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Expert Opinion Article

Efficacy Of Whole-Body Vibration In Improving Balance And Proprioception In Patients With Diabetic Foot Neuropathy: A Randomized Controlled Trial

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ABSTRACT

Background: Diabetic peripheral neuropathy often leads to deficits in proprioception and balance, which elevate the risk of falls. Whole-body vibration (WBV) has emerged as a novel rehabilitation strategy aimed at enhancing sensory-motor function. This study investigated the effects of WBV training on balance and proprioception in individuals with diabetic foot neuropathy.

Methods: A single-blind randomized controlled trial was conducted involving 20 participants with type 2 diabetes complicated by peripheral neuropathy. Subjects were randomly assigned to either a WBV group (n = 10) or a control group (n = 10) that performed conventional balance exercises. Both groups completed supervised sessions three times per week for four weeks. Balance performance was evaluated using the Y-Balance Test (composite, anterior–posterior, and medial–lateral stability indices), while functional mobility was assessed with the Timed Up and Go (TUG) test. Pre- and post-intervention outcomes were compared.

Results: Participants in the WBV group demonstrated significant improvements in dynamic balance indices and proprioceptive accuracy ($p < 0.001$). Functional mobility, as measured by TUG, also improved in the WBV group ($p = 0.011$), whereas no significant changes were observed in the control group. Effect size analysis revealed moderate-to-large improvements in balance measures following WBV training.

Conclusion: WBV appears to be an effective and practical intervention for enhancing proprioception, balance, and mobility in individuals with diabetic foot neuropathy. Further large-scale studies with longer follow-up periods are needed to validate the long-term benefits and clinical applicability of this approach.

Keywords: whole-body vibration, diabetic neuropathy, balance training, proprioception, rehabilitation.

INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder characterized by disturbances in glucose regulation due to impaired insulin secretion, resistance to insulin action, or both. The resulting hyperglycaemia progressively damages multiple organs, including the nerves, eyes, kidneys, and cardiovascular system[1]. Diabetes is currently considered one of the fastest-growing global health challenges. The International Diabetes Federation (IDF) estimates that approximately 537 million adults were living with diabetes in 2021, with projections rising to 643 million by 2030 and 783 million by 2045[2]. This escalating prevalence not only increases healthcare costs but also significantly impacts the quality of life of affected individuals.

Among the many complications of diabetes, diabetic peripheral neuropathy (DPN) is one of the most common and disabling. Studies indicate that up to 50% of individuals with long-standing diabetes develop neuropathic changes[3]. DPN is primarily characterized by damage to peripheral nerves, resulting in sensory loss, motor dysfunction, and autonomic abnormalities. Sensory involvement, especially in the feet and ankles, leads to reduced proprioception, impaired vibration sense, and diminished protective sensation[4]. Motor involvement may manifest as muscle weakness and altered gait mechanics, which further compromise mobility and functional independence.

Reduced proprioceptive feedback and neuromuscular control are major contributors to postural instability in individuals with DPN. Balance impairment, particularly in standing and walking tasks, predisposes patients to a substantially increased risk of falls. Evidence suggests that patients with DPN are up to 15 times more likely to experience falls compared to healthy individuals[5].

These falls frequently result in fractures, soft tissue injuries, and psychological consequences such as fear of falling, ultimately leading to reduced activity levels and diminished quality of life. Considering that falls are a leading cause of morbidity and mortality in older adults, the presence of DPN further amplifies the severity of this public health problem[6].

Given the heightened risk of falls and injuries, rehabilitation strategies that enhance proprioception and postural stability are essential in the management of DPN. Conventional physiotherapy approaches such as balance training, strengthening, and proprioceptive exercises have shown benefits but are often limited by patient adherence and the progressive nature of neuropathy[7]. Therefore, novel and engaging interventions that can stimulate neuromuscular pathways and enhance sensorimotor integration are of growing interest.

Whole-body vibration (WBV) therapy has emerged as a promising adjunct to traditional rehabilitation. It involves the use of oscillating platforms that deliver mechanical vibrations to the body. These vibrations activate muscle spindles and mechanoreceptors, thereby enhancing neuromuscular activation, reflexive muscle contractions, and proprioceptive feedback[8]. WBV has been shown to improve postural control, balance, muscle strength, and functional performance in healthy individuals, older adults, and certain patient populations such as those with neurological disorders[9],[10].

Although WBV appears promising, its effectiveness in individuals with diabetic neuropathy has not been extensively studied. Preliminary evidence suggests potential benefits in improving balance and proprioception, but findings remain inconclusive due to limited sample sizes and heterogeneous methodologies[11]. More robust clinical studies are required to establish whether WBV can serve as an effective, evidence-based rehabilitation strategy for this population.

AIM OF THE STUDY

The present study aims to investigate the effects of whole-body vibration therapy on balance and proprioception in patients with diabetic foot neuropathy. By addressing this gap in the literature, the study seeks to determine whether WBV can be integrated as a safe and effective rehabilitation intervention to reduce fall risk and improve functional outcomes in individuals with DPN.

