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# **Effect of oscillatory whole-body vibration versus neuromuscular exercise on static and dynamic balance in patients with knee osteoarthritis**

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**Abstract**---Objective: This study aimed to compare the effect of Whole body vibration (WBV) versus neuromuscular exercise (NEMEX) to prove which treatment produced significant effect on pain, knee function disability, static and dynamic postural stability in patients with knee osteoarthritis (KOA). Method: Forty-five patients (39 women and 6 men) aged 45 to 62 years with grade 2 KOA were randomly assigned into the following three groups (all n = 15): group A (control group) received traditional treatment only (US, stretching and strengthening exercise); group B received NEMEX and traditional treatment and group C received WBV exercise and traditional treatment. Outcome measures were assessed pre and post treatment and included pain severity using the Arabic numerical pain rating scale (ANPRS), functional disability by the Western Ontario and McMaster Universities Osteoarthritis index, static balance (close and open eye) by Unipedal Stance Test and dynamic stability by Biodex Balance System (BBS). Results: The within-group analysis showed significant changes in pain severity, functional disability, static and

dynamic stability index in groups B and C pre and post treatment ( $p < 0.05$ ). The between-group analysis showed significant differences in all variables after treatment between group A and B, Group A and C, but no significant differences between Group B and C. Conclusion: WBV and neuromuscular exercise are effective for the treatment of KOA.

**Keywords**--Whole body vibration; Neuromuscular exercise; Knee osteoarthritis; Biodex balance system.

## Introduction

Osteoarthritis (OA) is the most commonly documented reason for chronic musculoskeletal pain, mobility disability and joint instability and therefore denotes a significant problem on healthcare system<sup>1, 2</sup>. It is being confronted with rising frequency as the population remains to age<sup>3</sup>.

Dynamic balance is important for independence and those with knee OA expose diminishing in dynamic balance ability and increased risk of falling<sup>4</sup>.

Whole body vibration (WBV) is a neuromuscular rehabilitation that reduces pain improves balance, proprioception, strength and gait pattern in both athletic and non-athletic individual<sup>5, 6, 7, 8, 9</sup>. Recent research has demonstrated that it is a successful and non-invasive treatment option for people with KOA because it causes rapid changes in the length of the muscle-tendon complex and activates the primary endings of the muscle spindles in response to the tonic vibration reflex. These physiological changes enhance proprioceptive feedback, enhance function, and reduce the risk of further injuries<sup>10, 11, 12</sup>.

Neuromuscular exercise (NEMEX) combines of proprioceptive, strength, and balance exercises as part of a complete rehabilitation of the body<sup>13</sup>. NEMEX aims to improve sensorimotor control and functional joint stabilization by addressing movement quality in all three movement planes. NEMEX has also been proven to increase the quality of articular cartilage in middle-aged patients who have had menisctomies and are at high risk of KOA<sup>14</sup>. Moreover, Riemann and Lephart stated that neuromuscular training were originally designed for the management of chronic musculoskeletal painful conditions<sup>15</sup>.

WBV has proven to be effective on postural sway with comparison to conventional balance training<sup>8</sup>. Moreover, WBV can be used to acutely enhance spinal hyperexcitability, muscles co-contraction, and modulate neuromuscular control during balance postural demanding tasks especially with populations suffering from postural instability<sup>6, 8</sup>.

On the other hand, Trees et al demonstrated that while exercise and neuromuscular training are theoretically beneficial and common treatment for knee injury, their efficacy in treating knee injury and preventing OA and the superiority of one form of exercise intervention over another are not supported by high quality trials<sup>16</sup>.

Hence, the aim of this study was to compare between WBV with neuromuscular exercise to prove which one most effective treatment on pain, knee function disability, static and dynamic postural stability in patients with KOA.

## **Methods**

### **Study Design**

This study was a randomized controlled trial, conducted at the Outpatient Clinic Faculty of Physical Therapy, Cairo University through the period between (January to August 2021) to compare the effects of WBV and neuromuscular exercise on pain, functional disability, static and dynamic postural stability in patients with KOA. This study followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines for the trial.

### **Ethical approval**

The study was ethically approved by the ethical committee of the Faculty of Physical Therapy, Cairo University, Egypt (NO:P.T.REC/012/002780) and registered at Pan African Clinical Trial Registry (registration number ID PACTR 202010869767272).

### **Sample size calculation**

Sample size calculation was performed prior to the study using G\*Power statistical software (version 3.1.9.2; Franz Faul, University of Kiel, Germany). The calculations were based on an effect size of = 0.23,  $\alpha=0.05$  and power=0.95. The appropriate required sample size was 42. The primary outcome measure was pain score. To obtain the expected dropout rate before the end of the trial, a total of 45 patients were included in the study.

