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The Effects of Motor Control Approach with and without Whole-body Vibration on Pain and Static and Dynamic Balance in Female Nurses with Non-specific Chronic Low Back Pain: Randomized Clinical Trial

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Original Article

Abstract

Introduction: Chronic non-specific low back pain is one of the prevalent musculoskeletal disorders among nurses, which imposes significant burdens on society. The present research aimed to investigating the effect of motor control approach with and without whole-body vibration (WBV) on pain, static and dynamic balance of the female nurses with chronic non-specific low back pain (NLBP).

Materials and Methods: The statistical sample consisted of 75 female nurses with chronic NLBP and with a history of pain for more than three months. They were randomly divided into three groups: the combined group (motor control with whole-body vibration), the motor control group and the control group. The pain intensity was measured using a visual analog scale, and static and dynamic balance were measured using the Biodex balance meter. Tests were conducted before and after eight weeks. The Shapiro-Wilk test was used to check if the data were normally distributed; the parametric analysis of variance (ANOVA) and non-parametric Kruskal-Wallis tests were used if the data followed a normal distribution or did not, respectively.

Results: The research results showed a significant difference ($P < 0.001$) in pain intensity, and static and dynamic balance between the combined and motor control groups and the control group; however, no significant difference ($P > 0.05$) was observed between the combined and motor control groups.

Conclusion: It seems that exercise improves the symptoms of chronic NLBP in female nurses, and both exercise approaches were equally effective.

Keywords: Chronic non-specific low back pain; Pain; Balance; Nurse

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Introduction

Chronic non-specific low back pain (NLBP) is a type of back pain that occurs without any specific cause, such as degenerative changes, inflammatory conditions, infectious agents, bone metabolic diseases, pain of psychological origin, trauma, and congenital disorders. This type of pain is divided into three categories based on its duration and associated symptoms: acute (6 weeks), sub-acute (6 to 12 weeks), and chronic (more than 12 weeks) (1). NLBP is the most common musculoskeletal disorder, affecting many people each year, including various occupational groups (2). Nurses are at a higher risk of developing CLBP due to their profession. This disorder is caused by performing certain heavy tasks, such as lifting patients from their beds and applying

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shear forces on the vertebrae of the lumbar spine (3). Surveys have shown that 30-70% of Iranian nurses suffer from musculoskeletal disorders like low back pain every year (4). Another survey found that the prevalence of low back pain during the COVID-19 pandemic was 70.9% (5). Additionally, women are more susceptible to low back pain than men, which can be attributed to factors like hormonal changes during menstruation, changes related to pregnancy, and anatomical differences (6).

NLBP can negatively impact various aspects of a person's life. Interference in the pain signals sent to the motor cortex and spinal cord leads to increased presynaptic inhibition of muscle afferents and decreased muscle feedback (7). This leads to reduced muscle control in the lower back and lengthening delays (7). Consequently, low back pain can reduce balance and proprioception in the lower back area (8). Moreover, changing the electrical activity of muscles can affect factors such as agility, coordination, postural control, proprioceptive capacity, balance, strength, and endurance (9). Therefore, effective treatment solutions can play a significant role in improving back pain and restoring people's health. This can lead to a reduction in treatment costs at the macro level and an increase in the efficiency of human resources (10).

The motor control approach (11, 12) is one of the most commonly used treatments for musculoskeletal pain, particularly low back pain. This approach is based on the Motor Learning Approach (13), which considers the features of trunk posture, movement, and muscle activation related to symptoms. The muscle of the trunk is the main focus of this approach, including the rectus abdominus from the front, the internal and external oblique from the side, the erector spinae, multifidus, and quadratus lumborum from the back, the diaphragm from above, and the iliopsoas from below. This approach has many benefits, such as improving neuromuscular control, muscle strength, and endurance (14). Studies have also shown that this type of exercise, either alone or in combination with other approaches, can significantly reduce pain and disability and prevent the patient from developing chronic back pain again (15). With the advancement of technology and the availability of new medical sports equipment, different training approaches have been considered in recent years (16).

Whole-body vibration (WBV) refers to standing on a plane that fluctuates vertically or laterally with a predetermined frequency ranging from 0 to 45 Hz and a displacement range of 0 to 12 mm (17). Vibration is believed to relieve pain and improve performance in the treatment of musculoskeletal disorders and as part of rehabilitation programs for patients (18). The therapeutic mechanisms of this approach are still under investigation, but several hypotheses exist (19). For instance, the "Tonic Vibration Reflex" hypothesis suggests that vibration activates muscle spindles, stimulating alpha motor neurons and contacting extra-spindle muscle fibers (18). This approach may help activate muscles in individuals with chronic back pain by triggering a stretch reflex response of the trunk muscles. Furthermore, back pain may be associated with paravertebral muscle spasms, and WBV at frequencies below 20 Hz may help alleviate back pain by reducing spasms (18, 20).

Exposure to occupational vibrations, such as those experienced by drivers of heavy vehicles, can lead to back pain, sciatica pain syndrome, and spine injuries (21). This is because the intensity, amplitude, duration, and frequency of these vibrations are uncontrollable (22). On the other hand, it has been suggested that the vibrations produced by WBV devices can help reduce pain and improve muscle function, as the frequency, duration, amplitude, and intensity of the vibration can be controlled (23). It is hoped that the effectiveness of WBV, alone or in combination with other approaches, in improving balance and proprioception in patients with NLBP will be significant (24). However, due to the heterogeneity of existing study results and the lack of sufficient clinical trials, no definite conclusions can be made at present. Despite the research conducted in this regard (21-24), no study has examined the effect of combining the two approaches of motor control exercise and WBV on pain and balance in people with NLBP.

Therefore, the current research seeks to answer the question: Is there a difference between the effect of the motor control exercise with and without WBV on the pain and balance of nurses with NLBP?

