Effectiveness Of Whole-Body Vibrator And Inclined Treadmill To Improve Balance In Patients With Diabetic Neuropathy

ABSTRACT

Aims Diabetic neuropathy, present in 50% of diabetic patients, results in loss of sensation, muscle weakness, disturbance of balance and risk of falling. Balance impairment in diabetic neuropathy requires specific rehabilitation methods. New interventions like Whole-Body Vibration and Inclined Treadmill Training offered interesting alternatives to conventional balance training. The present study attempts to identify the effectiveness of whole-body vibrator and inclined treadmill training on enhancing balance in diabetic neuropathy patients.

Materials & Methods The comparative study was conducted on a clinical private setting, thirty patients were randomly chosen through simple random sampling using the lottery method and they were split into two groups (n=15 each). Group A received whole-body vibration therapy for 25 minutes, four times a week, while Group B participated in inclined treadmill sessions for same duration. Balance and mobility were assessed using the Berg Balance Scale (BBS) and Timed Up and Go (TUG) test before and after the treatment.

Findings Participants in the whole-body vibration group demonstrated significantly greater improvements in balance, reflected by a higher mean score of 48.67 on the BBS and a lower average of 7.00 seconds on the TUG Test. In contrast, those using the inclined treadmill showed mean scores of 41.27 and 10.00 seconds, respectively. Both differences were statistically significant ($p < .001$).

Conclusion Whole body vibration and inclined treadmill significantly improved balance, but whole-body vibration was more effective in enhancing stability and reducing fall risk. Whole body vibration therapy serves as a valuable alternative to conventional rehabilitation, promoting better dynamic balance.

Keywords Accidental Falls; Blood glucose; Postural balance; Quality of life

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Introduction

Diabetes is a disease that involves dysfunctional release of insulin, which causes blood sugar levels to rise and poses a risk for heart attacks, high blood pressure, kidney failure, and death. According to the International Diabetes Federation (IDF), the number of diagnosed individuals with diabetes will increase from 138 million to 202 million in 2035 [1,2]. Diabetic Neuropathy is the nervous system manifestation from diabetes mellitus. It occurs because high blood sugar levels damage the small blood vessels over time, this complication can damage the peripheral nerve fibres and the function of the peripheral nervous system [3,4]. Diabetic neuropathies encompass a broad range of disorders characterized by various neurological impairments. They are among the most frequent and serious long-term complications of diabetes, significantly contributing to illness and mortality. This condition can develop in individuals with any form of diabetes, including both insulin-dependent and non-insulin-dependent types [5]. Neuropathic manifestations are generally classified as either somatic or autonomic. Among the earliest and most common symptoms of diabetic neuropathy are paraesthesia, tingling, or prickling sensations in the legs and feet. As the condition advances, these symptoms often progress to numbness caused by sensory nerve damage, eventually resulting in a reduced or complete loss of touch, pain, temperature, vibration, and proprioception [6,7,8,9].

Diabetic peripheral neuropathy can influence balance as it affects the body's capacity to detect and react to shifts in position. Consequently, people have problems maintaining a stable centre of gravity, especially when standing or walking. This result in less feedback and an impaired motor response, then making it more difficult to make postural adjustments, thus bringing a potential increase in falls and instability [10]. Balance impairment prevalence increases with the duration of diabetes and poorer glycemic control. Research suggests that about 16% of those with diabetes have balance problems, rising to between 30% and 50% as the illness worsens [11,12]. In addition, diabetic neuropathy cause damage to sensory nerves can reduce proprioceptive awareness, affecting joint position and limb movement. This may lead to impaired balance and coordination, especially during

weight shifts and precise actions [13]. Balance issues in DPN are due to sensory loss, motor dysfunction, proprioceptive impairments, muscle weakness, and alterations in gait [14,15].

A range of medications is available to manage diabetes, with treatment plans typically tailored to individual needs [16,17]. Metformin is commonly the first drug of choice; it lowers the production of glucose in the liver and enhances the body's sensitivity to insulin. Sulfonylureas, such as glipizide, work by stimulating the pancreas to produce increased amounts of insulin. Meanwhile, SGLT2 inhibitors like empagliflozin help control blood sugar levels by promoting the excretion of glucose through urine [18]. There are many pharmacological treatment options for the treatment of diabetes but literature shows that they are not adequately effective as diabetes is multifactorial disorder like Sulfonylurea that has a higher risk of heart failure with high-dose monotherapy [19]. Traditional rehabilitations for balance in individuals with diabetic neuropathy may have some limitations. These programs can sometimes be ineffective due to reduced sensory feedback, slow progress, and difficulty in fully restoring postural stability [20].