In this study, 62 patients with moderate unilateral knee OA were identified as potential participants based on the orthopedic physical therapy clinic records. Twelve patients did not meet the inclusion criteria, and five subjects refused to participate in the study. A total of 45 patients were randomly assigned into three equal groups after they provided informed consent. Group A received traditional treatment only (US, stretching and strengthening exercise, group B received neuromuscular exercise and traditional treatment and group C received WBV exercise and traditional treatment. Randomization was performed using a sealed envelope (see **figure 1**).

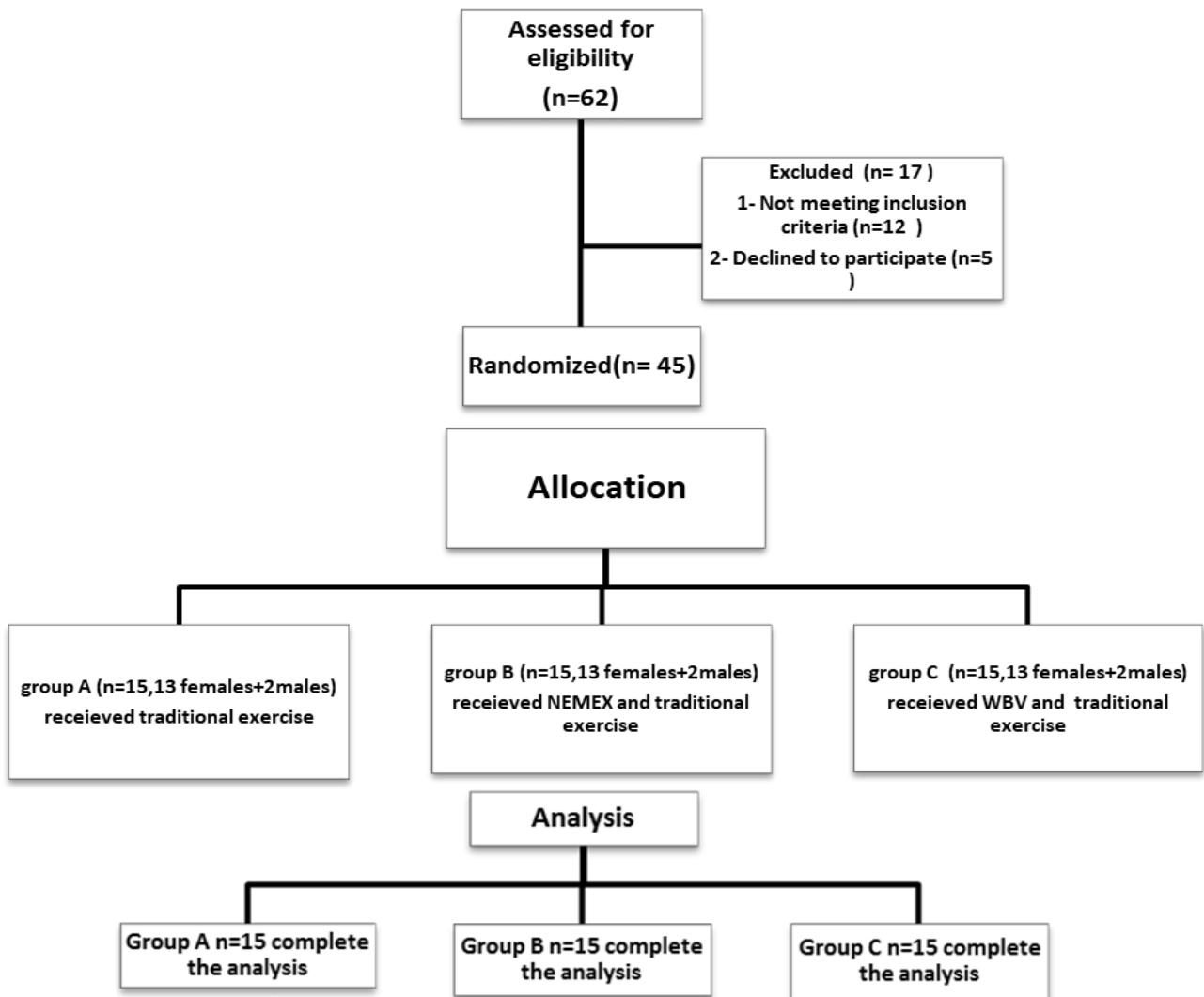
### **Patient characteristics**

The patients' examination and treatment procedures were carried out by the same therapist before and after the treatment period.

**The inclusion criteria** was patients aged 45 and 62 years <sup>17</sup>; with symptomatic unilateral KOA, which lasted for 3 months, based on the clinical criteria of the American College of Rheumatology as diagnosed by a physician <sup>18</sup>; patients with

grade 2 KOA based on X-ray results according to Kellgren and Lawrence classification<sup>18</sup>; and with grade 5 or higher pain intensity based on ANPRS <sup>19</sup>.