MATERIALS AND METHODOLOGY

This study was designed as a single-blind randomized controlled clinical trial (RCT) in accordance with the Consolidated Standards of Reporting Trials (CONSORT) guidelines. The trial aimed to evaluate the effects of whole-body vibration (WBV) therapy on balance and proprioception in individuals with diabetic peripheral neuropathy. To minimize bias, outcome assessors were blinded to group allocation.

A total of 20 participants with type 2 diabetes mellitus complicated by peripheral neuropathy were recruited from outpatient physiotherapy and endocrinology clinics through referral and advertisement. Screening was performed using predefined criteria. Eligible participants were aged between 40 and 75 years, had a body mass index (BMI) between 25–35 kg/m^2, and presented with moderate neuropathy confirmed by a Michigan Neuropathy Screening Instrument (MNSI) score of 13–29. All participants were required to have adequate glycemic control with HbA1c < 8.5% and stable blood glucose levels for the preceding three months. Individuals were excluded if they presented with active diabetic foot ulcers, local infection, significant vestibular or visual disorders, neurological conditions other than diabetic neuropathy (such as stroke or Parkinson's disease), recent lower-limb trauma or orthopedic surgery, or if they had implanted knee or pelvic prostheses, as vibration therapy could compromise implant safety.

Following informed consent, participants were randomly assigned to either the intervention (WBV) or control group using a computer-generated randomization sequence. Allocation concealment was ensured through opaque sealed envelopes prepared by an independent researcher. The outcome assessors remained blinded to participant group assignments throughout the study to reduce detection bias[12].

The WBV group received supervised vibration training on a commercially available vertical vibration platform. The platform was calibrated to a frequency of 30 Hz and an amplitude of 2 mm, parameters previously reported to be both safe and effective for neuromuscular stimulation in clinical populations[13]. Training consisted of six 30-second bouts, separated by 1-minute rest intervals, resulting in a total exposure of 3 minutes per session. Sessions were conducted three times per week for four consecutive weeks under the supervision of a physiotherapist. Participants were instructed to maintain a semi-squat posture with approximately 30° knee flexion. Correct positioning was monitored using a laser pointer aligned with a wall marker to prevent excessive vibration transmission to the head and spine[14]. Sessions were closely supervised to minimize any adverse effects such as dizziness, discomfort, or musculoskeletal strain.

The control group engaged in conventional balance training for 15 minutes per session, also three times per week for four weeks. The training program included sit-to-stand practice, weight-shifting exercises, functional reaching, bilateral and unilateral heel raises, and single-leg stance activities. These exercises were selected because they represent standard physiotherapy practices commonly prescribed for balance and proprioception training in individuals with diabetic neuropathy[15].

Outcome measures were recorded at baseline and after four weeks of intervention. Dynamic balance was assessed using the Y-Balance Test (YBT), which evaluates lower-limb stability across anterior, posteromedial, and posterolateral directions, with performance expressed as a composite reach score normalized to leg length[16]. Functional balance and mobility were measured using the Timed Up and Go (TUG) test, where participants were timed while rising from a chair, walking three meters, turning, and returning to sit down. This test has been shown to be reliable and predictive of fall risk in both diabetic and elderly populations[17]. Proprioceptive function was assessed through ankle joint position sense (JPS) testing. In this procedure, participants attempted to reproduce predetermined ankle joint angles, and the absolute error between the target and reproduced angle was calculated. This method is considered a valid measure of proprioceptive acuity in neuropathic populations[18].

All assessments were conducted by a blinded physiotherapist with more than five years of experience in neurological rehabilitation. Participants were instructed to continue their routine diabetes management during the study period and were asked to refrain from initiating any new physical training programs. The study protocol received approval from the Institutional Ethics Committee and was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants, and safety monitoring was performed during every intervention session to record any adverse events related to the procedures.

STATISTICAL ANALYSIS

All data were analyzed using SPSS version 22. Prior to statistical testing, the distribution of variables was examined using the Shapiro–Wilk test to determine normality. Depending on the data distribution, parametric or non-parametric tests were applied. For within-group comparisons (pre- vs post-intervention), paired t-tests were used for normally distributed variables, while the Wilcoxon signed-rank test was applied for skewed data. Between-group comparisons were carried out using independent t-tests or the Mann–Whitney U test, as appropriate. To provide an estimate of the magnitude of treatment effects beyond p-values, effect sizes were calculated using Cohen's d. The threshold for statistical significance was set at $p < 0.05$.

RESULTS

A total of 20 participants successfully completed the trial, with 10 allocated to the WBV intervention group and 10 to the control group. The mean age of participants in the WBV group was 60.0 ± 7.2 years, while the control group had a mean age of 50.0 ± 7.6 years. Baseline characteristics, including body weight, BMI, HbA1c levels, and duration of diabetes, did not differ significantly between groups, indicating successful randomization and comparability at study entry.