Whole-Body Vibration (WBV) therapy had been shown to enhance strength, balance, mobility, and circulation, particularly in older adults. It was also effective in rehabilitating conditions like musculoskeletal pain and diabetes management [21]. Treadmill training emerged as another effective rehabilitation method, significantly improving gait speed, cardiovascular parameters, and postural balance. Inclined treadmill training enhanced hip, knee, and ankle angles while increasing amplitude and stance time in the lower limbs [22,23]. However, studies on whole body vibrator training in stroke rehabilitation produced mixed results. Some studies showed improvements in balance and walking function, while others found no significant difference from routine rehabilitation [24].

Treadmills remained a widely used tool for enhancing dynamic balance and offered advantages over conventional rehabilitation. Inclined surfaces added complexity to locomotor control, particularly for individuals with neurological gait impairments. Adjustments in limb movement improved efficiency, increased mobility, and reduced balance-related risks [25]. Despite these promising interventions, most research on balance improvement in diabetic neuropathy patients focused on individual therapies. Few comparative studies evaluated the relative effectiveness of whole-body vibration and treadmill training. There was limited evidence on their optimal use in correcting balance deficits. The research was conducted to assess and contrast the efficacy of whole-body vibration and inclined treadmill exercises in enhancing balance in patients with diabetic neuropathy. Since balance impairments are common in this group, the research focused on identifying which intervention provided more significant improvements.

Material and Methods

Research Groups

A comparative study was carried out involving individuals diagnosed with diabetic neuropathy at Saveetha Medical College and Hospital, Chennai, India, between July 2024 to December2024. The sample size estimation was performed using G*Power software (version 3.1.9.4), considering the expected therapeutic impact on both absolute and relative power measures. The statistical parameters used for the calculation included a t-test with an alpha value of 0.05, a medium effect size (Cohen's d = 0.5), and a statistical power of 80%. This calculation indicated that a minimum of 30 participants would be sufficient to detect the expected therapeutic effect, even after considering a 10% dropout rate. A total of 124 individuals were screened for eligibility of which 94 were excluded for reasons such as not meeting inclusion criteria, declining participation, or incomplete baseline assessments. Finally, 30 participants were enrolled, which matched the required sample size (Figure 1).

All 30 participants were given a clear explanation of the study, their informed consent was collected and baseline characteristics were recorded (Table1). They were randomly assigned to two groups using a simple random sampling through lottery method: Group A (15 people) and Group B (15 people). To minimize detection bias, the randomization process was conducted with assessor blinding.

Therefore, the total estimated sample size was 30 patients. Group A received whole body vibration for 25 minutes, four times weekly and Group B received inclined treadmill training for the same duration. Each intervention was administered four times per week over a period of four weeks. To assess their effectiveness, post-treatment results were measured using the BBS and TUG.

Table 1. Baseline Character of Patients

Variable	Group A	Group B
Age (Mean/SD)	59.53 ± 7.03	61.53 ± 7.44

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Gender (Male/Female)	8/7	9/6
HbA1c (Mean/SD)	8.8 ± 1.19	8.74 ± 0.98
Body mass index (Mean/SD)	25.9 ± 2.54	27.5 ± 2.67

Note: Standard Deviation (SD)

The individuals included in the study were aged between 50 and 80 years who were confirmed case of type 2 diabetes mellitus persisting for over ten years, with poor glycaemic control. All participants presented with diabetic polyneuropathy and had glycated haemoglobin (HbA1c) levels ranging from 7% to 11%, alongside fasting plasma blood glucose concentrations ranging from 7.0 to 11.1 mmol/L. Functional balance assessment indicated moderate impairment, with Berg Balance Scale (BBS) scores falling between 21 and 40. Additionally, participants exhibited a Timed Up and Go (TUG) test time exceeding 10 seconds but not surpassing 30 seconds.