**The exclusion criteria** was inflammatory knee diseases; metabolic bone disease; history of knee trauma; past knee surgery; previous intra joint injection; and usage of analgesics in the previous three months <sup>20</sup>.



**Figure 1: Flow chart for patients in the study.**

### **Procedures Assessments**

**Pain intensity** was assessed by Arabic Numeric Pain Rating Scale (ANPRS), which is a ten- point pain scale with a 0 score indicating no pain and a 10

indicating the most severe pain <sup>21</sup>. The reliability of ANPRS was good to excellent <sup>21</sup>.

**The knee functional disability** was assessed using the valid and reliable modified Western Ontario and McMaster Universities Osteoarthritis index (WOMAC), which is a questionnaire that assesses people's abilities to perform daily tasks. This method is useful and valued since it is simple and allows patients' opinions on their functional limitations to be assessed <sup>22</sup>.

**Dynamic balance** was assessed using the biodex stability system (biodex medical systems, software version 3.1) which has a high level of accuracy for postural control assessment<sup>23</sup>. It establishes three numerical stability indexes to measure the deviation from the body's Center of Gravity: overall stability index (OSI), anterior-posterior stability index (API), and medial-lateral stability index (MLI). The API and MLI were used to represent the sagittal and frontal planes, respectively, while the OSI was used to represent the overall score in all directions. The lower the score, the more stable the situation <sup>24</sup>. Participants were advised to stand with both feet on the platform in a relaxed position. All subsequent tests would use the foot locations recorded in the first session. Each patient held the static position with the platform gradually declined in stability at level (6) <sup>25</sup> for 20 seconds; testing procedures were carried out with the eyes open with three test trials and a 10-second rest in between.

**Static balance** was assessed by reliable and valid Unipedal Stance Test<sup>26</sup>. Patients were instructed to stand barefoot on the affected leg while raising the other limb, so that the raised foot was near but not touching the stance limb's ankle. For the duration of the eyes open test, each patient was instructed to look on a point on the wall in front of him/her at eye level. The patient was told to cross his arms over his chest before lifting the limb. The investigator utilized a stopwatch to time the subject's ability to stand on one limb for a certain period of time. Time began when the patient lifted his foot off the floor.

When the patient lifted his foot off the floor, time began. Time was stopped when the subject: (1) uncrossed his arms, (2) utilized the raised foot (moved it near or away from the standing limb or touched the floor), (3) shifted the weight-bearing foot to maintain his balance (ie, rotated foot on the ground), (4) a maximum of 45 seconds had passed, or (5) opened eyes on eyes closed trials. The operation was done thrice, each time recording the results on the data collection sheet. The average of the three trials was recognized. Subjects alternated between three trials with their eyes open and three trials with their eyes closed. One trial set, for example, consisted of one trial with eyes open and one trial with eyes closed. To avoid tiredness, at least 5 minutes of rest were permitted between each trial <sup>27</sup>.

## **Interventions**

### **Whole Body vibration**

The oscillatory sinusoidal WBV plate (Crazy Fit machine, PS-CFM001) was used in this study. With a frequency of 50 Hz, the peak to peak amplitude was 5-8 mm <sup>28</sup>. The patients stood on the vibration platform with their feet shoulder-width

apart and their hands at their sides <sup>28</sup>. This session was performed thrice a week for four weeks <sup>29</sup>. The vibration protocol consisted of five bouts (60seconds for each bout) <sup>30</sup>.

### **Neuromuscular exercise**

Specific exercises were chosen because they involve knee movement in synergy with all lower extremity joints, are weight-bearing (closed-chain), and are functionally important. Participants will also be instructed to maintain neutral pelvic posture while performing the exercises. The selected exercises were taken from Clausen et al and Kim et al <sup>31, 32</sup>. Variations the repetitions, direction, and velocity of the movements, as well as increasing the load and/or modifying the support surface, will give progression. Each of the exercises in the program and their levels and frequencies are described in details in the following:

#### **Warning up**

Warm up performed on a stationary bicycle

**This was done for** 2 sets of 12 repetitions

#### **Lunge**

Stand with the feet a hip-width apart. Take a long step forward without lifting the toes of the rear foot. The landing must be controlled and done in 1 smooth motion. When it was done correctly, it progressed to:

**Level 1:** No requirements; upper limbs can be used for balance.

**Level 2:** This exercise is performed as level 1; in end position, perform an upper body rotation in direction of the front knee. Standing position, take a large step forward and then return. Hand support for balance if needed.