Materials and Methods

The current research followed the steps approved by the Research Ethics Committee of the Research Institute of Physical Education and Sports Sciences. Additionally, it was registered in the Iranian Clinical Trials System. The research was conducted with three groups, including a control group. The control group participants did not receive any intervention, but were recommended to participate in the treatment sessions after completing the research. The other two groups were the motor control exercises group and the combined group (motor control exercise with WBV).

The study recruited participants through coordination with the heads of hospitals in Tehran, Iran, starting in January 2023. The data collection took place in June and July 2023 at the Tehran

Institute of Physical Education, the Correctional Laboratory of Khawarzmi University, Moafaqian Rehabilitation Center, and Sepehrnovin Sports Club. The sampling method in this research was purposeful, and the statistical population was female nurses experiencing NLBP in Tehran with a pain history of more than three months. To determine the number of samples needed for the study, the G*Power software (G*Power 3.1.9.7 freeware, University of Düsseldorf, Düsseldorf, Germany) was used. The software calculated that 23 samples were required for each group, with a power of 0.8 and a significance level of 0.05, based on an average effect size derived from a previous study (25) and taking into account a 10% drop rate. However, to allow for possible loss of samples, 25 people were included in each group. In order to participate in the study, the participants were required to read and sign an informed consent form.

The study included 75 female nurses of 30-40 years of age, who had more than 3 years of work experience and had NLBP. The participants were selected based on the STarT Back Screening Tool (SBST) and had at least three months of back pain history. A specialist doctor confirmed that the pain was not caused by the structure of the spine and the pain reported was between the gluteal fold and the chest, with an intensity of 4-7 on the Visual Analogue Scale (VAS). The study participants were divided into three groups each consisting of 25 people.

The study exclusion criteria included any damage or abnormality that may affect the research process such as nerve root disorders of the lumbar spine leading to a decrease in strength and reflexes of the lower limbs, fracture, cancer, inflammatory arthritis of the lumbar vertebrae, cauda equina syndrome (CES), history of lumbar spine surgery, or being on the waiting list for surgery during the intervention period, cognitive disorders such as Alzheimer's, severe neuromuscular disorders, lack of permission for participation in the study from the examining physician in confirmation of the clinical health of the heart and lungs and the condition of the motor organs. Dissatisfaction or the lack of desire to participate in the research process could also result in exclusion. Non-participation of the subjects in two consecutive training sessions also led to their removal from the study. The SBST is a tool that helps to evaluate and classify patients suffering from NLBP. This questionnaire comprises nine items that cover various aspects, such as referred leg pain, disability (including two items), impatience, catastrophizing, fear, anxiety, and depression. All questions have dichotomous answers, where 'I agree' is marked as 1 and 'I do not agree' is marked as 0. However, the question about boredom is answered on a five-point Likert scale, where 0 indicates 'not at all', 'very little', and, 'average', and 1 indicates 'very high' and 'excessive'. Therefore, the total score can range from 0 to 9. The last five items are summarized in a psychological subscale, with a maximum score of 5. A high score indicates a high risk of developing NLBP. Individuals with an overall score of 0 to 3 are classified as low-risk and require minimal treatment, which can be managed with self-management strategies. Those who obtained a total score of at least 4 points, with a maximum of 3 points related to psycho-social factors, are classified in the medium-risk group and can be managed with physiotherapy. Those who score 4 or 5 on the psychological subscale are classified as high-risk and have a poor prognosis for a persistent disability that requires psychological awareness interventions (26). The Cronbach's alpha coefficient of this tool is 0.73, and its validity is reported to be 0.95 (27, 28).

To measure and quantify the intensity of pain, a visual analog scale was used. This scale is a 100 mm long horizontal bar with one end marked as zero, indicating no pain, and the other end marked as 10, indicating the most severe possible pain. The reliability of this scale is reported as 0.95 and its validity is reported as 0.97 (29). This criterion is widely used to evaluate pain intensity.

A Biodex balance meter (Balance System SD, 950-441, BIODEX Medical System Inc., Shirley, NY, USA) was used to assess both static and dynamic balance. The balance plate has 12 different positions (1 to 12), with level 12 being the most stable and least sensitive to changes in the center of gravity, while level 1 is the least stable and most sensitive to even the slightest displacement of the center of gravity. The plate is divided into four quadrants, with the right foot placed in the first quadrant, the left foot in the second, the left heel in the third, and the right foot in the fourth. Participants were asked to position their feet on the balance meter so that their heels were 10% of their height apart and each foot was turned 15 degrees outward. The balance performance of each participant was then measured for 20 seconds in anterior-posterior, internal-external, and general conditions on both stable (level 12) and unstable (level 8) levels with eyes open. The Biodex balance device calculated three anterior-posterior indices, an internal-external index, and a general balance index to evaluate static and dynamic balance. Each test was repeated three times and the average of the three repetitions, with a 10-second rest between each, was recorded as the individual score. The reliability of this device has been reported to evaluate optimal balance indices (ICC > 0.7) (30).

After gathering the initial information, the subjects underwent an exercise program for eight weeks. During the first four weeks, two sessions per week were conducted, and for the subsequent four weeks, one session per week was conducted. The subjects were advised not to engage in any other exercise program during this period except for the mentioned program. Before each training session, the subjects performed a 5-minute warm-up program, and after each session, they did a 5-minute cooling-down program. The motor control exercises lasted for 30 minutes, and WBV exercises lasted for 15 minutes.

The WBV device (Whole Body Vibration Turbosonic Therapy System, TT2590 X7, X5, version 11-2010, Internal Harmony, Linwood, NJ, USA) has a frequency range of 3 to 50 Hz and is rotated by a sound system with new magnetic circuits instead of a motor. One of the advantages of this device is that it no longer causes damage from mechanical vibrators. The device can improve strength, endurance, balance, and flexibility (31). Vibration can produce effects similar to regular strengthening exercises, but with less pressure on the joint and improve neuromuscular function (32).

