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EFFECTS OF VIBRATION FOOTWEAR APPLIED DURING GAIT CYCLE ON DYNAMIC BALANCE AND GAIT ABILITY IN PATIENTS WITH DIABETIC PERIPHERAL NEUROPATHY

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Abstract

Background: Diabetic peripheral neuropathy (DPN) is a prevalent complication of diabetes, leading to impaired sensory function and increased risk of falls. This study investigates the potential benefits of vibration footwear in individuals with DPN, aiming to address gaps in understanding the effects on dynamic balance, gait ability, and neuropathic symptoms.

Objective: To assess the impact of vibration footwear applied during the gait cycle on dynamic balance and gait ability in individuals with diabetic peripheral neuropathy.

Method: A randomized clinical trial was conducted with 60 participants diagnosed with DPN, divided into intervention and control groups. Baseline assessments included demographic data, baseline characteristics, and neuropathic symptoms. The intervention group wore vibration footwear, while the control group used standard footwear. Follow-up assessments included objective biomechanical data, patient-reported outcomes, and adherence measures.

Results: The intervention group demonstrated significant improvements in dynamic balance and gait ability, as evidenced by reduced Timed Up and Go Test times and increased gait speed compared to the control group. Neuropathic symptoms also decreased significantly in the intervention group. Adherence to vibration footwear was high, although not statistically different from the control group.

Conclusion: Vibration footwear shows promise as a therapeutic intervention for enhancing mobility and reducing neuropathic symptoms in individuals with diabetic peripheral neuropathy. The results emphasize the potential positive impact of this intervention on the overall well-being and functional mobility of individuals facing the challenges of DPN.

Key Words: Diabetic Peripheral Neuropathy, Vibration Footwear, Dynamic Balance, Gait Ability, Neuropathic Symptoms, Randomized Clinical Trial, Mobility Intervention.

Introduction

Neuropathy is a medical condition that involves the malfunction or impairment of nerves located outside of the brain and spinal cord. The peripheral nervous system is responsible for transmitting information from the brain and spinal cord of the central nervous system to the organs, muscles, and sensory organs of the body.(1, 2)

Neuropathy may cause a wide range of symptoms and affect a large number of nerves. Neuropathy is characterized by a wide range of symptoms, with pain, tingling, paralysis, and fatigue being the most common. The symptoms primarily appear in the extremities, starting with the hands and feet. Diabetic peripheral neuropathy (DPN) is a common consequence of diabetes that affects the nerves in the lower extremities, specifically the feet and legs.(3, 4) This ailment is categorized as a kind of peripheral neuropathy, characterized by damage to the nerves in the outer regions of the nervous system. Diabetic peripheral neuropathy (DPN) is a unique feature of the illness and a chronic outcome of extended exposure to elevated blood glucose levels. Individuals diagnosed with Diabetic Peripheral Neuropathy (DPN) may encounter sensations of discomfort, tingling, paralysis, and diminished muscular power in the afflicted regions, alongside several other symptoms. Initially, symptoms usually appear in the soles and feet before spreading to the thighs. Moreover, some people may lack feeling, impeding their capacity to perceive changes in body temperature, warning signs of danger, or physical harm.(5, 6) A direct relationship exists between uncontrolled diabetes and an increased likelihood of acquiring diabetic peripheral neuropathy. Individuals with a long-standing history of diabetes are much more vulnerable to developing this illness. In addition to tobacco use, hypertension, and high lipid contents in the blood, there are various additional variables that may affect diabetic peripheral neuropathy. DPN is accompanied with complications such as the development of foot ulcers and infections.(7, 8) Individuals with reduced senses have a diminished capacity to identify injuries or lesions in their foot. Failing to address these injuries or wounds might possibly result in serious infections or even the need for amputations. Diabetic peripheral neuropathy is a common condition often linked to diabetes mellitus. Diabetic peripheral neuropathy (DPN) is more common and worsens in patients with inadequately controlled blood glucose levels.(9) The actual prevalence rates may vary across different groups and are influenced by several variables, including the precise kind of diabetes, demographic features, and healthcare approaches being studied.(10, 11)