**This was done for** 2 sets of 12 repetitions

#### **Pelvic lift**

Lie supine with the feet on gymnasium ball with the knees extended to a maximum of 5 degree flexion. When it was done correctly, it progressed to:

**Level 1:** with both feet on the ball, lift and lower the pelvis in a slow, controlled manner.

**Level 2:** with both feet on the ball and pelvis lifted, extend and flex the knees in a slow, controlled manner.

**Level 3:** with 1 lower limb on the ball and the pelvis lifted during the whole exercise and with the hip extended, flex and extend the knee in a slow, controlled manner. The upper limbs are held to the sides for stability.

**This was done for** 2 sets of 12 repetitions

### **Squat**

#### **Level 1, Wall squats:**

Stand with your back to the wall, your feet 10cm apart, and one foot from the wall. Slowly slide down the wall to around a 30° curve, then slowly slide back up.

Wall squats (aim at positioning knee over foot).

#### **Level 2, Chair stands:**

Begin by sitting in a standard-height chair. Outstretch your hands in front of you. Slowly stand up and sit down.

**This was done for** 2 sets of 12 repetitions

### **Weight transfer**

Standing on a soft surface (thick mat or balance pillow), in broad standing with the hip external rotates, and knees well aligned over toes. When it was done correctly, it progressed to:

**Level 1:** Move body weight from side to side without lifting the feet from the ground.

**Level 2:** This exercise is performed as level 1. During the movement, lift the non-weight bearing lower limb.

**This was done for** 2 sets of 12 repetitions

### **Proprioception/balance**

Standing on different surfaces, take a double or single leg stance (ground, thick mat and balance board) with eyes open or close eye.

**This was done for** 2 sets of 12 repetitions

### **Elastic band**

Stand with straight lower limbs and the load on 1 lower limb. Perform the exercise in every direction, hip extension, hip flexion and knee flexion, hip internal and external rotation, hip adduction and abduction. Perform every direction in 1 sequence without lowering the working leg.

#### **Level 1**

**A. Hip abductors/hip adductors:** Standing on one leg, rubber band other leg. Pull rubber band out (hip abductors) and in (hip adductors). Make sure the

rubber band is taut in the resting position as well. Focus is on the hip abductors of the standing leg, keeping an appropriate position of the joints in the lower extremity in relation to each other and in relation to the trunk, i.e., without lateral displacement of the hip-pelvis region.

**B. Knee extensors/knee flexors:** Sitting position. Wrap a rubber band around one of your feet. Pull the rubber band forward (knee flexors) and backwards (knee flexors) (knee flexors). Make sure the rubber band is taut in the resting position as well.

**This was done for 2 sets of 12 repetitions**

## **Level 2**

**A. Hip abductors/hip adductors:** As above, standing on uneven surface (e.g., foam pillow or thick mattress).

**B. Knee extensors/knee flexors:** As above, with increasing repetitions.

**This was done for 2 sets of 12 repetitions**

## **Cooling down**

The cooling down part consists of walking exercises forward and backwards, approximately 10 meters in each direction, in front of mirror.

## **Traditional exercise**

### **Ultrasound**

Deep heating therapy was provided using ultrasound device (Gymna US, pulson 200). A 4-cm diameter applicator was used to apply continuous US waves with a 1- MHz frequency and 1-watt/cm<sup>2</sup> power. Each session of US therapy lasted 5 minutes <sup>34</sup>. US therapy was continued for four weeks for three sessions per week.

### **Stretching exercise**

Immediately after US application, each patient was instructed to perform hamstring and calf muscular stretching and strengthening exercises in the following order: hamstrings muscle stretching and calf muscle stretching. The passive stretching techniques were repeated three times every session by the physical therapist. Each stretch lasted 30 seconds, with 10-second rest periods between them <sup>34</sup>.

### **Strengthening exercise**

The patients were instructed to do the following tasks: 1) 20 repetitions of isometric quadriceps contraction (quadriceps drill) in full knee extension for 5 seconds, followed by a 5 second rest <sup>35</sup>; 2) straight leg raising exercise (the patient laid in the crock laying position with the other limb kept in a flexed position). The patients were asked to contract the quadriceps muscle, elevate the limb to 45

degrees and hold it for 6 seconds, then slowly lower the limb and release for 6 seconds; the exercise was done three times per session)<sup>34</sup>. Stretching and strengthening exercises were done three times a week for four weeks.

Treatment was summarized to WBV exercise and NEMEX exercise and traditional treatment (US, stretching and strengthening exercise).

### Data collection

Data were screened, for normality assumption test and homogeneity of variance. Normality test of data using Shapiro-Wilk test was used, that reflect the data was normally distributed ( $P > 0.05$ ) after removal outliers that detected by box and whiskers plots. Additionally, Levene's test for testing the homogeneity of variance revealed that there was no significant difference ( $P > 0.05$ ). So, the data are normally distributed and parametric analysis is done.