Motor control exercises (33) and WBV (34) were performed based on previous studies and as described in tables 1 and 2.

The participants in the motor control group took part in 12 supervised sessions, each lasting 30 minutes. During these sessions, they performed exercises based on a specific protocol that was tailored to their abilities and overseen by a specialist doctor. The exercises were conducted over 8 weeks, with two sessions per week in the first 4 weeks and one session per week in the second 4 weeks. The motor control exercises consisted of three parts, including promoting the independent activation of deep stabilizing muscles (such as the transversus abdominis and multifidus), training patients to use these muscles while lying still without any tools, and optimizing muscle contractions while standing, sitting, or kneeling. Participants also learned to combine these skills dynamically and functionally with the help of a gym ball (35) (Table 1).

The study involved a combination of motor control and WBV exercises. Participants were closely monitored during 12 sessions, each lasting 45 minutes. In each session, they performed motor control exercises for 30 minutes (see Table 1) followed by a WBV protocol for 15 minutes (see Table 2). The WBV protocol consisted of 5 movements (dynamic squat with a cable, squat with extension arms, lifting on the toes, static squat, and static squat by standing on the toe) performed in two sets with 5 to 8 repetitions at a specified frequency of 5 to 10 Hz displayed on a screen. Active rest periods of 30 seconds were included between each set, which included three exercises quiet standing, hip rotation, and hanging with a cable. Participants followed this routine for 8 weeks, with two sessions per week for the first 4 weeks and one session per week for the second 4 weeks.

The research data was analyzed in two sections: descriptive and inferential statistics. SPSS software (Version 26; IBM Corp., Armonk, NY, USA) was used for this purpose. The Shapiro-Wilk test was carried out to check whether the data followed a normal distribution. If the data followed a normal distribution, parametric ANOVA tests were carried out. However, if the data did not follow a normal distribution, non-parametric Kruskal-Wallis tests were used. To offset the pretest error caused by the non-identity of basic data in different groups, change analysis was used. A significance level of 0.05 was considered, and for intra-group comparison, Wilcoxon tests (non-normal distribution) and paired t-tests (normal distribution) were used. The subjects were selected and consent was obtained before the test. The participants were informed about the research objectives, methods, and benefits. They were also informed that their personal information and files would remain confidential and that they could refuse to continue participating in the research at any time. Additionally, the participants were ensured that the methods of measurement and participation in the research would not have any economic costs or physical risks for them.

Results

A total of 75 volunteer nurses participated in this research study. However, four people were excluded from the study, two from the motor control group due to illness and transferring to another workplace, and two from the combined group due to pregnancy and an accident (lower limb injury) (Figure 1). This resulted in an 8% drop rate in each of the experimental groups.

The Shapiro-Wilk test showed that the distribution of the overall index of static balance was normal with $P < 0.05$.

Therefore, the parametric analysis of variance (ANOVA) test with Tukey's post hoc test was used to analyze this index. However, the distribution of other variables, such as pain, static anterior-posterior and internal-external indices, and anterior-posterior and internal-external and overall dynamic indices, did not follow a normal distribution. Therefore, Kruskal-Wallis test was used to compare the three groups, and Mann-Whitney test was used to compare the two groups with Bonferroni correction ($P < 0.017$) (36).

Table 1. Motor control exercise protocol

Week	Exercise		Set × repetitions	Rest between movements (second)	Rest between sets (second)
1	Transverse abdominus muscle coactivation Multifidus muscles coactivation Abdominal isometric contraction	Knee bend and side to side movement Curl-up exercise	3 × 10	10 sec	20 sec
2	Multifidus muscles coactivation Abdominal muscle isometric contraction Knee side to side movement	Curl-up Knee to chest Hip extension	3 × 10	10 sec	20 sec
3	Multifidus muscle coactivation Knee bends and Side to side movement Curl-up Knee to chest	Prone hip extension Bridge exercise Bridge and one leg lift	3 × 10	10 sec	20 sec
4	Curl-up Knee to chest Prone hip extension Bridge exercise	Bridge exercise Kneeling with one hand extension Same as above Squat	3 × 12	12 sec	24 sec
5	Prone hip extension Bridge exercise Bridge with one leg off the floor Kneeling with one hand off the floor	Kneeling with one hand off the floor Squat exercise Lunge movement Lunge with one leg	3 × 12	12 sec	24 sec
6	Kneeling with one hand off the floor Kneeling with one hand off the floor Squat Lunge	One-leg lunge Isometric contraction of transverse abdominus and multifidus muscles Abdominal muscles contraction side to side movement	3 × 12	12 sec	24 sec
7	Lunge One-leg lunge Abdominal muscles contraction Side to side movement	Isometric contraction of transverse abdominus and multifidus muscles	3 × 15	13 sec	26 sec
8	Abdominal muscle contraction Side to side movement Lifting head from the ball	Lifting leg from the Swiss ball Both knee to chest with Swiss ball Side to side movement of the leg on the Swiss ball	3 × 15	13 sec	26 sec

Table 2. Whole-body vibration protocol

Week	Exercise	Set × repetitions	Duration (mm) and frequency (Hz)	Rest between movements	Rest between sets
1	Squat1: Perform a squat movement by holding the handles of the machine and with outstretched arms.	2 × (5-8)	4 mm 20 Hz	30 second (active rest)	60 second (30 sec active and 30 sec passive)
2	Squat2: squat movement without holding the handle and with outstretched arms	2 × (5-8)	4 mm 20 Hz	30 second (active rest)	60 second (30 sec active and 30 sec passive)
3	Leg movements: heel rise	2 × (5-8)	4 mm 20 Hz	30 second (active rest)	60 second (30 sec active and 30 sec passive)
4	Sitting leg movement:	2 × (5-8)	4 mm 20 Hz	30 second (active rest)	60 second (30 sec active and 30 sec passive)
5		2 × (5-8)	4 mm 20 Hz	30 second (active rest)	60 second (30 sec active and 30 sec passive)

The research subjects' demographic characteristics, including age, height, weight, body mass index, work history, and duration of back pain, are presented in Table 3.

