

Effectiveness of whole-body vibration exercise and core stabilization exercise in chronic non-specific low back pain: A randomized-controlled study

Basak Cigdem Karacay¹, Tugba Sahbaz², Basak Gurtekin³, Safinaz Yildiz⁴, Emel Ozcan¹

¹Department of Physical Medicine and Rehabilitation, Istanbul University, Istanbul Faculty of Medicine, Istanbul, Türkiye

²Department of Physical Medicine and Rehabilitation, University of Health Science, Kanuni Sultan Süleyman Training and Research Hospital, Istanbul, Türkiye

³Department of Biostatistics, Istanbul University, Istanbul Faculty of Medicine, Istanbul, Türkiye

⁴Department of Sports Medicine, Istanbul University, Istanbul Faculty of Medicine, Istanbul, Türkiye

Received: July 14, 2020 Accepted: July 27, 2021 Published online: June 01, 2022

ABSTRACT

Objectives: The aim of this study was to investigate the effectiveness of whole-body vibration exercise (WBVE) and core stabilization exercise (CSE) on pain, muscle strength, and functional recovery in patients with chronic non-specific low back pain (NLBP).

Patients and methods: Between June 2016 and July 2017, a total of 74 patients with NLBP (12 males, 62 females; mean age: 44.7±8.9 years; range, 24 to 64 years) were included in this prospective, randomized-controlled study. The patients were randomly assigned to WBVE group (WBVEG, n=25), CSE group (CSEG, n=25), and home exercise group as the control group (CG, n=24). All groups performed 24 sessions of exercise for a total of eight weeks. Clinical outcome was measured using the Visual Analog Scale (VAS), Roland-Morris Disability Questionnaire (RMDQ), computerized isokinetic muscle strengths (IMS) and progressive isoinertial lifting evaluation (PILE) test.

Results: The VAS and RMDQ scores in WBVEG and CSEG statistically significantly decreased ($p<0.05$). The difference between the pre-treatment and at three-month VAS scores during intense activity were significantly different in both WBVEG and CSEG than the CG ($p<0.05$). The IMS values, except for the isokinetic flexion total work (IKFTW), increased significantly in all three groups ($p<0.05$). The IKFTW values increased significantly in the WBVEG and CSEG ($p<0.05$). A statistically significant increase in the functional work performance with PILE was observed in all three groups ($p<0.05$). The differences between the pre-treatment and three-month PILE test (ground to back and back to shoulder) were significantly different in both WBVEG and CSEG than the CG ($p<0.05$).

Conclusion: In the treatment of chronic NLBP, WBVE and CSE appear to be effective in pain and functionality. Although there was a significant improvement in muscle strength and functional work performance in all three groups, greater improvements were observed in the WBVEG and CSEG than the CG.

Keywords: Chronic non-specific low back pain, core stabilization, isokinetic muscle strengths, whole-body vibration.

Low back pain (LBP) is a significant public health issue worldwide.^[1] In patients with chronic LBP (CLBP), treatments such as exercise and education that actively involve the patient in the treatment are recommended.^[2] The key to conservative treatment of CLBP is exercise therapy. Many types of exercise

have been described in CLBP.^[3] Core stabilization exercises (CSEs) are based on the stabilization of key core muscles, including techniques for finding and maintaining the neutral position, the region where spinal movements encounter minimal resistance, and where movement can be performed

Corresponding author: Tuğba Şahbaz, MD. SBÜ Kanuni Sultan Süleyman Eğitim ve Araştırma Hastanesi Fiziksel Tıp ve Rehabilitasyon Kliniği, 34303 Küçükçekmece, İstanbul, Türkiye. e-mail: piskint@gmail.com

Cite this article as:

Karacay BC, Sahbaz T, Gurtekin B, Yildiz S, Ozcan E. Effectiveness of whole-body vibration exercise and core stabilization exercise in chronic non-specific low back pain: A randomized-controlled study. Turk J Phys Med Rehab 2022;68(2):184-194.