### Statistical analysis

The statistical analysis was conducted by using statistical SPSS Package program version 25 for Windows (SPSS, Inc., Chicago, IL). Data are expressed as mean and standard deviation for age, weight, height, BMI, ANPRS, WOMAC function, static balance (close and open eye), and dynamic balance (OL, AP, and ML). Chi-square test used to compare for gender and side variables among control, NEMEX, and WBV groups. Multivariate analysis of variance (MANOVA) used to compare the tested major variables of interest at different tested groups and measuring periods. Mixed design 3 x 2 MANOVA-test was used, the first independent variable (between subject factors) was the tested group with 3 levels (control group, NEMEX group, and WBV group). The second independent variable (within subject factor) was measuring periods with 2 levels (pre- and post-treatment). Bonferroni correction test was used to compare between pairwise within and between groups of the tested variables which P- value was significant from MANOVA test. All statistical analyses were significant at probability ( $P \leq 0.05$ ).

### Results

Forty-five patients were participated in this study and distributed randomly into 15 patients in each group. There were no significant differences among control, NEMEX, and WBV groups for age ( $P = 0.890$ ;  $P < 0.05$ ), weight ( $P = 0.939$ ;  $P < 0.05$ ), height ( $P = 0.641$ ), BMI ( $P = 0.889$ ;  $P < 0.05$ ), gender ( $P = 1.000$ ;  $P < 0.05$ ), and side ( $P = 1.000$ ;  $P < 0.05$ ) as represented in Table (1).

**Table 1.**

Comparison of general characteristics among control, NEMEX, and WBV groups

Items	Groups			P-value
	Control group (n=15)	NEMEX group (n=15)	WBV group (n=15)	
Age (year)	52.47 ±6.82	53.07 ±5.44	53.53 ±5.85	0.890
Weight (kg)	79.93 ±8.24	79.13 ±7.09	79.93 ±5.81	0.939

Height (cm)	162.40 ±2.99	160.53 ±5.70	161.80 ±7.03	0.641
BMI (Kg/cm <sup>2</sup> )	30.28 ±2.74	30.73 ±2.79	30.59 ±2.30	0.889
Gender (males : females)	2 (13.30%): 13 (86.70%)	2 (13.30%):13 (86.70%)	2 (13.30%):13 (86.70%)	1.000
Side (right : left)	8 (53.30%):7 (46.70%)	8 (53.30%): 7 (46.70%)	8 (53.30%): 7 (46.70%)	1.000

Quantitative data are expressed as mean ±standard deviation (SD) and compared statistically by ANOVA test; Qualitative data are expressed as number (percentage) and compared statistically by Chi-square test; P-value: probability value; P-value>0.05: non-significant

The statistical analysis within each group (Table 2) revealed that there were significantly lower in ANPRS at post-treatment than pre-treatment within control group (P=0.0001; P<0.05), NEMEX group (P=0.0001; P<0.05), and WBV group (P=0.0001; P<0.05). The WOMAC function significantly decreased at post-treatment compared with pre-treatment within NEMEX group (P=0.0001; P<0.05) and WBV group (P=0.0001; P<0.05), but non-significant decreased was observed in control group (P=0.074; P>0.05) between pre-treatment and post-treatment.

The statistical analysis among 3 groups (Table 2) showed no significant differences in mean values of pre-treatment ANPRS (P=0.331; P>0.05) and WOMAC function (P=0.270; P>0.05). At post-treatment, there were significant differences in both ANPRS (P=0.0001; P<0.05) and WOMAC function (P=0.0001; P<0.05) due to group effect.

**Table 2.**

Inter- and intra-groups comparison for ANPRS and WOMAC function variables

Items	Items	Groups (Mean ±SD)			P-value
		Control group (n=15)	NEMEX group (n=15)	WBV group (n=15)	
ANPRS	Pre-treatment	7.60 ±1.24	8.40 ±1.24	7.93 ±1.53	0.331
	Post-treatment	5.33 ±1.98	3.13 ±1.59	1.84 ±1.01	0.0001*
	Mean difference	2.27	5.27	6.09	
	Change %	29.87%	62.74%	76.80%	
	P-value	0.0001*	0.0001*	0.0001*	
WOMAC function	Pre-treatment	49.73 ±14.95	41.40 ±12.15	54.00 ±17.29	0.270
	Post-treatment	41.26 ±11.37	16.86 ±9.34	18.45 ±9.73	0.0001*
	Mean difference	8.46	24.53	35.54	
	Change %	17.03%	59.28%	65.83%	
	P-value	0.074	0.0001*	0.0001*	

Data are expressed as mean ± standard deviation (SD)

P-value: probability value

\* Significant (P<0.05)

The statistical analysis within each group (Table 3) revealed that there were significantly ( $P < 0.05$ ) higher in close and open eye function at post-treatment than pre-treatment within NEMEX group ( $P = 0.0001$ ;  $P < 0.05$ ) and WBV group ( $P = 0.0001$ ;  $P < 0.05$ ), but non-significant ( $P > 0.05$ ) increase was noted within control group ( $P = 0.279$  and  $P = 0.409$ , respectively) between pre-treatment and post-treatment.

