flexi-bar or other oscillatory devices.[41]

This study has several limitations. One limitation is the inability to generalize the results due to the small sample size in this study. Second, the lack of true blindness for the treating physiotherapist due to the nature of the interventions. Third, we did not evaluate the effect of exercise on muscle function in these patients. Future studies are needed to investigate the electromyography activity of muscles and better discuss and conclude the effectiveness of exercises in these patients. Finally, the long-term effects of these exercises cannot be predicted, and future studies with extended follow-up periods are required.

In conclusion, this study was carried out to compare the efficacy of flexi-bar and stabilization exercises on postural control of NCLBP. This study showed that both exercise protocols were useful in postural control improvement of NCLBP. However, one exercise was superior to the other. Although stabilizing exercises have many benefits, the need for the help of a therapist while exercising is one of the limitations of this type of exercise at home. Flexi-bar is safe with low amplitude vibrational excitations and can be used easily without any particular technique.

Ethics Committee Approval: The study protocol was approved by the Shahid Beheshti University of Medical Sciences Ethics Committee (date: 20.10.2019, no: IR.SBMU.RETECH.REC.1398.341). This study was registered in the Clinical Trial Center with no: IRCT20191015045122N1. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, design control/supervision: M.M.R.; Data collection and/or processing: Y.S.; Analysis and/or interpretation: A.A.B.; Literature review, writing the article: F.A.; Critical review: S.S.N.

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