It is crucial to acknowledge that prevalence estimates are prone to variation throughout time. To get the latest information, go to hospital administrative databases, current research, or surveys. Research institutions, healthcare organizations, and government health authorities often perform research to determine the prevalence of peripheral neuropathy and other problems linked to diabetes.(12, 13) This research examines the capacity of vibration footwear to improve the dynamic balance and gait mechanics of persons with diabetic peripheral neuropathy across the whole gait cycle. More and more people are recognizing the potential advantages of vibration treatment in improving sensory input and neuromuscular adaptations. However, there is a shortage of scientific literature that thoroughly examines the precise influence of DPN on the dynamic balance and locomotion features of patients.(14, 15)

Studying the complex connection between vibration footwear, the way people walk, and their ability to maintain balance in the setting of diabetic peripheral neuropathy might lead to positive results in developing personalized therapeutic treatments. Our goal is to provide valuable insights that will help improve future treatment methods, namely by boosting functional mobility and reducing the risk of falls in patients dealing with the complexities of diabetic peripheral neuropathy. This will be accomplished by clarifying the potential benefits or drawbacks of this intervention. This study adds to the broader framework of diabetic care by improving the complete approach to treating persons with diabetes complications. By rectifying current gaps in knowledge, it aims to enhance the management of issues related to diabetes.(16-18)

In order to further the study of vibratory footwear, it is crucial to understand the complex relationship between neuropathic illnesses and the sensory abnormalities seen in individuals with diabetic peripheral neuropathy. Neuropathy-induced sensory impairment, especially in the lower limbs, along with reduced proprioception, is a crucial factor in altered movement and increased vulnerability to accidents.(19-21)

Research has shown that vibration treatment, which utilizes mechanical oscillations applied to the body, activates sensory receptors and enhances proprioceptive input. The use of vibration footwear shows potential in improving dynamic balance and gait mechanics in people with DPN by reducing sensory anomalies. The justification for using vibration footwear is as follows. However, the precise effect of these therapies on the complex relationship between sensory-motor integration and locomotor performance in individuals with diabetic peripheral neuropathy (DPN) is yet unknown. The main goal of this research is to thoroughly investigate the effects of vibration footwear on the locomotor capacities and dynamic balance of individuals with diabetic peripheral neuropathy, with the aim of addressing the significant lack of information in this area. By thoroughly analyzing objective biomechanical data and patient-reported results, our aim is to determine the possible long-term advantages of vibration treatment, in addition to its immediate impacts. By using vibration treatment, one may determine the possible benefits that go beyond the initial symptoms. Furthermore, we will analyze the possible connection between demographic characteristics and the severity of neuropathic symptoms, as well as changes in treatment effectiveness, given the diverse array of DPN manifestations.(22, 23)

This discovery has ramifications that go beyond academic investigation. It is essential for the advancement of personalized, targeted, scientifically validated therapies that seek to alleviate abnormalities in walking and decrease the chances of people with diabetic peripheral neuropathy experiencing falls. The aim of this study is to understand the complex connection between vibration footwear, dynamic balance, and gait performance. This data will expedite the development of pioneering treatment techniques that are readily compatible with the existing diabetic care infrastructure. The primary aim of this research project is to facilitate improved movement, self-sufficiency, and overall well-being among those affected by this widespread consequence of diabetes. Researchers are now studying the use of vibration footwear in diabetic peripheral neuropathy (DPN) patients during every phase of the gait cycle. This study is driven by the need to address the difficulties faced by persons with this diabetes condition. People diagnosed with DPN often struggle to keep their balance when walking, which increases their vulnerability to falls and consequent accidents. Due to the current lack of available treatment alternatives, there is an opportunity to investigate alternative treatments, such as vibration footwear, to broaden the existing tactics used to address functional problems related to DPN. This research seeks to investigate the impact of vibration footwear on sensory-motor integration and gait mechanics in order to uncover the possible advantages of using such footwear. The aim of this study is to improve the creation of a thorough and personalized method for treating diabetic peripheral neuropathy by combining objective assessments with the personal experiences of those affected by the disease. The primary goal of the study is to improve the overall well-being of those impacted by the condition.(24, 25)

Vibration footwear refers to footwear that produces mechanical oscillations or vibrations in the feet when walking or moving. Some insoles may also come into contact with vibration-resistant footwear. These vibrations specifically stimulate the sensory receptors in the foot and lower extremities to enhance their function. Vibration footwear is a conceptual concept that has tangible origins because to its ability to improve sensory input, enhance proprioception, and influence neuromuscular reactions. The potential applications of this technology have generated significant attention, especially in the context of various medical conditions such as diabetic peripheral neuropathy. This condition is characterized by changes in walking patterns and reduced sensation in the feet.(26) The objective of this study is to examine the potential benefits of incorporating vibration footwear into the walking regimens of individuals with diabetic peripheral neuropathy. The objective is to discover a distinctive and potentially effective solution that may assist alleviate the problems connected with this sickness. The research will prioritize enhancing dynamic balance, gait proficiency, and overall mobility.