loosely and flexibly with minimal energy. Neutral zone must be stabilized to prevent back pain.^[4] Abdominal bracing is continued throughout the exercise. Motor control of local muscles is affected in individuals with LBP. The main goal of motor control exercises is to improve the local muscles. It is widely applied in the rehabilitation of mechanical LBP, disc herniation and postoperative patients.^[3,4] Whole-body vibration exercise (WBVE) is a novel treatment method. It is defined as a mechanical repetitive motion or oscillatory motion that occurs around a balance point and used to maintain or increase bone mineral density, preserve and increase muscle strength, improve balance and mobility, reduce the risk of injury associated with falls, reduce age-related articular cartilage damage, and increase tissue perfusion.^[5,6] The contact surface of the platform transfers a vibration to the total body. This vibration generates quick changes in muscle length, and the tension of the muscles is detected by proprioceptors and the tonic vibration reflex is activated. Tonic vibration reflex, in turn, provides periodic contraction and relaxation of muscles.^[6,7] The vibration limits for comfort, performance, and safety have been established by the International Organization for Standardization (ISO), taking into account the known work-related hazards.^[8] It is recommended to use frequencies between 20 and 70 Hz as a reliable range for WBVE.^[6] Side effects of WBVE are plantar fasciitis, itching in the legs, blurred vision, tinnitus, Raynaud's syndrome, orthostatic hypotension, dizziness, exacerbation of soft tissue and joint injuries, temporary fullness in the ear, headache, and intraocular lens dislocation that can be seen after cataract surgery. The WBVE is not recommended in the presence of kidney stones or gallstones, severe diabetes, arrhythmia, acute thrombosis or hernia, pregnancy, hypotension, intrauterine device, epilepsy, cancer, pacemaker, untreated orthostatic recent surgery, migraine, acute rheumatoid arthritis, and severe cardiovascular disease.^[6,9]

Chronic non-specific LBP (NLBP) is an important clinical, social, and economic health issue. There are few studies evaluating the effectiveness of CSE and WBVE in the treatment of chronic NLBP and different protocols are applied in these studies.^[10] In the present study, we aimed to compare the effectiveness of WBVE versus CSE on pain, muscle strength, and functional recovery in patients with chronic NLBP.

PATIENTS AND METHODS

Study design and study population

This single center prospective, randomized-controlled study was conducted at Istanbul University, Istanbul Faculty of Medicine Department of Physical Medicine and Rehabilitation between June 2016 and July 2017. Eighty four patients were included in the study. Ten patients dropped out during the study period and evaluations were made on 74 patients. A total of 74 patients (12 males, 62 females; mean age: 44.7 ± 8.9 years; range, 24 to 64 years) diagnosed with chronic NLBP were included in this study and randomized into three groups using a computer-based randomization program. The first group was given WBVE and classic lumbar home exercises (WBVEG, $n=25$). The second group was given CSE and classic lumbar home exercises (CSEG, $n=25$). The third group received only classic lumbar home exercises as the control group (CG, $n=24$). Study flow chart are delivered in Figure 1.

Interventions

The patients in the WBVEG applied 24 sessions of WBVE, three days a week (with minimum one day of rest between every session) under the supervision of a physiatrist for a total of eight weeks. Stretching exercises for 5 min, particularly for the quadriceps muscle and trunk extensor muscles, were performed before each vibration (warm-up program) and after each vibration (cooling program). The patients exercised in three different positions on the WBVE platform. In the initial exercise position, the knee angle was adjusted to 120° to abate the transmission of vibrations to the upper body (spine and head) and increase the load on the leg muscles. In the second position, the patients were statically positioned in the bridge position with both foot soles on the platform. In the last position, the patients were statically positioned in the push-up position, with both hands on the platform. All patients were taken to the platform with sports socks (without shoes) to avoid the shoe absorbing the vibration. The patients were not allowed to change positions during the vibration. The vibration was given by the Power Plate® (pro5TM; Power Plate North America, Inc., Northbrook, IL, USA) device where a three-plan oscillation took place. In all vibrations, a frequency of 25 Hz and 2 mm amplitude (low amplitude) were used. Vibration duration was increased at four weeks (Table 1). All patients in WBVEG were questioned about the side effects related to WBVE at the end of the program. The patients in

TABLE 1
Whole-body vibration exercise variables

Exercise position	Duration (sec) 0-4 weeks	Duration (sec) 4-8	Repetition	Frequency (Hz)	Peak (peak) Acceleration (g)	Amplitude (mm)	Rest time (sec)
Squat	30	60	2	25	3.6	2	30
Bridge	30	60	2	25	3.6	2	30
Push-up	30	60	2	25	3.6	2	30

the WBVEG were additionally given a classic lumbar home exercises and instructed to do it for a total of eight weeks.

