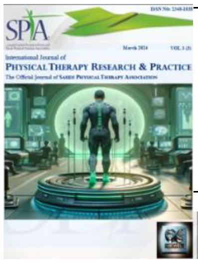

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Original Article

Enhancing Postural Stability in Patients with Diabetic Peripheral Neuropathy: Assessing the Impact of Vestibulo-Postural Training Using a Bipodalic Stabilometric Platform

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Abstract

Aims & Objective: The aim of this study is to evaluate the effectiveness of Vestibulo-Postural Training Using a Bipodalic Stabilometric Platform in patients with diabetic peripheral neuropathy. **Methodology:** Thirty-two participants were randomly allocated into either Level Bipodalic Stabilometric Training Group (LBSTG) or Tilted Bipodalic Stabilometric Training Group (TBSTG), using a computer-generated randomization sequence. The study's approach to evaluating postural control in individuals with Diabetic Peripheral Neuropathy (DPN) involved a precise methodology using a state-of-the-art ProKin 252 balancing platform (ProKin 252, TecnoBody, Italy). **Results:** The study revealed that while the LBSTG training did not produce a significant change in postural control for individuals with DPN, the TBSTG training led to a significant improvement. These results highlight the potential benefits of incorporating challenging balance tasks into rehabilitation programs for individuals with DPN to enhance postural control and stability. **Conclusions:** this study advocates for the importance of innovative balance training interventions in enhancing the stability and mobility of patients with DPN, potentially leading to improved clinical outcomes in the management of this condition.

Key Words: Diabetic peripheral neuropathy, Prokin 252, Proprioceptive Balance training, Stabilometric Platform

Introduction

Diabetes, a widespread chronic metabolic disorder, arises when the pancreas does not produce sufficient insulin or when the body's cells inadequately respond to insulin. This condition is projected to affect approximately 366 million people globally by 2030, significantly reducing the quality of life for patients and imposing substantial economic burdens on healthcare systems worldwide. A common complication of diabetes is Diabetic Peripheral Neuropathy (DPN), which affects nearly half of all diabetic individuals (Karroubi and Darwish, 2015). DPN leads to a loss of peripheral sensation, impaired proprioception, slower walking speed, shorter steps, limited ankle movement, weakened muscle strength, and compromised balance control (Nomura et. al.2018). These symptoms significantly increase the risk of falls among this population, often resulting in severe injuries and fractures, increased healthcare costs, reduced physical activity, diminished self-confidence, and heightened fear of future falls (Nomura et. al.2021). Given that gait or balance impairments are major predictors of future falls (Shaik et. al., 2021) there is a critical need for effective balance training interventions to reduce fall incidence and prevent related injuries (Antonio et al.,2013). Conventional balance training programmes, which are often characterized by repetition and lack of variety, have shown poor rates of engagement. Conversely, different methods of balance training, such as Tai-chi, softball, and line dancing, have shown enhancements in balance, mobility, and overall quality of life [Mao et. al, 2023). Interactive video-based workouts have shown to be useful in many patient groups, as demonstrated by recent improvements (Wuest et. al., 2014). The use of dynamometric platforms with haptic feedback has shown to be successful in enhancing walking resistance and diminishing the likelihood of falls in elderly individuals. Furthermore, the inclusion of visual input has been especially advantageous in preserving balance (Alonso et. al., 2023). Interactive workouts using sensors and providing visual feedback on joint movement effectively improved postural stability in individuals with DPN. These interactive programmes, which are more captivating than traditional treatment, have resulted in increased motivation and engagement rates. This has encouraged regular practice and focused attention throughout training, leading to improved long-term adherence (Grewal et al., 2015).

Therefore, the aim of this study is to evaluate the effectiveness of Vestibulo-Postural Training Using a Bipodalic Stabilometric Platform in patients with diabetic peripheral neuropathy, addressing the existing research gap in the application of instrument-based training for this medical condition. The study aims to provide evidence-based recommendations for integrating instrument-based training, to offer novel and efficient therapeutic choices for DPN patients, potentially resulting in improved results.

Methodology

The screening process was structured to assess participant eligibility through defined inclusion criteria, necessitating that each subject has a documented diagnosis of type 2 diabetes along with peripheral neuropathy, as confirmed by medical records to ensure that all study participants shared a common baseline from which the impact of intervention on DPN could be assessed. Subjects were excluded from participation if they had any diagnosis of cognitive, vestibular, or central neurological impairments, which could confound the study's outcomes. Similarly, those with musculoskeletal anomalies, active foot ulcers, Charcot's joints, or a history of balance disturbances not directly attributable to DPN were also excluded.