Objective: The objective of this study was to determine the effects of vibration footwear applied during gait cycle on dynamic balance and gait ability in patients with diabetic peripheral neuropathy.

Methodology

For this study, a randomized clinical trial (RCT) design was employed to investigate the impact of vibration footwear on dynamic balance and gait ability in individuals with diabetic peripheral neuropathy (DPN). The data for this study was collected from Johar Poly Clinic located in Lahore, Pakistan. The clinic served as the primary site for participant recruitment, baseline assessments, and follow-up evaluations. A total of 60 participants were recruited for the trial, with 30 individuals allocated to each group. The inclusion criteria comprised adults diagnosed with DPN, aged between 40 and 70 years, and exhibiting characteristic symptoms such as neuropathic pain, tingling, or numbness. Participants were randomly assigned to either the intervention group, receiving vibration footwear during the gait cycle, or the control group with standard footwear. Exclusion criteria included individuals with severe peripheral arterial disease, cognitive impairment, or those unable to ambulate independently.

Data collection involved a multi-faceted approach. Baseline assessments of dynamic balance and gait ability were conducted using standardized tests, including the Timed Up and Go (TUG) test and the 10-Meter Walk Test. Participants' demographic information, medical history, and baseline characteristics were also recorded. Subsequently, the intervention group received vibration footwear to be worn during daily activities for a specified duration, while the control group continued with standard footwear. Follow-up assessments were conducted at regular intervals, and additional data on adherence to wearing the footwear, any adverse events, and changes in neuropathic symptoms were collected.

Data analysis will be performed using appropriate statistical methods. Descriptive statistics will summarize baseline characteristics, and inferential statistics, such as t-tests or non-parametric equivalents, will be applied to compare outcomes between the intervention and control groups. Subgroup analyses based on demographic factors and severity of neuropathy will be conducted to explore potential variations in treatment response. The significance level will be set at $p < 0.05$. This rigorous methodology aims to provide valuable insights into the effectiveness of vibration footwear as an intervention for improving dynamic balance and gait ability in individuals with diabetic peripheral neuropathy.

Results

The study examined the effects of vibration footwear on individuals with diabetic peripheral neuropathy (DPN). Demographically balanced groups, each comprising 30 participants, underwent baseline assessments and interventions. In Table 1, age, gender, duration of diabetes, and neuropathy severity were comparable between the intervention and control groups. Table 2 outlined baseline characteristics, including mobility and neuropathic symptoms. The intervention group exhibited a mean Timed Up and Go (TUG) Test time of 10.3 seconds, compared to 12.8 seconds in the control group ($p<0.001$). Similarly, the intervention group demonstrated a higher 10-Meter Walk Test speed (0.9 m/s) than the control group (0.6 m/s, $p<0.001$). Neuropathic symptoms were significantly reduced in the intervention group (mean score 5.2) compared to the control group (mean score 7.8, $p<0.001$). Adherence to vibration footwear was slightly lower in the intervention group (92.5%) than the control group (94.1%), but the difference was not statistically significant (p=0.321). Overall, the findings suggest that vibration footwear positively impacted mobility and neuropathic symptoms in individuals with DPN.

Table 1 Demographic Data

Characteristic	Intervention Group (n=30)	Control Group (n=30)	p-value
Age (years)	Mean ± SD: 55.2 ± 6.3	Mean ± SD: 54.8 ± 7.1	0.721
Gender (Male/Female)	16/14	18/12	0.498
Duration of Diabetes (years)	Mean ± SD: 8.7 ± 3.2	Mean ± SD: 9.1 ± 2.9	0.632
Neuropathy Severity	Moderate (n=15), Severe (n=15)	Moderate (n=16), Severe (n=14)	0.895

Table 1 displays the demographic details of participants in both the intervention and control groups. The average age was similar in both groups, with the intervention group having a mean age of 55.2 years and the control group 54.8 years. The gender distribution showed 16 males and 14 females in the intervention group, while the control group had 18 males and 12 females. The duration of diabetes was also comparable, with mean values of 8.7 years for the intervention group and 9.1 years for the control group. Neuropathy severity, categorized as Moderate or Severe, exhibited no significant difference between the two groups, with p-value 0.895. These findings indicate a balanced distribution of demographic characteristics between the intervention and control groups in the study.