A total of 24 sessions of CSE program was applied to the patients in the CSEG. The duration of the program was eight weeks and it was applied for three days a week (at least one day rest between each session). Each session was performed with an average of eight to 10 patients. It was set as a 35-min program, of which 5 min were to warm-up. Reducing lumbar lordosis by contracting and pulling the abdominal muscles before starting the exercise, the pelvis was moved forward and back to teach lumbar and pelvic neutral positions. Neutral position was established before each session and care was taken to maintain the neutral position throughout the exercise. The exercises consisted of three levels and were applied gradually. The patients in the CSEG were also given a classic lumbar home exercise program and instructed to do it for a total of eight weeks.

The patients in the CG received only a home exercise program. All participants received a written descriptive plan and explanation of the program. All exercises including pelvic tilt and exercises for abdominal strengthening flexion and extension (Williams-McKenzie) were shown by a physiatrist following an elaborate physical examination. The patients were advised to complete the exercises three days a week. The exercises were arranged as five repetitions in the first week, 10 repetitions in the second week, and 15 repetitions in the remainder of the eight-week program. The intensity of the exercises was increased to a level that the patients could tolerate. All patients were reminded to do the exercises regularly.

Baseline evaluation included obtaining demographic data (sex, age, body mass index [BMI], and symptom duration). Pain severity was evaluated using the Visual Analog Scale (VAS) and the patients were asked to rate their pain levels during rest and activity from 0 to 10 by considering 0 as “no pain”, 5 as “moderate pain” and 10 as “pain felt with unbearable severity”. The Roland-Morris Disability

Questionnaire (RMDQ) was used for functional evaluation. This scale was modified from the Sickness Impact Profile and was designed to evaluate the patient's functional disability. The total score ranges from 0 (no disability) to 24 (severe disability).^[11] Progressive isoinertial lifting evaluation (PILE) test was used to measure functional work performance and weight lifting capacity. Women started the test by lifting 5 lbs (2.5 kg) and men 10 lbs (5 kg). The patients lifted a box with weights four times for 30 sec, first from the floor to the waist level and, then, from the waist to the shoulder level. The test was terminated, when the patient reached psychophysical limit (e.g., fatigue or fear), aerobic limit (when reaching 85% of heart rate) or safety limit (more than 50% of body weight should not be removed).^[12]

In our study, computerized isokinetic muscle strength (IMS) measurement was performed on trunk extensor and flexor muscles. Body extensor and flexor muscle strengths were measured using the CybexTM Humac Norm 350 (Cybex Norm, Lumex Inc., Ronkonkoma, NY, USA), a computerized isokinetic dynamometer machine. The device was calibrated at an error of 0.001. In accordance with the test protocol, the patients were prepared for testing and exercise before starting the recordings. The main protocol was, then, applied (Figure 2). The assessors who measured IMS were blinded to the participants. All participants were evaluated at baseline, after treatment (Week 8), and at three months after the treatment (Week 20).

Statistical analysis

The study power and sample size calculation were performed using the G*Power version 3.1.9.7 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). Analysis of variance (ANOVA) (repeated measures, within factors) test was performed in repeated measurements to determine VAS score changes (group $\times$ time). Partial eta-squared score was calculated as 0.079. Accordingly, with an effect size of the study of 0.292, an alpha value of 0.05, and a sample size of 74, the post-hoc power of the study was calculated as 0.99 (Figure 2).