In this study, we employed stratified random sampling to enroll participants, ensuring a representative sample of patients with diabetic peripheral neuropathy based on specific criteria for inclusion and exclusion. We used a sample size calculation using expected differences in postural stability outcomes across the groups, with a level of significance of 0.05 and a power of 80%. Considering a moderate effect size, the calculation, using G*Power software, indicated that 14 participants per group would be sufficient to detect statistically significant differences. Given the level of accuracy needed for specialized analysis and an expected dropout rate of 10-15%, the final sample size will consist of 32 participants, with sixteen participants in each group. Participants were randomly allocated into either Level Bipodalic Stabilometric Training Group (LBSTG) or Tilted Bipodalic Stabilometric Training Group (TBSTG), using a computer-generated randomization sequence to ensure equal distribution across intervention arms. This random assignment was blinded to researchers assessing outcomes to mitigate measurement bias and enhance the study's internal validity.

The study's approach to evaluating postural control in individuals with Diabetic Peripheral Neuropathy (DPN) involved a precise methodology using a state-of-the-art ProKin 252 balancing platform (ProKin 252, TecnoBody, Italy). This instrument was selected for its ability to accurately measure the nuances of postural stability and balance. Prior to the commencement of the tests, participants received detailed instructions to ensure uniformity in their starting positions. They were to stand barefoot on a firm surface marked with graduated lines, positioning their feet so that they formed an approximate 30-degree angle with respect to the midline, ensuring both heels were aligned. This stance was crucial for standardizing the initial posture of all subjects. Participants were instructed to maintain an upright posture, with their arms hanging naturally at their sides throughout the testing process.

Figure 1: Vestibulo-Postural Training Interface and Bipodalic Stabilometric Platform

The assessment protocol comprised four tasks, each designed to evaluate balance under varying visual and support conditions. The first two tasks were conducted with participants from the Level Bipodalic Stabilometric Training Group. In the first task, participants executed a double-leg stance for 30 seconds on a level bipodalic stabilometric platform with eyes open (EO), allowing for balance assessment with visual support. The second task replicated the first, but with eyes closed (EC), removing visual cues to challenge the participants' balance further (Fig. 1).

Participants from the Tilted Bipodalic Stabilometric Training Group undertook the third and fourth tasks. The third task involved maintaining a double-leg stance with eyes open on a bipodalic stabilometric platform inclined at a 30-degree angle, assessing balance on an uneven base. The fourth task required participants to maintain balance under the same inclined conditions as the third task but with their eyes closed, further escalating the challenge by eliminating visual input. Both tasks were to be maintained for a duration of 30 seconds, testing the participants' ability to stabilize under more demanding conditions (Fig. 1).

Each of these tasks was performed three times to ensure reliability, with a one-minute rest between trials to prevent fatigue. The initial 5 seconds of each trial were excluded from analysis to allow for postural stabilization. The study focused on analyzing two primary metrics for balance: the path length and the sway area of the Center of Pressure (COP). Path length refers to the total distance the pressure center moved during the 30-second period, while sway area measures the total area covered by the COP's movement. The mean values of these metrics, derived from the repeated trials, were used for statistical analysis.

The Balance Training Protocol, tailored for patients with diabetic peripheral neuropathy, is focused on improving their balance and proprioception. It leverages the Technobody ProKin 252 dynamic platform and encompasses a regimen to be followed three times weekly for four weeks. Each session begins with a five-minute warm-up featuring gentle stretches for the lower limbs, leading into the main 20 to 25-minute balance training exercise.

This program aims to bolster control over the center of mass (CoM) and enhance the coordination of lower extremities through simulated tasks. It includes an ankle-reaching exercise and a virtual obstacle-crossing task, both supported by visual feedback for improved effectiveness. The ankle-reaching task is designed to teach patients about proper weight distribution and the synchronized movements of the hip and ankle joints, which are essential for stabilizing and balancing, especially in individuals suffering from DPN. The routine is divided into four parts, each consisting of 20 repetitions, focusing initially on anterior-posterior directions, and subsequently introducing combined movements that incorporate medial-lateral directions. Each part is designed to be completed in under five minutes, followed by a minute's rest to minimize fatigue.