The results of the Kruskal-Wallis test indicate that there was a significant difference in pain intensity scores among the three groups. The Mann-Whitney test with Bonferroni correction was used to compare the two groups at a significance level of 0.017 (36). In this study, Bonferroni correction was used to prevent alpha error (Type 1) by correcting the significance level. To clarify, the p-value of 0.05 was divided by the number of groups to get a corrected significance level of 0.017 in the Benferroni test. The results showed a significant difference ($P < 0.001$) between the motor control group and the control group, as well as between the combined group and the control group. However, there was no significant difference ($P = 0.02$) between the motor control and combined groups (Tables 4 and 5).

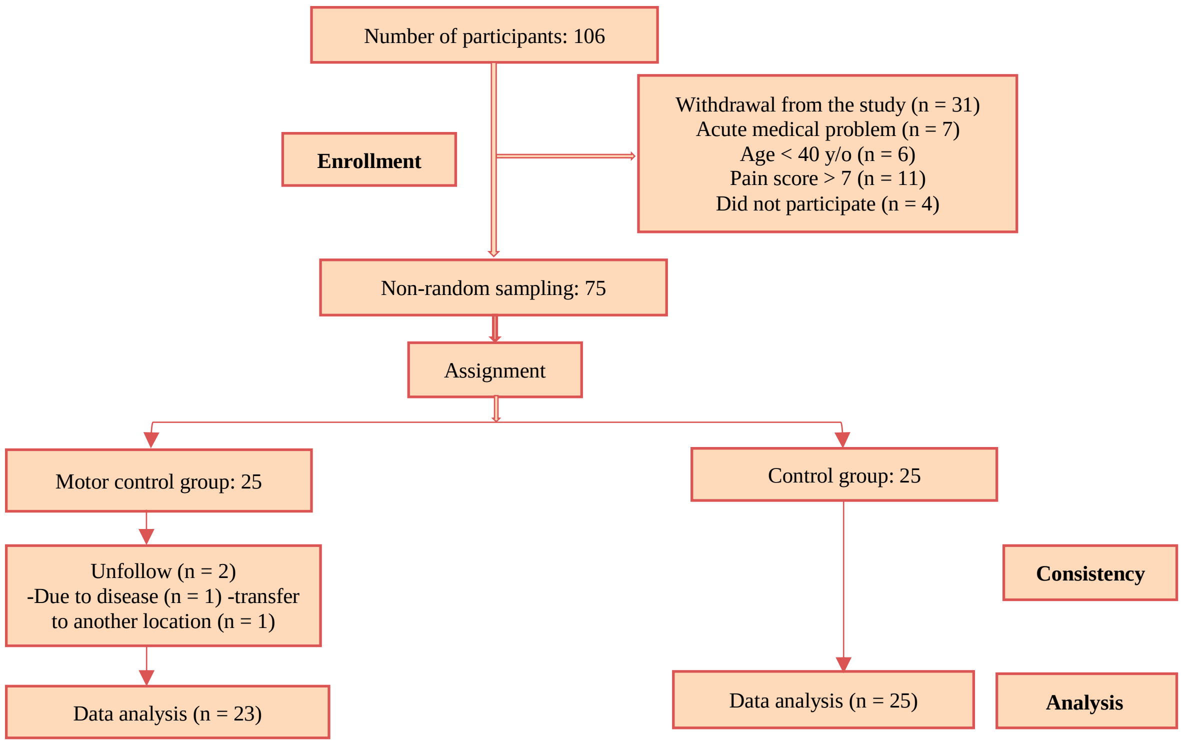

Figure 1. Chart of the loss of participants in different stages of the study

Table 3. Demographic characteristics of subjects in different research groups

Variable	Motor control group (n = 23)	Combination group (n = 23)	Control group (n = 25)
Age (years)	35.75 ± 2.11	37.29 ± 1.90	34.80 ± 2.79
Height (cm)	162.40 ± 4.46	159.64 ± 2.75	160.59 ± 3.06
Weight (kg)	68.28 ± 4.37	71.3 ± 2.62	67.59 ± 3.61
Body mass index (kg.m2)	25.87 ± 0.82	27.97 ± 0.45	26.19 ± 0.81
Working history(year)	13.76 ± 1.59	16.3 ± 2.18	12.4 ± 2.20
LBP duration (year)	3.5 ± 2.07	6.8 ± 1.96	3.21 ± 1.87

A study was conducted to compare the effect of therapeutic exercises on postural stability between the three groups. The Kruskal-Wallis test was used to analyze the data regarding dynamic balance (general stability, anterior-posterior, and internal-external stability) and static balance (anterior-posterior and internal-external stability). The overall static stability index was analyzed using ANOVA. The results showed a significant difference ($P < 0.001$) between the three groups in all indices of dynamic balance and in anterior-posterior and internal-external indices of static balance. The control group was significantly different from the other two groups ($P < 0.001$) as determined by comparing the two groups using the Mann-Whitney test with Benferroni correction at a significance level of 0.017. However, no significant difference was observed between the movement and combined control groups. ANOVA with Tukey's post hoc test for total static balance index showed that the control group had a significant difference ($P < 0.001$) with the movement and combination control groups. However, no significant difference ($P = 0.931$) was observed between the motor control group and the combined group (Table 6).