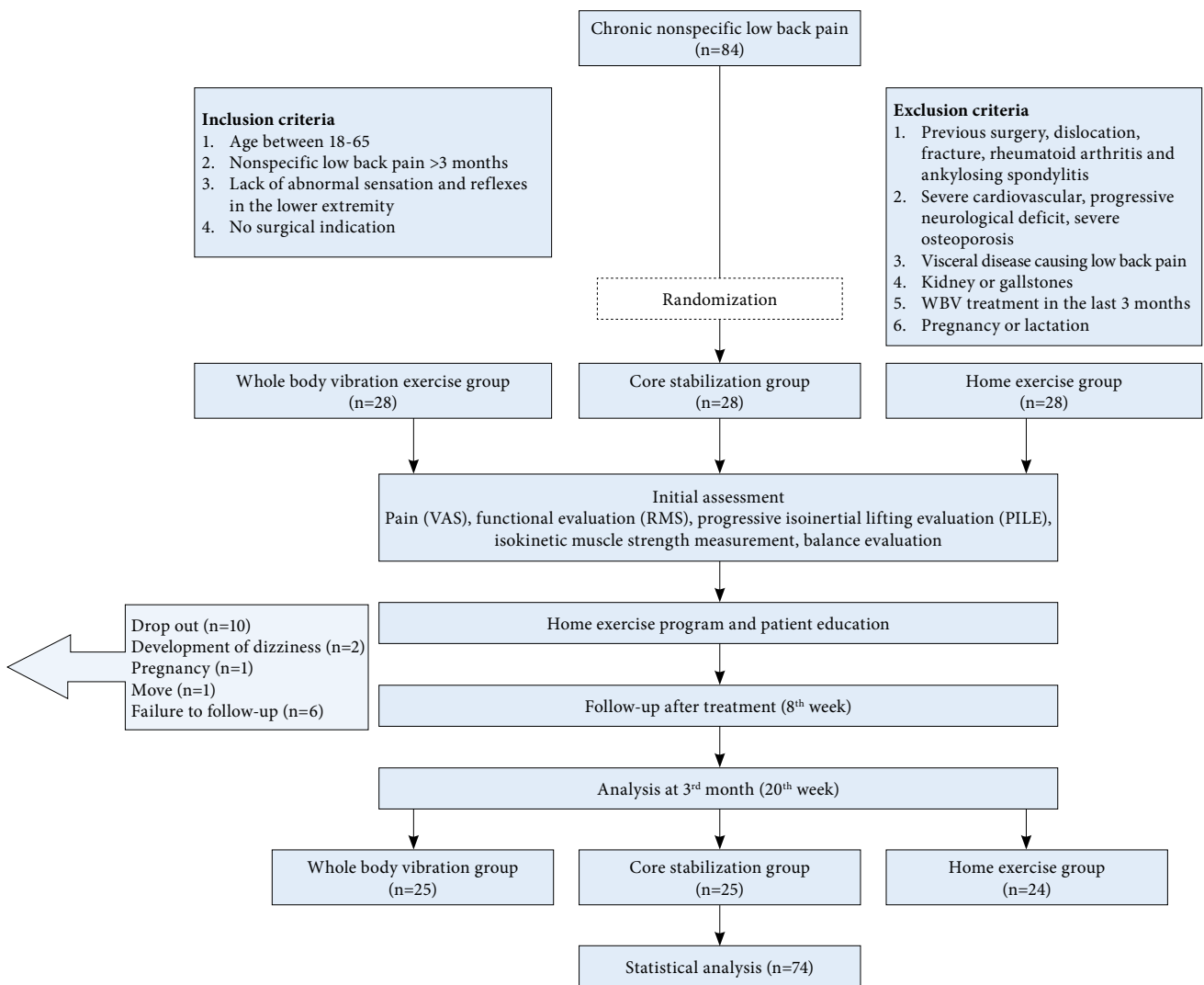


Figure 1. Study flow chart.

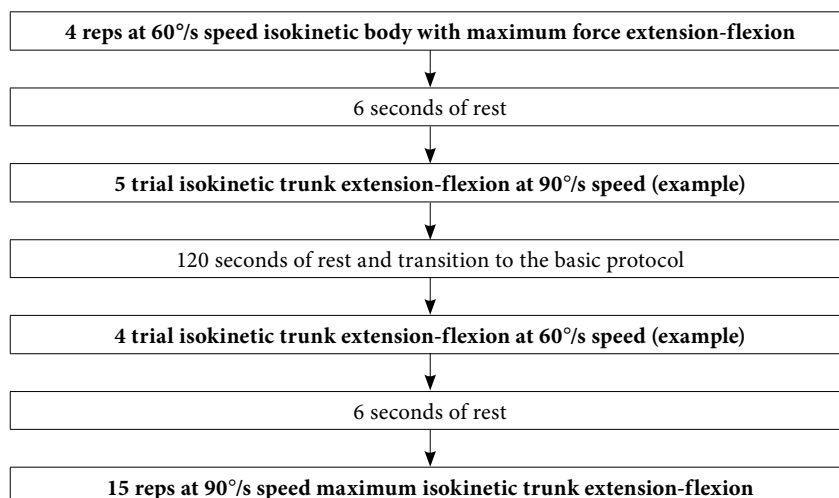


Figure 2. Isokinetic test protocol.