Table 2 Baseline Characteristics

Characteristic	Intervention Group (n=30)	Control Group (n=30)
Baseline TUG Test (seconds)	Mean ± SD: 15.2 ± 2.1	Mean ± SD: 15.5 ± 2.3
Baseline 10-Meter Walk Test (m/s)	Mean ± SD: 0.5 ± 0.2	Mean ± SD: 0.6 ± 0.3
Neuropathic Symptoms Score (1-10)	Mean ± SD: 7.2 ± 1.4	Mean ± SD: 7.5 ± 1.2

This table outlines the baseline characteristics of participants in both the intervention and control groups. The baseline Timed Up and Go (TUG) Test, measuring mobility, showed mean values of 15.2 seconds in the intervention group and 15.5 seconds in the control group. Gait speed, assessed by the 10-Meter Walk Test, indicated mean speeds of 0.5 m/s for the intervention group and 0.6 m/s for the control group. The Neuropathic Symptoms Score, reflecting sensory symptoms, demonstrated mean scores of 7.2 for the intervention group and 7.5 for the control group. These baseline measures provide a snapshot of participants' initial mobility, gait speed, and neuropathic symptoms before the intervention.

Table 3 Outcome Measures

Outcome Measure	Intervention Group	Control Group	p-value
Timed Up and Go (TUG) Test	Mean ± SD: 10.3 ± 1.2 seconds	Mean ± SD: 12.8 ± 2.5 seconds	<0.001
10-Meter Walk Test (m/s)	Mean ± SD: 0.9 ± 0.2	Mean ± SD: 0.6 ± 0.3	<0.001
Neuropathic Symptoms Score	Mean ± SD: 5.2 ± 1.1	Mean ± SD: 7.8 ± 1.5	<0.001
Adherence to Vibration Footwear (%)	Mean ± SD: 92.5 ± 5.3	Mean ± SD: 94.1 ± 4.8	0.321

This table presents the outcome measures comparing the intervention and control groups. The Timed Up and Go (TUG) Test showed a significant reduction in time for the intervention group (10.3 seconds) compared to the control group (12.8 seconds), with p-value <0.001. Gait speed, assessed by the 10-Meter Walk Test, was notably higher in the intervention group (0.9 m/s) compared to the control group (0.6 m/s), with p-value <0.001. The Neuropathic Symptoms Score demonstrated a significant decrease in the intervention group (5.2) compared to the control group (7.8), with p-value <0.001. Adherence to Vibration Footwear, although slightly lower in the intervention group (92.5%) compared to the control group (94.1%), did not reach statistical significance (p-value = 0.321). These results suggest positive effects of vibration footwear on mobility, neuropathic symptoms, and adherence in individuals with diabetic peripheral neuropathy.

Discussion

The study's results on the impact of vibration footwear on individuals with diabetic peripheral neuropathy (DPN) provide valuable insights into potential treatment alternatives for enhancing mobility and relieving neuropathic symptoms. The demographic data, indicating that the intervention and control groups had an equitable distribution of age, gender, duration of diabetes, and severity of neuropathy, enhanced the credibility of the research findings.(27)

Table 2 demonstrates that the fundamental characteristics of the patients in both groups indicated that their initial levels of mobility and neuropathic symptoms were comparable. The intervention group exhibited a significantly lower average duration of 10.3 seconds during the Timed Up and Go (TUG) Test compared to the control group's average duration of 12.8 seconds. From the provided information, it can be inferred that the use of vibration footwear enhanced dynamic balance and mobility, leading to a reduced time to complete the TUG test.(28)

In addition, the average velocity of the intervention group during the 10-Meter Walk Test was 0.9 m/s, which was higher than that of the control group (0.6 m/s). This discrepancy indicates that the intervention group had superior locomotor capabilities. The corroborating evidence supporting the existing literature on the beneficial impact of vibration therapy on locomotor performance and sensory-motor integration lends credibility to our own results. The decrease in neuropathic symptoms seen in the intervention group provides evidence for the potential benefits of using vibration footwear to treat sensory abnormalities linked to diabetic peripheral neuropathy (DPN).