The statistical analysis among 3 groups (Table 3) showed no significant differences in mean values of pre-treatment close eye ( $P = 0.442$ ;  $P > 0.05$ ) and open eye ( $P = 1.000$ ;  $P > 0.05$ ). But, there were significant differences in close eye ( $P = 0.0001$ ;  $P < 0.05$ ) and open eye ( $P = 0.011$ ;  $P < 0.05$ ) at post-treatment among control, NEMEX, and WBV groups.

**Table 3.**  
Inter- and intra-groups comparison for static balance variables

Items	Items	Groups (Mean $\pm$ SD)			P-value
		Control group (n=15)	NEMEX group (n=15)	WBV group (n=15)	
Close eye	Pre-treatment	3.73 $\pm$ 1.62	4.50 $\pm$ 2.09	4.81 $\pm$ 1.71	0.442
	Post-treatment	4.64 $\pm$ 1.86	8.47 $\pm$ 3.92	7.95 $\pm$ 1.78	0.0001*
	Mean difference	0.91	3.97	3.14	
	Change %	27.00%	88.22%	65.28%	
	P-value	0.279	0.0001*	0.0001*	
Open eye	Pre-treatment	16.23 $\pm$ 8.77	16.22 $\pm$ 9.93	16.30 $\pm$ 8.47	1.000
	Post-treatment	19.48 $\pm$ 9.16	30.71 $\pm$ 11.60	28.82 $\pm$ 10.73	0.011*
	Mean difference	3.25	14.49	12.52	
	Change %	20.03%	89.33%	76.81%	
	P-value	0.409	0.0001*	0.002*	

Data are expressed as mean  $\pm$  standard deviation (SD)

P-value: probability value

\* Significant ( $P < 0.05$ )

The statistical analysis within each group (Table 4) revealed that there were significantly ( $P < 0.05$ ) decreased in OL at post-treatment than pre-treatment within NEMEX group ( $P = 0.001$ ;  $P < 0.05$ ) and WBV group ( $P = 0.0001$ ;  $P < 0.05$ ), but non-significant decrease was observed within control group ( $P = 0.832$ ;  $P > 0.05$ ) between pre-treatment and post-treatment. The WBV group had significantly lower effect on AP ( $P = 0.0001$ ;  $P < 0.05$ ) and ML ( $P = 0.0001$ ;  $P < 0.05$ ) at post-treatment than NEMEX group and control group, which gave a non-significant ( $P > 0.05$ ) decrease on AP ( $P = 0.090$  and  $P = 0.373$ , respectively) and ML ( $P = 0.164$  and  $P = 0.537$ , respectively).

The statistical analysis among 3 groups (Table 4) showed no significant differences in mean values of pre-treatment OL ( $P = 0.147$ ;  $P > 0.05$ ), AP ( $P = 0.070$ ,  $P > 0.05$ ), and ML ( $P = 0.300$ ;  $P > 0.05$ ). But, at post-treatment, there were

significantly differences due to groups effect on OL ( $P=0.004$ ;  $P<0.05$ ), AP ( $P=0.028$ ,  $P<0.05$ ), and ML ( $P=0.007$ ;  $P<0.05$ ).

Post-hoc test for ANPRS, WOMAC function, static balance, and dynamic balance variables between pairwise of the groups as presented in Table (5). There were significant differences ( $P<0.05$ ) in ANPRS ( $P=0.0001$ ), WOMAC function ( $P=0.0001$ ), close eye ( $P=0.0001$ ), open eye ( $P=0.016$ ), OL ( $P=0.019$ ), AP ( $P=0.046$ ), and ML ( $P=0.025$ ) between control group vs. NEMEX group and there were significant differences ( $P<0.05$ ) in ANPRS ( $P=0.0001$ ), WOMAC function ( $P=0.0001$ ), close eye ( $P=0.001$ ), open eye ( $P=0.048$ ), OL ( $P=0.006$ ), AP ( $P=0.038$ ), and ML ( $P=0.014$ ) between control group vs. WBV group. But, no significant differences ( $P>0.05$ ) in ANPRS ( $P=0.056$ ), WOMAC function ( $P=1.000$ ), close eye ( $P=1.000$ ), open eye ( $P=1.000$ ), OL ( $P=1.000$ ), AP ( $P=1.000$ ), and ML ( $P=1.000$ ) between NEMEX group vs. WBV group.