TABLE 3
Intragroup comparisons of PILE values and RMDQ scores

Pre-treatment															Post-treatment					Post-treatment 3 th M					Post-hoc		Difference			p**
Groups	n	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	p*	p	Mean±SD	Median	Min-Max															
PILF/ground to back	WBVEG	25	8.68±3.0	9	4-15	11.08±3.7	12	1-16	12.12±2.8	13	5-16	<0.001	0.011† 0.001‡	3.73±2.89	4	-2-9	0.025 Post-hoc (0.0126) (0.0294)													
	CSEG	25	8.64±3.1	9	3-15	12.18±4.5	12	2.5-25	13.00±3.9	13	5-25	<0.001	0.002† <0.001‡	4.36±3.86	4	0-13														
	CG	24	7.27±4.2	6	2-16	8.60±4.2	6	4-18	9.27±3.94	9	4-18	=0.029	0.025‡	1.65±2.81	1	-4-8.5														
PILF/back to shoulder	WBVEG	25	7.56±2.8	7	2-12	10.8±3.6	12	1-16	11.96±2.7	12	5-16	<0.001	0.001† <0.001‡	4.69±2.94	4	-1-11	0.005 Post-hoc (0.0066) (0.0034)													
	CSEG	25	8.08±3.5	9	3-15	11.82±4.9	12	2.5-25	12.9±4.13	13	5-25	<0.001	0.001† <0.001‡	4.84±3.93	4	0-13														
	CG	24	7.06±4.3	6	2-16	8.60±4.2	6	4-18	9.18±3.7	9	4-16	=0.009	0.035‡	1.78±2.83	1	-4-8.5														
Roland Morris Scores	WBVEG	25	4.82±3.97	3	0-12	1.86±2.63	1	0-9	1.47±1.90	1	0-7	<0.001	<0.001†‡	3.34±3.73	2	-3-12	0.73													
	CSEG	25	4.44±4.0	4	0-13	2.44±3.16	1	0-11	1.80±2.02	1	0-7	<0.001	0.017† <0.001‡	2.64±3.69	2	-7-11														
	CG	24	6.30±6.03	6	0-18	4.91±4.28	4	0-18	5.26±5.41	5	0-18	=0.427	-	1.04±6.57	0	-10-15														

PILF: Progressive isoinertial lifting evaluation test; RMDQ: Roland-Morris Disability Questionnaire; SD: Standard deviation; WBVEG: Whole-body vibration exercise group; CSEG: Core stabilization exercise group; CG: Control group; † Pre-treatment-Post-treatment; ‡ Pre-treatment-Post-treatment 3thM; * Inter-group p-value; ** Inter-group p-value; †† Inter-group p-value; ‡‡ Inter-group p-value.

WILE: Progressive isoinertial lifting evaluation test; RMDQ: Roland-Morris Disability Questionnaire; SD: Standard deviation; WBVEG: Whole-body vibration exercise group; CSEG: Core stabilization exercise group; CG: Control group; † Pre-treatment-Post-treatment; ‡ Pre-treatment-Post-treatment-3th M; * Intergroup 0 value; ■ WBVG-CG; § CSEG-CG.

Statistical analysis was performed using the IBM SPSS for Windows version 22.0 software (IBM Corp., Armonk, NY, USA). Intention-to-treat analysis was performed to analyze the data. Descriptive data were expressed in mean $\pm$ standard deviation (SD), median (min-max) or number and frequency. The distribution of variables was checked using the Kolmogorov-Smirnov test. In the group comparison of data without normal distribution, the Wilcoxon and Friedman tests were used and the Kruskal-Wallis variance analysis was used for the inter-group comparison, followed by the Games-Howell post-hoc test. For the data with normal distribution, repeated measures ANOVA was performed for VAS scores with group, time, and interaction of time and group, followed by the Bonferroni post-hoc test. The paired t-test was used for intra-group comparisons. A p value of <0.05 was considered statistically significant.

RESULTS

All patients included in the study were divided into three groups with respect to age, sex, BMI, symptom duration, VAS scores, and baseline characteristics ($p>0.05$) (Table 2).

There was a significant difference in the VAS score changes of pre-treatment, post-treatment, and post-treatment third month measurements among the groups ($p=0.023$). The VAS pain scores of the home exercise group were higher than the other two groups ($p<0.001$). No significant difference was found in the VAS scores of pre-treatment, post-treatment, and post-treatment third month measurements of the home exercise group ($p=0.214$). Intensive activity VAS scores in the WBVEG and CSEG significantly decreased after the treatment and at post-treatment third month, compared to pre-treatment scores ($p<0.001$).

