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RESEARCH ARTICLE

Effect of whole-body vibration on sensation, functional mobility and gait on diabetic neuropathy patients

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Abstract

Diabetic neuropathy (DN) manifests as decreased sensation due to nerve damage, limiting daily activities. Changes in foot pressure distribution, caused by reduced protective sensations, can lead to gait variations and reduced functional mobility. The aim of the study is to investigate the effect of whole-body vibration (WBV) on sensation, functional mobility, and gait in diabetic neuropathy patients. About 60 participants, both male and female, aged between 40 to 60 years, with diabetic neuropathy, were selected based on inclusion and exclusion criteria and allocated to the vibration group (VT) and sensorimotor group (ST). Both groups received the treatment three days per week for four weeks. In the experimental group, each session consisted of two sets of five 30-second vibration squats along with the sensorimotor training. The control group received only sensorimotor training. The subjects were assessed using the monofilament, timed up and go test (TUGT), and dynamic gait index (DGI). After the intervention, the mean and standard deviation (SD) values for the control group increased from (5.30 ± 1.208) to (6.77 ± 0.971, $p = 0.000$) for monofilament, for TUGT from (19.13 ± 5.198) to (16.40 ± 5.001, $p = 0.000$), and for DGI from (14.60 ± 2.749) to (16.93 ± 2.180, $p = 0.000$). For the experimental group, the mean and SD values for monofilament increased from (4.90 ± 1.213) to (7.47 ± 0.973, p = 0.000), for TUGT from (20.23 ± 4.297) to (16.10 ± 3.960, $p = 0.001$), and for DGI from (13.97 ± 2.539) to (17.30 ± 2.246, $p = 0.0000$). Whole-body vibration therapy demonstrates greater effectiveness in improving sensation, functional mobility, and gait in diabetic neuropathy patients when compared with sensorimotor training. WBV and sensorimotor training both proved to be effective training programs in enhancing sensation and improving functional mobility and gait.

Keywords: Diabetic neuropathy, Whole Body Vibration training, Sensorimotor training, Monofilament, Gait, Functional mobility.

Introduction

Diabetic peripheral neuropathy (DPN) is a microvascular complication of diabetes that damages peripheral nerves due to impaired glucose metabolism (Sohrabzadeh *et al*., 2021). The prevalence rate varies from 54% in type 1 to 45% in others (Jahantigh *et al*., 2020). Activation or inhibition of neuronal pathways and cellular homeostasis can be disturbed due to prolonged hyperglycemia (Wang *et al*., 2022), which can lead to apoptosis and mitochondrial dysfunctions, resulting in neuropathy (Sanaye & Kavishwar, 2023). In diabetic neuropathy (DN), the patient is unable to perform activities of daily living because of impaired sensations due to damage to peripheral nerves (Sabziparvar *et al*., 2021; Kang *et al*., 2019; Schnapp & Delcroix, 2022). It also increases the risk of diabetic foot by disrupting balance and altering pressure distribution on the feet (Sabziparvar *et al*., 2021). Because of this damage, there is impairment in muscle function, notably affecting mobility, especially in the geriatric population (Holmes & Hastings, 2021).

The alterations in sensory and motor control due to diabetic neuropathy impact both the quality and quantity of sensory information needed for walking (Melese *et al*., 2020). Studies indicate that daily step count in diabetic patients is inversely associated with the presence of fatty tissues, suggesting that muscle impairment adds to low levels of physical activity. This results in a reduced range of motion in the ankle and foot and diminished gait speed (Monteiro *et al*., 2022). Sensorimotor training mainly focuses on sensory and motor systems. It facilitates proprioception and somatosensory inputs, corrects muscle imbalances, and thus executes proper motor functions (Ahmad *et al*., 2019). The key component of the training is balance exercises. The goal is to advance the accurate recruitment of muscles to maintain proper joint stability (Ahmad *et al*., 2020).

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Whole-body vibration (WBV) training involves the subject standing on a vibrating surface that generates sinusoidal oscillations (Kalaoglu *et al*., 2023; Van Heuvelen *et al*., 2021). Vibrations generated from the machine are transmitted through the body via the feet and stimulate muscle spindles, which then send signals to the prefrontal cortex and neurotransmitter systems (Kalaoğlu *et al*., 2023; Rodrigues *et al*., 2022; Oroszi *et al*., 2020). According to a review conducted by Guedes *et al*. in 2023, postmenopausal women demonstrated enhancements in muscle strength and functionality following the implementation of WBV therapy (Guedes *et al*., 2023). Previous studies investigating healthy individuals have indicated that continuous vibration protocols resulted in a decrease in plantar tactile sensitivity over a short-term follow-up period (Robinson *et al*., 2018). Based on preliminary evidence, the current study aims to determine the effect of WBV on sensation, functional mobility, and gait in DN patients.