Participants were excluded if they had undergone recent surgical procedures or sustained injuries affecting lower limb function. Other exclusion criteria included malnutrition, characterized by a body mass index (BMI) of less than 21 kg/m^2 or a significant, unintended reduction in body weight over the previous six months. Individuals with active foot ulcers, a history of major cardiovascular incidents, or severe musculoskeletal or neurological disorders impacting mobility were also not eligible for the study.

The interventions were provided by experienced physiotherapists familiar with the specific technique used in the study. To maintain consistency and competence, all the physiotherapists underwent a comprehensive training program on the intervention procedures. All missed appointments and any protocol deviations were documented and discussed to ensure standardization in the way the interventions were being delivered.

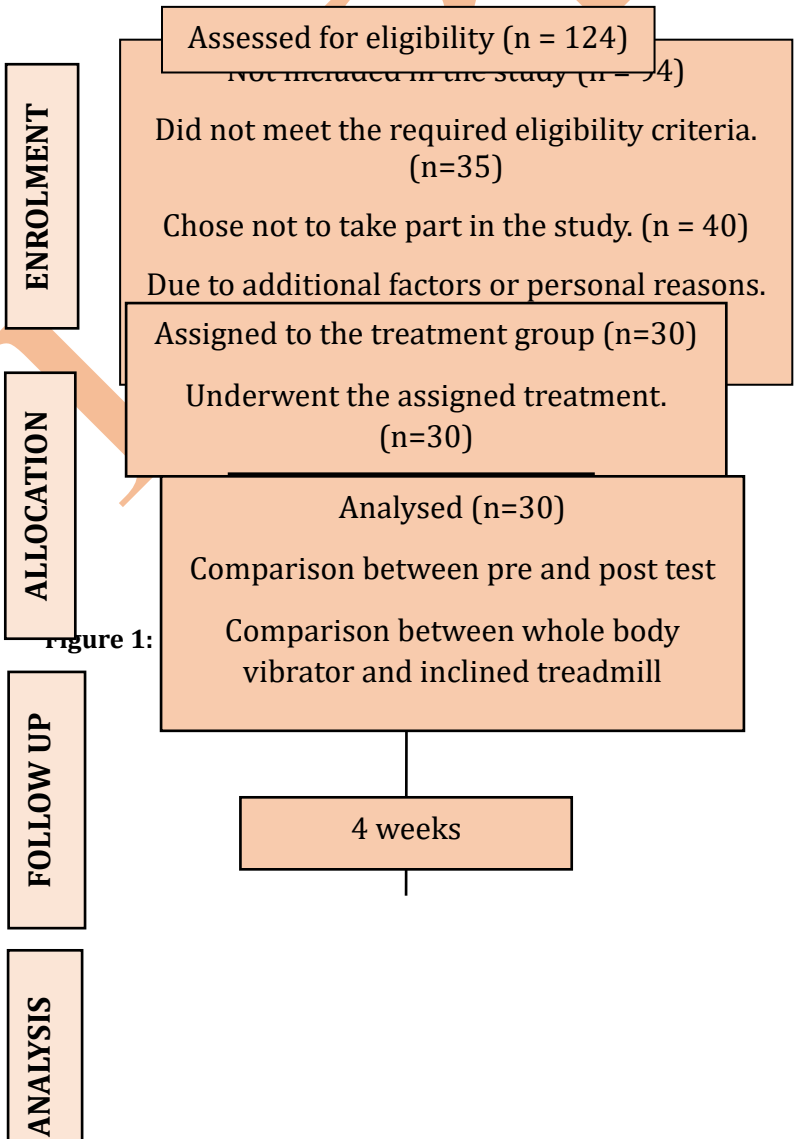

Figure 1:

Tools

Berg Balance Scale

BBS is a scale designed to evaluate both static and dynamic balance, especially in older adults. It has a maximum score of 56 and comprises of 14 tasks with scores ranging from 0 to 4. The test, which usually takes 15 to 20 minutes, assesses functional mobility and fall risk. The test includes 14 tasks that gradually increase in difficulty, each component is assessed using a five-point scale ranging from 0 to 4. The highest attainable score is 56, where lower totals indicate greater impairment in balance. The BBS demonstrates excellent validity and shows strong consistency between different raters (inter-rater reliability of 0.97) and across repeated assessments by the same rater (intra-rater reliability of 0.98). Its overall reliability is variable across the scale with minimal detectable change and more homogeneity at the higher end of the scoring range [26].