The intention to treat (ITT) analysis results indicate two dropouts in each of the motor control and combined exercise groups, equivalent to 8%. This rate is not significantly different from this study's expected dropout rate of 10%. The present study measured pain levels and static and dynamic balance indicators (anterior-posterior, internal-external, and total balance) for the out-group comparison (compared to the control group), as well as the in-group comparison (pretest-posttest) for two significant experimental groups ($P < 0.001$). Saragiotto et al. (37) also similarly analyzed the effect of subjects dropping out on the pretest and posttest.

Discussion

This study aimed to examine the impact of a motor control exercise with and without WBV on the pain and static and dynamic balance of female nurses with non-specific chronic back pain. The study found that motor control exercises with and without WBV resulted in a reduction in pain for female nurses with non-specific chronic back pain. A previous research suggests that motor control exercises are effective in reducing pain and disability caused by non-specific chronic back pain (38). Furthermore, a combination of eight weeks of motor control exercises and neuroscience training has been found to be effective in reducing pain and improving static and dynamic balance (39). Trunk stability exercises, which are part of motor control exercises, are believed to reduce pain by increasing the amount of endorphins and strengthening the central muscles of the trunk (40). This reduces tension in the ligaments and joints of the vertebrae and stabilizes them in a normal state, and in turn, increases the patient's confidence in the treatment method (41).

Table 4. Pain intensity and static and dynamic balance indices in the three study groups before and after eight weeks (standard deviation ± mean)

Group	Test time	Pain intensity (mm)	Static balance index			Dynamic balance index		
			Anterior posterior	Internal-external	Total	Anterior posterior	Internal-external	Total
Control	Pretest	5.10 ± 1.54	0.38 ± 0.21	0.69 ± 0.31	0.88 ± 0.49	0.91 ± 0.46	1.24 ± 0.40	1.27 ± 0.67
	Posttest	4.90 ± 1.41	0.39 ± 0.17	0.72 ± 0.40	0.87 ± 0.42	0.96 ± 0.46	1.23 ± 0.71	1.31 ± 0.67
P-value intragroup		0.120	0.454	0.548	0.855	0.198	0.860	0.433
Motor	Pretest	4.79 ± 0.92	0.38 ± 0.22	0.761 ± 0.30	0.88 ± 0.42	0.64 ± 0.31	1.01 ± 0.45	1.23 ± 0.70
control	Posttest	3.67 ± 1.42	0.15 ± 0.13	0.40 ± 0.16	0.53 ± 0.41	0.36 ± 0.15	0.73 ± 0.40	0.90 ± 0.39
P-value intragroup		<0.001*	<0.001*	<0.001*	<0.001**	<0.001*	<0.001*	0.007*
Combined	Pretest	5.20 ± 1.67	0.81 ± 0.33	0.40 ± 0.25	0.89 ± 0.54	1.10 ± 0.11	0.77 ± 0.42	1.28 ± 0.70
	Posttest	3.54 ± 1.62	0.47 ± 0.22	0.18 ± 0.05	0.51 ± 0.30	0.70 ± 0.30	0.35 ± 0.33	0.88 ± 0.40
P-value intragroup		<0.001*	<0.001*	<0.001*	<0.001**	<0.001*	<0.001*	<0.001*

*Significant intra-group difference in the Wilcoxon test ($P < 0.05$), **Significant intra-group difference in the paired t-test

Table 5. The results of the Kruskal-Wallis and Mann-Whitney test between the three groups in the indices of pain intensity and static and dynamic balance

Test	Index	Pain intensity differences (mm)	Static balance indices differences (scale)		Dynamic balance indices differences (scale)		
			Anterior-posterior	Internal-external	Anterior posterior	Internal-external	Total
Kruskal-Wallis/ ANOVA	Chi-square	37.764	35.571	24.422	33.824	15.819	17.118
	Degree of freedom	2	2	2	2	2	2
	P-value	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
Mann-Whitney/ Tukey	Motor control and control	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
	Combined and control	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
	Motor control and combined	0.02	0.111	0.135	0.129	0.024	0.860

*Significant differences between groups in Kruskal-Wallis ($P < 0.05$), **Significant differences between groups in Mann-Whitney ($P < 0.05$)

The transverse abdominus muscles, which play a critical role in maintaining spinal stability, are retrained to facilitate the reduction of back pain (42). Another study found that motor control training in the form of daily walking had beneficial effects on the physical health of people with chronic back pain (43). WBV has also been shown to improve pain in musculoskeletal disorders (44). Additionally, microscopic changes in musculoskeletal structures caused by WBV lead to an immediate improvement in muscle activity levels and the properties of intermuscular connective tissue (45, 46). In elderly subjects with sarcopenia, WBV for 20 weeks improved muscle function and quality of life (QOL) for 12 weeks (47). Finally, the use of WBV has been found to reduce pain in patients with non-specific chronic back pain (48).

After eight weeks of study, it was observed that motor control exercises, with or without WBV (WBV), were effective in improving both static and dynamic balance when compared to the control group. Interestingly, there was no significant difference in results between the two educational groups. Studies have shown that back pain may be the result of a reduction in the size of type II muscle fibers (49). However, stability training can help reverse this atrophy and affect muscle fiber diameter (50). Furthermore, core exercises designed to develop muscle strength and functional coordination can improve trunk muscle function (51). It is important to avoid inappropriate activities that can worsen NLBP. Most patients with low back pain refrain from using back muscles, which can lead to atrophy, reduced strength and endurance, stiffness of ligaments and joints, and ultimately aggravation of symptoms (52). In addition, research has found that individuals with low back pain experience changes in the physiological mechanism of the balance system (53), which can cause incorrect information about the body's location to be sent to the brain stem. This results in inappropriate movement commands and abnormal body positioning. Compared to static balance, dynamic balance requires greater effort, and it can be difficult for individuals with NLBP to adapt to changing conditions (54).