**Table 4**  
Inter- and intra-groups comparison for dynamic balance variables

Items	Items	Groups (Mean $\pm$ SD)			P-value
		Control group (n=15)	NEMEX group (n=15)	WBV group (n=15)	
OL	Pre-treatment	4.20 $\pm$ 1.10	4.38 $\pm$ 2.10	5.22 $\pm$ 1.95	0.147
	Post-treatment	4.08 $\pm$ 1.86	2.55 $\pm$ 0.59	2.34 $\pm$ 0.51	0.004*
	Mean difference	0.12	1.83	2.87	
	Change %	2.86%	41.78%	55.17%	
	P-value	0.832	0.001*	0.0001*	
AP	Pre-treatment	3.55 $\pm$ 1.08	2.91 $\pm$ 1.49	4.07 $\pm$ 2.13	0.070
	Post-treatment	3.11 $\pm$ 1.53	2.06 $\pm$ 0.56	1.85 $\pm$ 0.63	0.028*
	Mean difference	0.44	0.85	2.22	
	Change %	14.15%	29.21%	54.55%	
	P-value	0.373	0.090	0.0001*	
ML	Pre-treatment	2.72 $\pm$ 1.33	2.11 $\pm$ 1.27	3.23 $\pm$ 0.87	0.300
	Post-treatment	2.52 $\pm$ 0.52	1.65 $\pm$ 0.40	1.59 $\pm$ 0.26	0.007*
	Mean difference	0.20	0.45	1.64	
	Change %	7.35%	21.80%	50.77%	
	P-value	0.537	0.164	0.0001*	

Data are expressed as mean  $\pm$  standard deviation (SD); P-value: probability value;

\* Significant ( $P<0.05$ )

**Table 5.**  
Post-hoc test for outcomes variables between pairwise of NEMEX, WBV, and control groups

Variables	Items	Post-hoc (Bonferroni test)		
		Control NEMEX	vs.	Control vs. WBV NEMEX vs. WBV

ANPRS	Mean	5.33 ±1.98	3.13 ±1.59	1.84 ±1.01
	Mean difference	2.20	3.48	1.28
	P-value	0.0001*	0.0001*	0.056
WOMAC function	Mean	41.26 ±11.37	16.86 ±9.34	18.45 ±9.73
	Mean difference	24.40	22.81	1.58
	P-value	0.0001*	0.0001*	1.000
Close eye	Mean	4.64 ±1.86	8.47 ±3.92	7.95 ±1.78
	Mean difference	3.82	3.30	0.52
	P-value	0.0001*	0.001*	1.000
Open eye	Mean	19.48 ±9.16	30.71 ±11.60	28.82 ±10.73
	Mean difference	11.23	9.34	1.89
	P-value	0.016*	0.048*	1.000
OL	Mean	4.08 ±1.86	2.55 ±0.59	2.34 ±0.51
	Mean difference	1.53	1.74	0.21
	P-value	0.019*	0.006*	1.000
AP	Mean	3.11 ±1.53	2.06 ±0.56	1.85 ±0.63
	Mean difference	1.05	1.26	0.21
	P-value	0.046*	0.038*	1.000
ML	Mean	2.52 ±0.52	1.65 ±0.40	1.59 ±0.26
	Mean difference	0.87	0.93	0.06
	P-value	0.025*	0.014*	1.000

P-value: probability value

\* Significant (P<0.05)

## Discussion

This study was conducted to determine and compare the effects between WBV versus neuromuscular exercise on the treatment of KOA. According to our results, there was a statistically significant difference in pain, knee function disability, static and dynamic postural stability after WBV and neuromuscular exercise, and there was no statistically significant difference between them.

It is theorized that this decreased dynamic balancing ability may be attributed to neuromuscular changes related to impairments combined with the disease and beyond those changes normally experienced with healthy aging <sup>36</sup>.

Saijo et al stated that WBV motivates receptors Pacinian corpuscle and Meissner corpuscles which endure the vibration and stimulates interneurons within the spinal cord by producing signals through myelinated fiber A-beta fiber. Also, it suppresses the pain transmitted by C-fiber or A-delta fiber <sup>37</sup>. In addition, Jorn Rittweger stated that WBV might diminish the perception of pain because vibration influences the afferent discharge of nociceptors <sup>38</sup>. Furthermore, the results of this study came in agreement with the results of Zafar et al who revealed that systematic review of the WBV on knee OA concluded that WBV was effective in reducing knee pain and improving function <sup>39</sup>.

Moreover, Ageberg et al discovered that neuromuscular exercise is allowing for more synchronization and coordination in the activation of lower limb muscle groups during knee motions, thus improving the execution of functional activities <sup>40, 41</sup>.

Additionally, Villadsen et al who confirmed that neuromuscular training has been shown to enhance physical function and pain by up to 20% in clinically relevant methods <sup>42</sup>.