Time Up and Go Test

TUG evaluates functional mobility and balance. After being put in seats, the participants were instructed to go three meters, turn around, go back to their chairs, and sit down. The "ready, set, go" signal would start the timer, which would stop when the individual sat down. The average of the three test results was used to calculate the mean TUG Test. The TUG test has proven to be both reliable and valid, with strong recognition as a functional mobility assessment tool. It has been proven to have excellent concurrent validity with physical movements as well as having a high level of consistency for both intra and inter-rater reliability (ICC = 0.99) [27].

Procedure

WBV Therapy

The session commenced with the patient standing on the vibration platform barefoot in a way that facilitated equal distribution of weight between the two feet. To make the patient get used to the sensation of whole-body vibration (WBV), the initial exposure was provided at a lower frequency and amplitude, and then progressed to the prescribed parameters of 30 Hz frequency and 2 mm amplitude. The patient started in an initial position of knee flexion approximately 30 degrees, which was done in five repetitions of 30 seconds vibration, with an interval of a one-minute pause in between. Following knee flexion, the patient performed a series of functional movements on the platform, which were designed to provoke the greatest muscle activation and maximize balance.

The exercises employed in the study were squats, performed in three sets of one minute with 30 seconds of rest in between; tandem stance, performed in two sets of one minute with 30 seconds of rest in between; and alternating lunges, performed in three sets of one minute with 30 seconds of rest in between. The overall program in total was planned to take around 25 minutes, thereby progressively challenging postural control and dynamic stability [28].

Inclined Treadmill Training

During the therapy session, patients walked on a treadmill at speeds between 1.2 and 1.6 m/sec. As they got better, the speed was slowly increased to the highest level they felt comfortable with, while keeping their posture upright. If they felt unsteady or uncomfortable, they were encouraged to hold onto the rails for support, and help was given when needed. The session included walking at a 10% incline for 10 minutes, then a 5-minute rest, followed by another 10 minutes at a 20% incline [29].

Data Collection and Analysis

IBM SPSS Statistics (Version 29) was used to perform both descriptive and inferential analyses. All statistical tests were conducted at a 95% confidence interval. The analysis included calculating the mean and standard deviation for scores from the Berg Balance Scale (BBS) and Timed Up and Go (TUG) tests were collected before and after the intervention. Paired t-tests were used to evaluate changes within each group over the course of the study, while independent t-tests were applied to compare the outcomes between the two groups following the intervention.

Findings

Our study found that patients with diabetic peripheral neuropathy who received whole-body vibration therapy (Group A) and inclined treadmill training (Group B) improved significantly, with small differences. Among them, those who had whole-body vibration therapy showed better improvement. The members of Group A had larger gains in their BBS scores compared to those of Group B, where Group A showed a mean of 48.67 and Group B averaged 41.27. In addition, Group A also showed development in the TUG test by having a mean of 7.00, While Group B had a mean of 10.00. The findings were moreover supported by effect size analysis, which indicated substantial

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impacts. In Group A, the estimated Cohen's d values were 6.081 for BBS and 1.710 for the TUG, reflecting strong effects. Similarly, Group B also showed remarkable effect sizes, with Cohen's d calculated at 3.321 for BBS and 2.200 for TUG. Although each intervention resulted in meaningful statistical improvements ($p < 0.001$), the greater mean differences and effect sizes suggest that whole-body vibration therapy is a more effective method for enhancing balance and mobility in patients with diabetic neuropathy. Statistical analyses were represented in tables 2&3.