Materials and Methods

The study was a two-group pre- and post-experimental study, and the sample was collected using a convenience sampling technique. A total of 60 subjects, both male and female, were selected for the study. All the subjects were conveniently assigned to the vibration group (VT) (n = 30) and sensorimotor group (ST) (n = 30). Institutional Ethical Committee approval was obtained (Ref: EC-MPT/23/PHY/014). The procedure was explained to all the subjects, and informed consent was obtained.

The study was conducted in the Krupanidhi College of Physiotherapy OPD with a study duration of two months. Inclusion criteria were patients who were diagnosed with diabetic neuropathy, Semmes-Weinstein Monofilament Scale: 2 and above (Olaiya *et al*., 2019), Michigan Neuropathy Screening Instrument: ≥ 7 (Herman *et al*., 2012; Moghtaderi *et al*., 2006), ability to perform partial squats for 30 seconds, ability to walk without support for 20 feet, and age range of 40 to 60. Exclusion criteria included the presence of active plantar ulcers (Jamal *et al*., 2020), knee deformities (genu varum, genu valgum, knee flexion deformity) (Robinson *et al*., 2018), lower limb implants and/or orthosis (Jamal *et al*., 2020), inability to walk with or without assistance, vascular complications such as varicose veins and DVT (Çekok *et al*., 2020), lower limb fractures within the past 12 months, amputation of lower extremities other than toes (Monteiro *et al*., 2018), and active malignancy (Çekok *et al*., 2020).

Treatment was administered three days per week for four weeks, with a session duration of 30 minutes for the control group and 50 minutes for the experimental group.

Procedure

Patients in the experimental group were given sensorimotor training for 30 minutes, the same as the control group. In addition, the experimental group received whole-body vibration for 20 minutes. In WBV, vertical vibration (using KH75 Crazy Fit, Viva Fitness, India) was given in 5 different squat positions: squat with 125° knee bend, squat with heels raised, slight knee flexion with hands in 90° forward raise, slight knee flexion with hands raised sideward, and slight knee flexion with elbow flexion. Each position was maintained for 30 seconds, and a total of two sets were performed (Jamal *et al*., 2020; Manimmanakorn *et al*., 2017). About 32^{nd} rest periods were given in between. Sensorimotor training included wall slides with a ball, sit-to-stand, single-leg standing, tandem stance, toe and heel raises, walking on a straight line, high-knee march walk, and bridging (Ahmad *et al*., 2020).

Outcome Measures

Monofilament test
Timed Up and Go test
Dynamic Gait Index

Statistical Analysis

The data were analysed using SPSS for Windows. Descriptive statistics were conducted to assess the mean and standard deviation (SD) of the baseline characteristics and outcome measures. The chi-square test was employed to find the statistically significant differences between the groups. A paired t-test was utilized for within-group analysis.

Results

The mean age in both groups was 42, while the mean BMI for the control group was 24, and for the experimental group was 21, as shown in Table 1.

Table 2 shows the comparison of the monofilament, TUGT and DGI between the groups.

Table 3 shows the comparison of pre and post-test outcomes among the study participants between the groups.

Discussion

Diabetes often triggers microvascular changes that lead to nerve damage (Lepesis *et al*., 2023). It has many adverse effects on patients' lives; independence can sometimes be challenging, and the quality of life can decline without proper care and treatment (Zaino *et al*., 2023). Improvement in gait functions is an important aspect of enhancing functional mobility. Common findings in DN include loss of sensation in the foot, reduced functional mobility,

Table 1: Baseline data

Variable	*ST group*	*p-value*	*VT group*	*p-value*
Age	42 ± 59		42 ± 59	
Weight (Kg)	60 ± 97	0.732	50 ± 97	0.410
Height (Cm)	150 ± 185		150 ± 185	
BMI	24 ± 32.6		21.0 ± 31.4	

Table 2: Between the group comparison of monofilament, TUGT and DGI

Outcome measures	*ST Group*			*VT group*		
	Pre-test	*Post-test*	*p-value*	*Pre-test*	*Post-test*	*p-value*
Monofilament	5.30 ± 1.208	6.77 ± 0.971	0.000	4.90 ± 1.213	7.47 ± 0.973	0.000
TUGT	19.13 ± 5.198	16.40 ± 5.001	0.000	20.23 ± 4.297	16.23 ± 4.240	0.000
DGI	14.60 ± 2.749	16.93 ± 2.180	0.000	13.97 ± 2.539	17.33 ± 2.155	0.000

Table 3: Comparison of Pre- and Post-test outcome measure among study participants in between the groups