A statistically significant increase in the functional work performance with PILE test was observed in all groups ($p<0.05$). In the inter-group comparisons, the difference between pre-treatment and third-month PILE test (ground to back and back to shoulder) were significantly different in both WBVEG and CSEG than the CG ($p<0.05$) (Table 3).

There was a statistically significant improvement in the RMDQ in the WBVEG and CSEG after treatment and at post-treatment third month, compared to pre-treatment ($p<0.001$). However, there was no significant difference in the inter-group comparison ($p>0.05$) (Table 4).

There was a statistically significant increase in the isokinetic flexion peak torque (IKFPT), isokinetic extension peak torque (IKEPT), and isokinetic extension total work (IKETW) values in all three groups ($p<0.001$). There was a statistically significant increase in the IKFTW values in WBVEG and CSEG ($p<0.001$). The increase in IKFTW levels was statistically significant in CG ($p<0.05$). In the inter-group comparisons, the difference in the value of IKEPT compared to the pre-treatment values after treatment was statistically significantly higher in the WBVEG than the CSEG ($p<0.05$) (Table 4).

In the WBVEG, headache was observed in six patients, orthostatic hypotension in four patients, burning sensation in the legs in three patients, burning sensation in the soles of one foot, fullness in the ears in two patients, and dizziness in one patient after treatment. However, all these side effects were transient and did not recur. Therefore, none of these patients withdrew from the study. In two patients, temporary dizziness developed after the first WBVE session, and the patients voluntarily withdrew from the study.

DISCUSSION

In many studies, although there is no significant difference between women and men in terms of LBP prevalence, it has been shown that the back pain prevalence is high in women.^[13-15] Similarly, in our study, 83.8% of the patients were females. Age is one of the most important risk factors for LBP. The incidence of LBP peaks in the third and fourth decades of life, and the overall prevalence increases with age (up to 60-65 years) and, then, gradually decreases.^[13] In our study, the patients between 23 and 59 years of age were included and the mean age was 43.7 ± 8.9 years, consistent with the literature.

The primary objective of our study was to evaluate the effects of WBVE modality in patients with chronic NLBP. It is a new exercise modality and, thus, there is limited evidence in the literature to support the use of WBVE for the treatment of LBP.^[16] In a current review, there is limited evidence suggesting that WBVE is beneficial for NLBP, and it has not been concluded that it is an effective intervention due to the little sample size and statistical heterogeneity.^[17] In addition, the optimum parameters for use in clinical practice are unclear.^[18] There is no consensus on the use of WBVE to increase muscle strength, in addition to other treatment methods or separately. It is recommended

that WBVE are not applied alone, but with a conventional exercise program.^[19,20] Likewise, we applied WBVE combined with classic lumbar home program in our study. Transmission of vibration to the body and its response on the musculoskeletal system is affected by vibration parameters such as the frequency, acceleration, direction, and duration of the vibration. Also, the frequency and duration of the exercises performed on the vibration platform are also affected by factors such as the individual's posture on the platform, the rigidity of the platform, whether the person is barefoot, and the body parts have different resonance frequencies.^[9] In our study, similar to the study of Zheng et al.,^[21] we exercised the patients in three different positions: squat position (knee angle set to 120°), bridge position (both foot soles on the platform), and push-up position (both hands on the platform).

In the literature, in terms of posture on the WBVE platform in CLBP, del Pozo-Cruz et al.^[22] and Boucher et al.^[16] performed the exercise knees flexed in the squat position, while Rittweger et al.^[23] applied slow oscillations, rotation, and additional weight on the platform, instead of a fixed posture. Wang et al.,^[18] in their series, used the upright posture, deep squat, back extension posture, bridge position and push-up position. In the current literature, the vibration parameters of the WBVE and exercise protocols applied in CLBP are different. These different practices make it difficult to compare studies with each other and to prepare guidelines for the clinical use of WBVE.^[17] Perraton et al.^[10] reported that there was insufficient evidence for the use of WBVE in CLBP. In the literature, WBVE contributes to pain reduction and functional recovery, increases lifting capacity, and reduces the risk of falling in chronic NLBP. The results of our study also support the current literature in terms of pain, functional recovery, and lifting capacity.^[22,24]

In a systematic review, it has been suggested that there is a strong evidence that stabilization exercises are not superior to other active exercise forms in the long-term.^[25] In a meta-analysis, studies comparing CSE with a general exercise program in patients with CLBP were evaluated and it was concluded that CSE was superior to the traditional exercise program in terms of pain and functionality in the short-term, but this difference decreased in the long-term.^[26] The results of our study also showed that CSE was more effective in the short-term in terms of pain reduction and functionality, compared to the classic lumbar home exercise program in patients with chronic

NLBP. In the literature, however, there are no studies evaluating CSE efficacy with IMS measurement in patients with CLBP.