The oscillating waves of vibration increase motor unit synchronization, promote antagonistic muscle inhibition, coordinate agonist and antagonist muscle contraction, and amplify motor unit firing rate. These neural adaptations of the lower extremities play an important role in balance and body mobility as it stimulates the neuromuscular system and activates the calf muscles and posture through a phenomenon also known as the “tonic vibration reflex.” and eventually facilitate muscle contractions. Furthermore, WBV-induced central nervous system stimulation is another reason to improve balance <sup>43</sup>.

This was supported by Melnyk et al indicated that a single vibration session increased the hamstrings' short latency response, improved knee joint stability, and caused postactivation potentiation mostly downstream of the neuromuscular junction <sup>44</sup>. Additionally, Bruyere et al who stated that the assumption of enhanced proprioceptive input generated by excessive stimulation of the muscle spindles as a result of whole-body vibration is frequently followed with an improvement in static balance <sup>45</sup>. As the results of this study came in agreement with Bogarets et al who reported that WBV was associated with a reduction in the frequency of falls on a moving platform and improved some aspects of postural control in the elderly <sup>46</sup>.

Rittweger et al stated that WBV improves heart rate and oxygen uptake, which in the long run may translate into higher cardiorespiratory efficiency <sup>47</sup>.

Slavko et al stated that WBV can affect the neuromuscular system and enhance reflex responses due to vibration's ability to (a) stimulate subcutaneous proprioceptors, (b) stimulation of the muscle spindles, (c) activate golgi tendon organs, improving the tonic and antagonist vibration reflexes, and (d) stimulation of subcutaneous contractile proprioceptors making muscle contraction receptors <sup>48</sup>.

Our results were consistent with the results of Roos et al who stated that neuromuscular training may enhance limb segmental alignment, sensorimotor control, and joint stability <sup>49</sup>.

Similarly In their randomized study, Roos and Dahlberg found that 4 months of NEMEX were associated with increased proteoglycan content of the cartilage matrix immediately after an exercise intervention. Increased proteoglycan content translates into greater cartilage stiffness and a greater ability to withstand load <sup>50</sup>. Moreover, there is evidence that moderate neuromuscular exercise improves joint symptoms and function and cartilage quality in those at high risk of developing OA <sup>50</sup>.

Additionally, Kapreli et al who suggested that the neuromuscular training increased coordination between muscle groups and improved the response to sensorial information. In neuromuscular training, the patient progresses through exercises in different postures, base of support, and challenges to their center of

gravity. So, each exercise elicits automatic and reflexive muscular stabilization demanding the patient to maintain postural control under a variety of situations<sup>51</sup>.

Additionally, Rogers et al have shown that neuromuscular techniques improves dynamic joint stability using a series of physical activities such as agility and balance exercises to activate, challenge, and adapt the nervous system's proprioceptors to maintain balance and to improve activities of daily living function<sup>52</sup>.

As the results of this study came in agreement with Ahmed et al who confirmed that the neuromuscular training produced significant improvement of all balance measurements<sup>53</sup>.

Contrary to our results, Pollock et al who demonstrated that an acute bout of high or low amplitude WBV had no effect on joint position perception, static balance, or decreased cutaneous sensitivity in young healthy adults<sup>54</sup>.

Our results also contradict the results of Carmeli et al who showed that there was a documented lack of improvement in both postural control and balance in these subjects 6 months after the intervention of WBV<sup>55</sup>.

Furthermore, our results also contradict the results of Mani et al who discovered that three out of five studies showed a decline in standing balance following WBV exposure, while two simulated laboratory experiments showed no changes in standing balance<sup>56</sup>.

Also, a controversial result was noted by Zahov and Medzhidieva who stated that WBV could have side effects as low back pain (LBP), altered peripheral nervous system function, visual and vestibular disturbances (e.g., motion sickness, giddiness and disturbed balance), as well as prostate and gastrointestinal problems<sup>57</sup>.

Our results also contradict of the results of Torvinen et al's studies found that the WBV intervention had no effect on the individuals' dynamic or static balance in either short-term (4-monthes) or long-term (8-monthes) therapy<sup>58</sup>.

A controversial result was noted by Clausen et al who stated that with few reports of short-term increased pain from neuromuscular exercise<sup>59</sup>.

### **Study limitation**

This study had the following limitation: Firstly, it did not have a control over the daily activities of the patients. Secondly, the long-term effects of this treatment were not identified.

### **Conclusion**

WBV and neuromuscular exercise are effective for the treatment of patients with KOA, without difference between them.

## Recommendations

Future studies aim to look into the optimum type of exercise therapy for enhancing neuromuscular function, reducing symptoms, and maybe slowing the progression of degenerative knee disease in different individuals.

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