S. No.	*Group*	*Pre-test*			*Post-test*		
		Mono- filament	*TUGT*	*DGI*	*Mono-filament*	*TUGT*	*DGI*
		Mean ± SD	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*
1.	ST	5.30 ± 1.208	19.13 ± 5.198	14.60 ± 2.749	6.77 ± 0.971	16.40 ± 5.001	16.93 ± 2.180
2.	VT	4.90 ± 1.213	20.23 ± 4.27	13.97 ± 2.539	6.30 ± 1.149	16.10 ± 4.831	16.50 ± 2.177
Paired t-test *p-value*		T=1.153 p =0.355 (NS)	T=1.234 p =0.345 (NS)	T=0.674 p =0.708 (NS)	T=36.880 p =0.000* (S)	T=46.690 p = 0.000* (S)	T=19.892 p = 0.000* (S)

and impaired gait patterns. The present study aimed to determine the effects on sensation, functional mobility, and gait through the application of WBV. Baseline scores for sensation, functional mobility, and gait were measured using the Monofilament, TUGT, and DGI for both groups, and the post-test scores were recorded at the fourth week post-intervention.

The pre-test scores were taken using the Monofilament, TUGT, and DGI for both groups. There was a notable difference between the pre- and post-values of the groups for sensation using the monofilament. In the ST, the mean and SD scores improved from 5.30 ± 1.208 to 6.77 ± 0.971, while in the VT, the scores increased from 4.90 ± 1.213 to 7.47 ± 0.973. Functional mobility was assessed using TUGT, and the scores for ST and VT showed a notable difference. The pre- and post-evaluation means and SD for ST were 19.13 ± 5.198 and 16.40 ± 5.001, respectively, whereas the values for VT were 20.23 ± 4.297 and 16.10 ± 3.960. Gait was evaluated using DGI, and the score for VT exhibited a noteworthy increase in mean scores from pre-test to post-test. In ST, the pre-test DGI score was 14.60 ± 2.749, which increased to 16.93 ± 2.180 in the post-test. In the experimental group, the pre-test mean score of 13.97 ± 2.539 rose to 17.30 ± 2.246 in the post-test.

The present study showed an improvement in foot sensation in diabetic neuropathy patients. Sohrabzadeh ran a similar study to find out the immediate effect of a single session of WBV on sole-foot sensations and stated that WBV could immediately improve sole-foot sensation (p = 0.001) (Sohrabzadeh *et al*., 2021). However, the outcomes of this study do not match those of the study conducted by Pollock *et al*., who stated that there was no considerable effect of WBV on JPS or static balance. However, this study was conducted on young and healthy subjects (Pollock *et al*., 2011).

This study observed a significant improvement in functional mobility. Previous studies by various authors have concluded that WBV training can decrease the TUGT score, hence improving functional mobility (p < 0.05) (Sen *et al*., 2020; Krause *et al*., 2022). Unfortunately, the study by Saucedo *et al*. contrasts with our study (Saucedo *et al*., 2021). A total of 17 participants were included in their study. There were no noteworthy improvements (p > 0.05) between groups.

The study showed a significant improvement in gait. Ilgın *et al*. evaluated the effect of WBV in stroke patients and concluded that WBV significantly improves gait parameters in terms of stride length and walking velocity (Ilgın *et al*., 2019). Another study by Xiao *et al*. showed similar results in the stroke population, stating WBV improved gait in hemiplegic patients with stroke (p < 0.05) (Xiao *et al*., 2022).

The present study findings could be explained by previous articles stating that vibration stimulation activates type Ia and II afferent fibers, escalating sensory input to the CNS. This stimulation leads to the excitation of various brain areas and promotes neuroplasticity (Zeng *et al*., 2024).

Additionally, vibration causes tonic reflexive contraction of the muscle due to the stimulation of muscle spindles, as a result of the activation of the alpha-motor neuron. Lee *et al*. reported in their study that WBV exercises enhance corticospinal excitability, which in turn improves motor functions (Lee *et al*., 2020). Interestingly, some studies found that WBV increases the sensitivity of mechanoreceptors mediated by Merkel's discs and Ruffini endings (Manimmanakorn *et al*., 2017). WBV is linked with improvements in fasting glucose and HbA1c in subjects with type 2 diabetes (Stambolieva *et al*., 2017).

The present study included sensorimotor training. The improvement in the ST group could be due to the stimulation of mechanoreceptors, which enhance proprioceptive inputs from various body parts.

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Limitation and Recommendations

The sample size of the study was small (30 participants in each group), so further studies can be conducted on a larger population. Additionally, longer-duration studies can be performed to determine the long-term effects of WBV. There was a lack of homogeneity in gender distribution.

Conclusion

Whole-body vibration therapy demonstrates greater efficacy in improving sensation, functional mobility, and gait in diabetic neuropathy patients when compared with sensorimotor training. WBV and sensorimotor training both proved to be effective in enhancing sensation and improving functional mobility and gait.

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