Table 2. Comparison of BBS and TUG within Group A and Group B

Outcome Measure	Groups	Pre-Test Mean ± SD	Post-Test Mean ± SD	t value	*p* value
BBS	Group A (N=15)	29.80±3.321	48.67 ± 4.402	-12.016	<.001
	Group B (N=15)	29.47 ± 2.924	41.27 ± 2.187	-13.762	<.001
TUG	Group A (N=15)	12.73 ± 1.751	7.00 ± 0.926	12.986	<.001
	Group B (N=15)	13.13 ± 2.326	10.00 ± 0.846	5.517	<.001

Note: Berg Balance Scale (BBS); Time Up and Go Test (TUG); Standard Deviation (SD)

Table 3. Comparison of Group-A & B post-test between BBS and TUG

Groups	Post test	Mean±SD	t value	*p* value
Group-A	BBS	48.67±4.402	5.831	<.001
	TUG	7.00±0.926	-9.269	<.001
Group-B	BBS	41.27±2.187	5.831	<.001
	TUG	10.00±0.846	-9.269	<.001

Note: Berg Balance Scale (BBS); Time Up and Go Test (TUG); Standard Deviation (SD)

Discussion

In the present study, we compared the effectiveness of two rehabilitation modalities: whole-body vibration therapy (Group A) and inclined treadmill training (Group B). Both groups improved significantly on functional results with a p-value less than .001, indicating strong statistical significance. Remarkably, whole-body vibration therapy was specifically effective in enhancing balance and neuromuscular control.

Our findings showed a significant improvement in the scores of the BBS on patients who received WBV therapy. This result is consistent with earlier research findings that have shown significant improvements in balance outcomes after WBV interventions. Subjects who received balance training plus WBV had larger gains in BBS scores and postural control compared to subjects who received only balance training [30]. These findings are in agreement with the findings of previous research, who also had remarkable improvements in clinical measures of balance following a WBV exercise program. Although such encouraging results have been reported, potential limitations need to be borne in mind [31].

Heterogeneity in WBV protocols ranging from variation in frequency, amplitude, and duration of sessions could influence both the efficacy of the intervention and the compatibility of comparative studies among them [32]. Again, long-term gains in balance retained following WBV treatment remain indeterminate, particularly for patients with diseases like diabetic neuropathy. To address the inconsistency in WBV, our study implemented a standardized protocol.

Aside from enhancing mobility and balance, whole-body vibration therapy has also been shown to improve confidence in movement and the ability to implement activities of daily living. There are, however, some studies that have raised concerns over its potential side effects. The researcher hypothesized that whole-body vibration temporarily disrupts the somatosensory system, leading to balance disturbances and heightened risk of falls [33].

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Moreover, the use of whole-body vibration activates the tonic vibration reflex, triggering involuntary muscle contractions that improve postural support and balance. It also stimulates both agonist and antagonist muscles, promoting muscular balance and reducing the risk of injury, ultimately leading to greater overall stability and strength [34]. On the other hand, whole-body vibration therapy offers a harmless and gentle approach to improving balance and stability, making it a valuable tool in rehabilitation programs [35].

While inclined treadmills have shown strong effects compared to other types of treadmill training, previous research has also supported their specific benefits. For instance, it found that 10 weeks of inclined treadmill training not only significantly improved walking ability and balance but also had no adverse effects on muscle function in patients [36]. Likewise, tilting a treadmill for walking can improve postural balance with gait by producing increased dorsiflexion of the ankle, leading to a more vertical pelvis and trunk alignment. These beneficial effects indicate that walking on an incline treadmill is an effective lower limb stabilizer.

In general, the research shows that whole-body vibration is used to enhance balance, gait function, and functional mobility in diabetic neuropathy. It provides a feeling of confidence and can be trained within an individual or within a group rehabilitation program.

This study has several limitations, including the absence of double blinding, the lack of a control group, a relatively short intervention duration, and inconsistent patient adherence. Future investigations should consider incorporating emerging technologies such as mixed reality, wearable devices, and individualized training programs to enhance treatment outcomes. Moreover, examining the combined effects of whole-body vibration therapy with pharmacological or nutritional support may offer valuable insights for improving balance-related results. Expanding research to include more diverse populations and longer intervention periods will be critical for establishing more robust and generalizable treatment approaches. Addressing these aspects is key to advancing effective and reliable therapeutic strategies.

Conclusion

The study identified that both whole-body vibration (WBV) therapy and inclined treadmill training led to comparable development in participants, with a statistically meaningful distinction observed between the two groups. Despite this, WBV therapy showed encouraging results in improving balance and postural control. As a non-surgical intervention, WBV appears to be an effective option for addressing balance problems in individuals with diabetic neuropathy.

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