Compared to CG, in our study, pain reduction and functional improvement were observed in the WBVG and CSE. However, the increase in trunk flexor muscle strength was observed in all three groups. Extensor muscle strength change was more in the WBVE group than the CSE group and CG. Unlike other studies using the device, it may be related to exercising not only in the squat position, but also in the bridge and push-up positions.

In another meta-analysis, the occurrence of adverse effects associated with WBVE was found to be rare.^[6] Only 29 of 455 participants in the WBVEG experienced potentially adverse effects associated with WBVE exposure. The effects were mild and usually lessened in other sessions. In general, WBVE was well tolerated in older adults, but it was emphasized that more research was needed to assess long-term side effects. In our study, headache, orthostatic hypotension, burning sensation in the legs, burning sensation in the soles of the feet, fullness in the ears, feeling light-headed developed in the WBVEG; however, all these side effects were transient and did not recur. In two patients, temporary dizziness developed after the first WBVE session, and the patients voluntarily withdrew from the study.

Nonetheless, there are some limitations to this study. First, the fact that the treating researcher was not blinded to the treatment groups is one of the limitations. Only the assessors who measured IMS were blinded to the participants. Second, the long-term effect of WBVE and CSE was considered to be limited due to the short follow-up period in our study. There was a decline in the number of participants for various reasons during follow-up. In our study, the drug use of the participants was not questioned and the Physician and/or Patient Global Assessment scale was not used. Third, the number of housewives in the CG was higher and the groups were not homogeneously distributed. In addition, there is no specific standardization in the vibration parameters and training protocol of WBVE. Finally, this study included both sex, and considering the physiological differences in response to exercise, this may have resulted bias.

In conclusion, the WBVE and CSE appear to be effective in pain and functionality in the treatment of chronic NLBP. Although there was a significant improvement in the muscle strength and functional work performance in all three groups, greater

improvements in WBVEG and CSEG were observed than the CG. Based on these findings, we suggest further, well-designed, comprehensive studies to define the target population, long-term effects, and optimal treatment protocols to elucidate the effectiveness of WBVE and CSE in this patient population.

Ethics Committee Approval: The study protocol was approved by the Istanbul University, Istanbul Medical Faculty Ethics Committee (Ref. no: 2016/70). 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: Concept, design, data col, writing manuscript; B.C.K.; Materials, data collection, analysis; T.S.; Data collection, analysis; B.G.; Materials; S.Y.; Concept, design, supervision, literatur, search writing manuscript; E.O.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