The outcomes of this study raise fascinating issues about the feasibility and effectiveness of integrating vibration footwear into the standard therapy for individuals with diabetic peripheral neuropathy (DPN). Given the absence of a statistically significant disparity in adherence levels between the control and intervention groups, it is reasonable to infer that, on average, the participants shown a collaborative disposition towards wearing the vibration footwear. This discovery provides support for the notion that this intervention might be advantageous in practical scenarios. Conversely, the study emphasizes the need for further investigation into the lasting impacts of vibration footwear and the adherence to the prescribed routine.(29)

Although the findings are promising, it is crucial to acknowledge the presence of certain limitations. To enhance the generalizability of the results, it is recommended that future studies use larger sample sizes and longer durations of study. In addition, the research failed to examine potential variations in treatment response based on demographic variables or the degree of neuropathy. This is a variable that should be taken into account in future investigations. While there is currently no direct comparison to past research, it is possible to discover similarities and differences in the effects of vibration footwear on individuals with diabetic peripheral neuropathy (DPN) by examining the existing literature.(30)

The reduction in time required to complete the Timed Up and Go (TUG) Test in the intervention group demonstrates an improvement in dynamic balance, aligning with the results of several other research. Studies on whole-body vibration therapy have shown that individuals with peripheral neuropathy had improved balance and gait attributes. The results align with those from the current investigation.

Likewise, the enhancement in walking ability shown in the group receiving the therapy, as evaluated using the 10-Meter Walk Test, aligns with prior research indicating that vibration therapies enhance walking mechanics and speed. Enhancing locomotor patterns is crucial for reducing the likelihood of falls and enhancing overall mobility, which are significant considerations for individuals with diabetic peripheral neuropathy. Several studies have examined the impact of vibration treatment on sensory complaints. The reduction in neuropathic symptoms seen in the intervention group aligns with the results of other research. Scientists noted that applying vibratory stimulation to peripheral nerves enhanced sensory input and alleviated neuropathic symptoms.

Nevertheless, it is crucial to bear in mind that the published findings may change as a consequence of variations in the design of the research, characteristics of the participants, and the metrics used to assess the outcomes. Other variables that might impact the overall comparability of the research include the duration, frequency, and kind of vibration intervention. The lack of statistical significance in the disparity of vibration footwear adherence between the intervention and control groups implies that the findings of this research may differ from those of earlier investigations. Prior research on vibration therapies revealed disparities in adherence, which may be ascribed to many variables such as participant motivation, convenience, and happiness with the experience.(31)

To summarize, the present study's results align with prior research regarding the positive impacts of vibration therapies on individuals with peripheral neuropathy. However, the distinctive attributes and methodological variations emphasize the need for prudence when generalizing the findings. Conducting more research on diabetic peripheral neuropathy, such as systematic reviews and meta-analyses, would enhance our understanding of the existing evidence on vibration treatment.

This study provides valuable and distinctive findings on diabetes treatment by showing that the use of vibration footwear might enhance dynamic balance, locomotor skills, and alleviate neuropathic symptoms in individuals diagnosed with diabetic peripheral neuropathy (DPN). These results provide a foundation for further investigation and the creation of customized therapy approaches that have the potential to enhance the functional mobility and general well-being of individuals with diabetic peripheral neuropathy issues.(32)

Conclusion:

The study examining the impact of vibration footwear on individuals with diabetic peripheral neuropathy yielded favorable results. The research found that those who wore the footwear saw enhancements in their dynamic balance, gait skills, and a decrease in neuropathic symptoms. Based on the provided data, using vibration footwear as a therapy intervention for individuals with diabetic peripheral neuropathy may lead to notable improvements in symptom control and mobility.

While the outcomes were positive, it is crucial to acknowledge that some constraints existed. The investigation's brevity and limited sample size may constrain the potential long-term importance and generalizability of the outcomes. The lack of study on the influence of demographic characteristics or the degree of neuropathy on therapeutic response makes it challenging to evaluate the results. This adds complexity to the process of assessing the data. To further elaborate on the significance of the present study's results, future research should investigate the long-term sustainability of the observed advantages and the level of compliance with vibration footwear treatment. To conduct a more comprehensive assessment of the intervention's effectiveness, it would be beneficial to examine variations in treatment response based on demographic factors and the degree of neuropathy.

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