Specific exercises that focus on the core region can help improve stability in the upper body, pelvic floor muscles, co-contraction of abdominal muscles, multifidus, and spinal motor function (55). These exercises can also reduce the shear force applied to the back (54), resulting in an improved range of motion. The motor control training program can include exercises that target simultaneous contraction of the abdominal, multifidus, diaphragm, and pelvic floor muscles, along with exercises that improve and control organ function. Such exercises can effectively improve both static and dynamic balance (56).

Muscle spindles maintain balance with the myotatic reflex (57). Vibration exercises can enhance the sensitivity of the muscle spindle, speed of mechanical and physiological responses, and neuromuscular improvement (58). This leads to the simultaneous activation of alpha and gamma motor neurons, which facilitates muscle contraction (59).

Table 6. The results of Tukey's post hoc test and analysis of variance between three groups in the total index of static stability

Group name	Group	Mean difference	Standard error	P-value	95% Confidence interval	
					Lower limit	Upper limit
Control group	Motor control group	0.33819	0.08753	< 0.001*	0.1285	0.5479
	Combined group	0.37037	0.08753	< 0.001*	0.1606	0.5801
Motor control group	Combined group	0.03217	0.08933	0.931	- 0.1819	0.2462

Significant difference between groups in Tukey's post hoc test in analysis of variance ($P < 0.05$)

Therefore, WBV training is known to be effective in improving balance by increasing muscle spindle sensitivity, improving neuromuscular control, and stimulating the central nervous system (60). Improving and stimulating the central nervous system leads to the coordination of agonist and antagonist muscles, ultimately helping maintain balance (24, 60, 61). WBV exercises increase sympathetic muscle activity during maximal muscle contraction while simultaneously decreasing contralateral muscle activity. This increase in lower limb neuromuscular activity helps control body position (62, 63). According to the muscle tuning hypothesis, the body uses an alternative strategy called postural control to cope with the vibration, frequency, and disturbance caused by WBV (in the resonant frequency range of 5-65 Hz) and to avoid possible injuries (63). In this strategy, muscle activity is changed during the frequency transition to dampen the vibration. These changes affect the receptors of the muscle spindle and accompanying proprioception, preventing additional information from being sent to the central nervous system, and ultimately reducing the addition of proprioceptive information, which helps maintain balance (63).

Limitations

Due to financial constraints, a control group consisting of healthy individuals with similar demographic characteristics as the groups with back pain was not included in this study. Therefore, the study's results cannot be compared or evaluated against healthy individuals. Additionally, this study did not include a follow-up stage to determine the duration of the exercises' effects after the study's end. Furthermore, the study did not include subjective tools such as the Oswestry Disability Index (ODI) to measure participants' perspectives on treatment satisfaction. Incorporating this information, along with the data obtained from advanced tools like Biodex, can be beneficial in clinical decision-making and treatment prescription.

Recommendations

It has been suggested that future studies compare the effect of motor control exercises on both static and dynamic stability of non-specific chronic back pain patients with healthy individuals of different genders and occupations. Furthermore, it would be desirable to predict the follow-up phase in these studies. In addition to the variables that have been previously reported, future studies should investigate the person's level of satisfaction with the treatment, level of disability, and QOL.

Conclusion

The study found that performing motor control exercises and combined exercises for eight weeks can have a positive impact on the pain level and balance of nurses suffering from non-specific chronic back pain. The exercises also helped reduce the symptoms related to back pain. Although combined exercises showed more improvement than single exercises, no significant difference was found between the two approaches. Therefore, more research is needed in this field to determine which exercise approach is superior.

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Conflict of Interest

The authors did not have a conflict of interest.