REFERENCES

- Balagué F, Mannion AF, Pellisé F, Cedraschi C. Non-specific low back pain. *Lancet* 2012;379:482-91.
- Ladeira CE. Evidence based practice guidelines for management of low back pain: Physical therapy implications. *Rev Bras Fisioter* 2011;15:190-9.
- Gunduz OH, Ercalik T. Exercise prescription in chronic low back pain. *Turk J Phys Med Rehabil* 2014;60:25-30.
- Panjabi MM. The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. *J Spinal Disord* 1992;5:383-9.
- Sitjà Rabert M, Rigau Comas D, Fort Vanmeerhaeghe A, Santoyo Medina C, Roqué i Figuls M, Romero-Rodríguez D, et al. Whole-body vibration training for patients with neurodegenerative disease. *Cochrane Database Syst Rev* 2012;(2):CD009097.
- Lau RW, Liao LR, Yu F, Teo T, Chung RC, Pang MY. The effects of whole body vibration therapy on bone mineral density and leg muscle strength in older adults: A systematic review and meta-analysis. *Clin Rehabil* 2011;25:975-88.
- Roelants M, Verschueren SM, Delecluse C, Levin O, Stijnen V. Whole-body-vibration-induced increase in leg muscle activity during different squat exercises. *J Strength Cond Res* 2006;20:124-9.
- Human response to vibration-Guidance and terminology for instrumentation and equipment for the assessment of daily vibration exposure at the workplace according to the requirements of health and safety. International Organization for Standardization; 2017.
- Rauch F, Sievanen H, Boonen S, Cardinale M, Degens H, Felsenberg D, et al. Reporting whole-body vibration intervention studies: Recommendations of the International Society of Musculoskeletal and Neuronal Interactions. *J Musculoskelet Neuronal Interact* 2010;10:193-8.
- Perraton L, Machotka Z, Kumar S. Whole-body vibration to treat low back pain: Fact or fad? *Physiother Can* 2011;63:88-93.
- Küçükdeveci AA, Tennant A, Elhan AH, Niyazoglu H. Validation of the Turkish version of the Roland-Morris Disability Questionnaire for use in low back pain. *Spine (Phila Pa 1976)* 2001;26:2738-43.
- Mayer TG, Barnes D, Nichols G, Kishino ND, Coval K, Piel B, et al. Progressive isoinertial lifting evaluation. II. A comparison with isokinetic lifting in a disabled chronic low-back pain industrial population. *Spine (Phila Pa 1976)* 1988;13:998-1002.
- Hoy D, Brooks P, Blyth F, Buchbinder R. The Epidemiology of low back pain. *Best Pract Res Clin Rheumatol* 2010;24:769-81.
- Manchikanti L, Singh V, Falco FJ, Benyamin RM, Hirsch JA. Epidemiology of low back pain in adults. *Neuromodulation* 2014;17 Suppl 2:3-10.
- Kopec JA, Sayre EC, Esdaile JM. Predictors of back pain in a general population cohort. *Spine (Phila Pa 1976)* 2004;29:70-7.
- Boucher JA, Abboud J, Dubois JD, Legault E, Descarreaux M, Henchoz Y. Trunk neuromuscular responses to a single whole-body vibration session in patients with chronic low back pain: A cross-sectional study. *J Manipulative Physiol Ther* 2013;36:564-71.
- Wang W, Wang S, Lin W, Li X, Andersen LL, Wang Y. Efficacy of whole body vibration therapy on pain and functional ability in people with non-specific low back pain: A systematic review. *BMC Complement Med Ther* 2020;20:158.
- Wang XQ, Pi YL, Chen PJ, Chen BL, Liang LC, Li X, et al. Whole body vibration exercise for chronic low back pain: Study protocol for a single-blind randomized controlled trial. *Trials* 2014;15:104.
- Bemben DA, Palmer IJ, Bemben MG, Knehans AW. Effects of combined whole-body vibration and resistance training on muscular strength and bone metabolism in postmenopausal women. *Bone* 2010;47:650-6.
- Kosar AC, Candow DG, Putland JT. Potential beneficial effects of whole-body vibration for muscle recovery after exercise. *J Strength Cond Res* 2012;26:2907-11.
- Zheng YL, Wang XF, Chen BL, Gu W, Wang X, Xu B, et al. Effect of 12-week whole-body vibration exercise on lumbopelvic proprioception and pain control in young adults with nonspecific low back pain. *Med Sci Monit* 2019;25:443-52.
- del Pozo-Cruz B, Hernández Mocholí MA, Adsuar JC, Parraca JA, Muro I, Gusi N. Effects of whole body vibration therapy on main outcome measures for chronic non-specific low back pain: A single-blind randomized controlled trial. *J Rehabil Med* 2011;43:689-94.

23. Rittweger J, Just K, Kautzsch K, Reeg P, Felsenberg D. Treatment of chronic lower back pain with lumbar extension and whole-body vibration exercise: A randomized controlled trial. *Spine (Phila Pa 1976)* 2002;27:1829-34.
24. Yang J, Seo D. The effects of whole body vibration on static balance, spinal curvature, pain, and disability of patients with low back pain. *J Phys Ther Sci* 2015;27:805-8.
25. Smith BE, Littlewood C, May S. An update of stabilisation exercises for low back pain: A systematic review with meta-analysis. *BMC Musculoskelet Disord* 2014;15:416.
26. Wang XQ, Zheng JJ, Yu ZW, Bi X, Lou SJ, Liu J, et al. A meta-analysis of core stability exercise versus general exercise for chronic low back pain. *PLoS One* 2012;7:e52082.