Within-group analysis revealed that participants receiving WBV demonstrated significant post-intervention improvements across multiple outcomes. Specifically, notable gains were observed in overall stability index ($p < 0.001$), anterior–posterior stability index ($p = 0.033$), and medial–lateral stability index ($p < 0.001$), reflecting enhanced dynamic postural control. Functional mobility, as measured by the Timed Up and Go (TUG) test, also showed significant improvement in the WBV group ($p = 0.011$), suggesting better movement efficiency and reduced fall risk. Additionally, sensory function of the plantar surface of the foot improved markedly ($p = 0.001$), highlighting the potential of WBV to enhance proprioceptive feedback mechanisms in neuropathic patients.

In contrast, the control group, which engaged in conventional balance training, did not exhibit significant improvements in any of the measured outcomes over the study period. When comparing post-intervention outcomes between the two groups, participants in the WBV group consistently outperformed the control group across all dynamic balance indices, with between-group differences reaching statistical significance ($p < 0.001$). These findings collectively suggest that WBV training was more effective than conventional balance exercises in improving both postural stability and functional performance in individuals with diabetic peripheral neuropathy.

DISCUSSION

This randomized controlled trial demonstrated that whole-body vibration (WBV) therapy produced significant improvements in proprioception, postural stability, and functional mobility in individuals with diabetic foot neuropathy. These results align with previous findings showing that WBV enhances balance, neuromuscular coordination, and postural control in both older adults and populations with neurological impairments.[19,20]

The observed improvements in stability indices and the Timed Up and Go (TUG) test suggest that WBV exerts benefits through both neuromuscular and functional mechanisms. Vibration stimulates cutaneous mechanoreceptors, particularly Pacinian corpuscles, and activates muscle spindles and Golgi tendon organs, thereby enhancing proprioceptive input and postural reflexes.[21] This leads to reflexive muscle contractions that improve joint stabilization, dynamic balance control, and muscle activation patterns.[22] In addition, WBV has been shown to facilitate cortical reorganization and improve central sensory integration, which may further explain the enhancements in motor responses and functional performance.[23]

Recent clinical research supports these findings. Jain and Varathan (2025) demonstrated that WBV combined with sensorimotor training significantly improved sensation, dynamic gait, and functional independence in patients with diabetic neuropathy compared to sensorimotor training alone.[19] Similarly, a systematic review and meta-analysis published in *Scientific Reports* (2024) concluded that WBV improves muscle strength, balance performance, and glycemic outcomes in individuals with type 2 diabetes and peripheral neuropathy.[20] Another review in *Frontiers in Endocrinology* (2024) highlighted WBV as a promising adjunct intervention capable of modulating neuromuscular function, metabolic control, and proprioceptive feedback in diabetic populations.[24]

Importantly, WBV is safe, non-invasive, and time-efficient, making it a practical complement to conventional physiotherapy. Its feasibility, low physical strain, and adaptability make it particularly suitable for patients with neuropathy who often have reduced tolerance for high-intensity exercise.[25] By reducing fall risk, improving balance confidence, and enhancing mobility, WBV has the potential to contribute meaningfully to improved independence and quality of life in individuals with diabetic neuropathy.

Nevertheless, the present study has limitations. The small sample size and short intervention duration restrict the generalizability of results. Future trials should recruit larger, more diverse cohorts and extend follow-up periods to assess the sustainability of benefits and the long-term impact on fall prevention, nerve conduction, and daily activity participation. Including mechanistic outcomes such as vascular perfusion, inflammatory markers, and electrophysiological measures may further clarify the pathways through which WBV exerts its therapeutic effects.

In summary, this study provides preliminary evidence that WBV is an effective adjunctive intervention for improving proprioception, balance, and functional mobility in individuals with diabetic neuropathy. When incorporated into structured rehabilitation programs, WBV may help reduce fall risk, improve independence, and enhance quality of life.

CONCLUSION

This study demonstrates that whole-body vibration (WBV) therapy can produce meaningful improvements in proprioception and balance among individuals with diabetic foot neuropathy. As a non-invasive, time-efficient modality, WBV appears to be a valuable adjunct to conventional rehabilitation programs. The observed gains in both dynamic and functional balance suggest that WBV enhances neuromuscular control while simultaneously supporting better performance in daily activities. By stimulating sensory receptors and eliciting reflexive muscle activation, WBV directly addresses deficits in proprioception and postural stability that are characteristic of neuropathy. Clinically, this may translate into reduced fall risk, greater independence, and improved quality of life for patients. Furthermore, the superior outcomes observed when compared to traditional balance training indicate that WBV has potential for broader integration into physiotherapy practice. Nonetheless, confirmation of these findings requires larger-scale studies with extended follow-up to establish long-term efficacy and to refine optimal treatment parameters.

DECLARATIONS

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval done by Ethical committee KG College of physiotherapy Coimbatore affiliated to The Tamil Nadu Dr.MGR Medical University Chennai. In addition, before beginning the research process, all participants in this study provided informed consent.

CONSENT FOR PUBLICATION

Not applicable, as this manuscript does not include any individual person's data in any form

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