References

1. Jaromi M, Szilagyi B, Velenyi A, Leidecker E, Raposa BL, Hock M, et al. Assessment of health-related quality of life and patient's knowledge in chronic non-specific low back pain. BMC Public Health 2021; 21(Suppl 1): 1479.
2. Haile G, Hailemariam TT, Haile TG. Effectiveness of ultrasound therapy on the management of chronic non-specific low back pain: A systematic review. J Pain Res 2021; 14: 1251-7.
3. Gilchrist A, Pokorna A. Prevalence of musculoskeletal low back pain among registered nurses: Results of an online survey. J Clin Nurs 2021; 30(11-12): 1675-83.
4. Tonkaboni N, Bagheri M, Gholian-Aval M, Ghaemi-Amiri M, Pourhaji F, Abdollahi M, et al. Musculoskeletal disorders due to patient transportation in health workers: A systematic review in Iran. International Journal of Musculoskeletal Pain Prevention 2023; 8(2): 864-73.
5. Arca M, Donmezdil S, Durmaz ED. The effect of the COVID-19 Pandemic on anxiety, depression, and musculoskeletal system complaints in healthcare workers. Work 2021; 69(1): 47-54.
6. Laxdal A. The sex gap in sports and exercise medicine research: who does research on females? Scientometrics 2023; 128(3): 1987-94.
7. Ruhe A, Fejer R, Walker B. Center of pressure excursion as a measure of balance performance in patients with non-specific low back pain compared to healthy controls: A systematic review of the literature. Eur Spine J 2011; 20(3): 358-68.
8. 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(3): 805-8.
9. Mann L, Kleinpaul JF, Pereira Moro AR, Mota CB, Carpes FP. Effect of low back pain on postural stability in younger women: influence of visual deprivation. J Bodyw Mov Ther 2010; 14(4): 361-6.
10. Gold JE, Punnett L, Cherniack M, Wegman DH. Digital vibration threshold testing and ergonomic stressors in automobile manufacturing workers: A cross-sectional assessment. Ergonomics 2005; 48(1): 66-77.
11. Macedo LG, Hodges PW, Bostick G, Hancock M, Laberge M, Hanna S, et al. Which exercise for low back pain? (WELBack) trial predicting response to exercise treatments for patients with low back pain: A validation randomised controlled trial protocol. BMJ Open 2021; 11(1): e042792.
12. Louw A, Puentedura EJ, Diener I, Zimney KJ, Cox T. Pain neuroscience education: Which pain neuroscience education metaphor worked best? S Afr J Physiother 2019; 75(1): 1329.
13. Hodges PW, Van Dillen LR, McGill S, Brumagne S, Hides JA, Moseley GL. Integrated clinical approach to motor control interventions in low back and pelvic pain. In: Hodges PW, Cholewicki J, Van Dillen LR, editors. Spinal control: The rehabilitation of back pain: State of the art and science. Edinburgh, UK: Churchill Livingstone; 2013. p. 243-309.
14. Oliva-Lozano JM, Muyor JM. Core muscle activity during physical fitness exercises: A systematic review. Int J Environ Res Public Health 2020; 17(12).
15. Effect of whole body vibration on the electromyographic activity of core stabilizer muscles: WBV on core stabilizer muscles. J Bodyw Mov Ther 2021; 25: 1-5.
16. Perraton L, Machotka Z, Kumar S. Whole-body vibration to treat low back pain: Fact or fad? Physiother Can 2011; 63(1): 88-93.
17. Cochrane DJ, Stannard SR, Firth EC, Rittweger J. Acute whole-body vibration elicits post-activation potentiation. Eur J Appl Physiol 2010; 108(2): 311-9.
18. 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(1): 158.
19. Zaidell LN, Mileva KN, Sumners DP, Bowtell JL. Experimental evidence of the tonic vibration reflex during whole-body vibration of the loaded and unloaded leg. PLoS One 2013; 8(12): e85247.
20. Rittweger J, Mutschelknauss M, Felsenberg D. Acute changes in neuromuscular excitability after exhaustive whole body vibration exercise as compared to exhaustion by squatting exercise. Clin Physiol Funct Imaging 2003; 23(2): 81-6.
21. Zheng YL, Zhang ZJ, Peng MS, Hu HY, Zhang J, Wang XQ. Whole-body vibration exercise for low back pain: A meta-analysis protocol of randomized controlled trial. Medicine (Baltimore) 2018; 97(38): e12534.
22. Patterson F, Miralami R, Tansey KE, Prabhu RK, Priddy LB. Deleterious effects of whole-body vibration on the spine: A review of in vivo, ex vivo, and in vitro models. Animal Model Exp Med 2021; 4(2): 77-86.
23. Cigdem KB, 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 Rehabil 2022; 68(2): 184-94.
24. Tariq N, Khan Z, Veqar Z. Effect of whole-body vibration on balance or proprioception in nonspecific chronic low back pain: A systematic review. J Chiropr Med 2023; 22(4): 284-93.
25. Kim H, Kwon BS, Park JW, Lee H, Nam K, Park T, et al. Effect of whole body horizontal vibration exercise in chronic low back

pain patients: Vertical versus horizontal vibration exercise. Ann Rehabil Med 2018; 42(6): 804-13.
26. Hill JC, Whitehurst DG, Lewis M, Bryan S, Dunn KM, Foster NE, et al. Comparison of stratified primary care management for low back pain with current best practice (STarT Back): A randomised controlled trial. Lancet 2011; 378(9802): 1560-71.
27. Hill JC, Dunn KM, Lewis M, Mullis R, Main CJ, Foster NE, et al. A primary care back pain screening tool: identifying patient subgroups for initial treatment. Arthritis Rheum 2008; 59(5): 632-41.
28. Abedi M, Manshadi FD, Khalkhali M, Mousavi SJ, Baghban AA, Montazeri A, et al. Translation and validation of the Persian version of the STarT Back Screening Tool in patients with nonspecific low back pain. Man Ther 2015; 20(6): 850-4.
29. Bijur PE, Silver W, Gallagher EJ. Reliability of the visual analog scale for measurement of acute pain. Acad Emerg Med 2001; 8(12): 1153-7.
30. Arifin N, Abu Osman NA, Wan Abas WA. Intrarater test-retest reliability of static and dynamic stability indexes measurement using the Biodex Stability System during unilateral stance. J Appl Biomech 2014; 30(2): 300-4.
31. Osugi T, Iwamoto J, Yamazaki M, Takakuwa M. Effect of a combination of whole body vibration exercise and squat training on body balance, muscle power, and walking ability in the elderly. Ther Clin Risk Manag 2014; 10: 131-8.
32. Alam MM, Khan AA, Farooq M. Effect of whole-body vibration on neuromuscular performance: A literature review. Work 2018; 59(4): 571-83.
33. Hodges P. Which exercise for chronic low back pain? (NHMRC Project Grant administered by the University of Sydney) (2007–2010). Sydney, Australia: University of Sydney; 2007.
34. Micke F, Weissenfels A, Wirtz N, von SS, Dormann U, Kohl M, et al. Similar pain intensity reductions and trunk strength improvements following whole-body electromyostimulation vs. whole-body vibration vs. conventional back-strengthening training in chronic non-specific low back pain patients: A three-armed randomized controlled trial. Front Physiol 2021; 12: 664991.
35. Armstrong RA. When to use the Bonferroni correction. Ophthalmic Physiol Opt 2014; 34(5): 502-8.
36. Pourmohammadi M, Tagharrobi Z, Sharifi K, Sooki Z, Zare Joshaghani F. Effect of auriculotherapy on sleep quality in elderly with chronic low back pain: A single-blind randomized clinical trial. Complement Med J 2021; 10(4): 308-27.
37. Saragiotto BT, Maher CG, Yamato TP, Costa LOP, Costa LCM, Ostelo RWJG, et al. motor control exercise for nonspecific low back pain: a cochrane review. Spine (Phila Pa 1976) 2016; 41(16): 1284-95.
38. Gorji SM, Mohammadi Nia SH, Watt P, Henrique MP, Oliveira R. Pain neuroscience education and motor control exercises versus core stability exercises on pain, disability, and balance in women with chronic low back pain. Int J Environ Res Public Health 2022; 19(5).
39. Paungmali A, Joseph LH, Punturee K, Sitilertpisan P, Pirunsan U, Uthaikhup S. Immediate effects of core stabilization exercise on beta-endorphin and cortisol levels among patients with chronic nonspecific low back pain: A randomized crossover design. J Manipulative Physiol Ther 2018; 41(3): 181-8.
40. Chimenti RL, Frey-Law LA, Sluka KA. A mechanism-based approach to physical therapist management of pain. Phys Ther 2018; 98(5): 302-14.
41. Kwon SH, Oh SJ, Kim DH. The effects of lumbar stabilization exercise on transversus abdominis muscle activation capacity and function in low back pain patients. Isokinetics and Exercise Science 2020; 28(2): 147-52.
42. Ibrahim AA, Akindele MO, Ganiyu SO. Effectiveness of patient education plus motor control exercise versus patient education alone versus motor control exercise alone for rural community-dwelling adults with chronic low back pain: A randomised clinical trial. BMC Musculoskelet Disord 2023; 24(1): 142.
43. Dong Y, Wang W, Zheng J, Chen S, Qiao J, Wang X. Whole body vibration exercise for chronic musculoskeletal pain: A systematic review and meta-analysis of randomized controlled trials. Arch Phys Med Rehabil 2019; 100(11): 2167-78.
44. Marin PJ, Garcia-Gutierrez MT, Da Silva-Grigoletto ME, Hazell TJ. The addition of synchronous whole-body vibration to battling rope exercise increases skeletal muscle activity. J Musculoskelet Neuronal Interact 2015; 15(3): 240-8.
45. Donahue RB, Vingren JL, Duplanty AA, Levitt DE, Luk HY, Kraemer WJ. Acute effect of whole-body vibration warm-up on footspeed quickness. J Strength Cond Res 2016; 30(8): 2286-91.
46. Chang SF, Lin PC, Yang RS, Yang RJ. The preliminary effect of whole-body vibration intervention on improving the skeletal muscle mass index, physical fitness, and quality of life among older people with sarcopenia. BMC Geriatr 2018; 18(1): 17.
47. del Pozo-Cruz B, Hernandez Mocholi 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(8): 689-94.
48. Demoulin C, Crielaard JM, Vanderthommen M. Spinal muscle evaluation in healthy individuals and low-back-pain patients: A literature review. Joint Bone Spine 2007; 74(1): 9-13.
49. Ong A, Anderson J, Roche J. A pilot study of the prevalence of lumbar disc degeneration in elite athletes with lower back pain at the Sydney 2000 Olympic Games. Br J Sports Med 2003; 37(3): 263-6.
50. Omkar SN, Vishwas S, Tech B. Yoga techniques as a means of core stability training. J Bodyw Mov Ther 2009; 13(1): 98-103.
51. Jeffreys I. Developing a progressive core stability program. Strength Conditioning J 2002; 24(5): 65-6.
52. Detmar SB, Aaronson NK. Quality of life assessment in daily clinical oncology practice: A feasibility study. European Journal of Cancer 1998; 34(8): 1181-6.

53. Kang SH, Kim CW, Kim YI, Kim KB, Lee SS, Shin KO. Alterations of muscular strength and left and right limb balance in weightlifters after an 8-week balance training program. J Phys Ther Sci 2013; 25(7): 895-900.
54. Behm DG, Anderson K, Curnew RS. Muscle force and activation under stable and unstable conditions. J Strength Cond Res 2002; 16(3): 416-22.
55. Gardner T, Refshauge K, McAuley J, Hubscher M, Goodall S, Smith L. Combined education and patient-led goal setting intervention reduced chronic low back pain disability and intensity at 12 months: A randomised controlled trial. Br J Sports Med 2019; 53(22): 1424-31.
56. Dolbow J, Throckmorton Z. Neuroanatomy, spinal cord myotatic reflex. In: StatPearls. Treasure Island, FL: StatPearls Publishing; 2022.
57. Lai Z, Lee S, Chen Y, Wang L. Comparison of whole-body vibration training and quadriceps strength training on physical function and neuromuscular function of individuals with knee osteoarthritis: A randomised clinical trial. J Exerc Sci Fit 2021; 19(3): 150-7.
58. Chaltron C. Influence of whole body vibration on hamstrings neuromuscular function in healthy individuals. Toledo, OH: ToledoUniversity of Toledo; 2020.
59. Delecluse C, Roelants M, Verschueren S. Strength increase after whole-body vibration compared with resistance training. Med Sci Sports Exerc 2003; 35(6): 1033-41.
60. Arinli Y, Umutlu G, Pehlevan Z. The interactions between agonist-to-antagonist muscle strength performance and plantar pressure distribution, foot contact area, and impulse in novice ballet dancers. J Back Musculoskelet Rehabil 2023; 36(6): 1385-97.
61. Lidiane CC, Edgar R, Daniel T, Samara A, Rafael L, da Costa KSA, et al. Whole body vibration on the neuromuscular performance of elderls: randomized controlled trial. Phys Occup Ther Geriatr 2023; 41(1): 75-88.
62. Shadmehr A. The effects of whole body vibration on balance disorders. Aud Vestib Res. 2017; 22(1): 1-9.