The more challenging obstacle-crossing task immerses participants in a virtual environment where they navigate through a series of virtual barriers by stepping in place, adjusting to obstacles that vary in height from 10% to 30% of their leg length. This variety ensures a broad range of training intensities within a safe setting that eliminates the risk of tripping. Participants tackle ten obstacles in succession for each height level, alternating feet, thereby mimicking real-life mobility challenges in a controlled, hazard-free environment.

This integrated approach not only aims to challenge participants but also safely replicates the navigation tasks encountered in daily life, ensuring a comprehensive training experience that addresses the unique needs of those with diabetic peripheral neuropathy.

Results

The effectiveness of the balance training protocol for individuals with Diabetic Peripheral Neuropathy (DPN) was assessed using a ProKin 252 balancing platform. This advanced technology facilitated the measurement of postural stability and balance nuances through a series of controlled tasks.

Level Bipodalic Stabilometric Training Group (LBSTG)

For the LBSTG, trajectory lengths pre-treatment revealed a mean of 470.1 mm (SD = 110.3 mm), while post-treatment measurements displayed a mean of 433.4 mm (SD = 112.7 mm). The paired samples t-test indicated no statistically significant difference in the mean trajectory lengths pre-treatment and post-treatment ($t(15) = 0.93$, $p = .359$). This suggests that the training protocol may not have led to significant changes in the balance as measured by the path length of the Center of Pressure (COP) for the LBSTG with eyes open (Table 1).

Table 1: Effect of four-week Vestibulo-Postural Training Using a Bipodalic Stabilometric Platformin diabetic peripheral neuropathy patients.

			Pre-Training Mean ± SD N=16	Post-Training Mean ± SD N=16	Paired t-test	
					t	p
Eyes Open	Trajectory lengths, mm					
	LBSTG		470.1±110.3	433.4±112.7	0.93	0.359
	TBSTG		526.5±129	696.6±71.8	-5.169	0.001
	Independent t-test	t	-1.329	-7.879		
		P	0.193	0		
	Elliptical trajectory, mm2					
	LBSTG		709.4±204.3	788.8±221.2	-1.055	0.3
	TBSTG		735.9±209.5	949.4±241.8	-2.669	0.012
	Independent t-test	t	-0.362	-1.9602		
		P	0.719	0.05		
Eyes closed	Trajectory lengths, mm					
	LBSTG		764.9±194.5	901.5±187.5	-2.023	0.05
	TBSTG		647.6±172.9	846.8±187.2	3.127	0.004
	Independent t-test	t	1.803	0.826		
		P	0.081	0.415		
	Elliptical trajectory, mm2					
	LBSTG		1499.4±471.2	1104.8±283.8	-2.869	0.007
	TBSTG		1368±345.2	1435.8±359.6	-0.0756	0.94
	Independent t-test	t	0.899	-0.369		
		P	0.375	0.714		

Key: LBSTG: Level Bipodalic Stabilometric Training Group; TBSTG: Tilted Bipodalic Stabilometric Training Group

Tilted Bipodalic Stabilometric Training Group (TBSTG)

In contrast, the TBSTG exhibited a significant improvement in postural control post-treatment. The pre-treatment mean trajectory length was 526.5 mm (SD = 129.0 mm), which increased to a post-treatment mean of 696.6 mm (SD = 71.8 mm). The paired samples t-test demonstrated a statistically significant difference ($t(15) = -5.169$, $p = .001$), indicating that the training protocol significantly affected the balance in terms of trajectory length with the eyes open (Table 1).

An independent samples t-test was conducted to compare the trajectory lengths between the two groups. Pre-treatment, there was no significant difference in trajectory lengths between LBSTG and TBSTG ($t(30) = -1.329$, $p = .193$). However, post-treatment, a significant difference emerged ($t(30) = -7.879$, $p < .001$), indicating that the TBSTG benefited more substantially from the balance training protocol than the LBSTG.

The absence of a significant improvement in the LBSTG may be attributed to the nature of their training, which did not involve the challenge of an inclined platform. The TBSTG's tasks, which included maintaining balance on an inclined surface with both eyes open and closed, appear to have provided a more intense challenge, contributing to a greater improvement in postural control. The statistically significant improvements in the TBSTG suggest that training under more challenging conditions may be more effective for improving balance in individuals with DPN.

Discussion

This study sought to assess the impact of a four-week balance training intervention on static and dynamic balance in patients with diabetic peripheral neuropathy (DPN). The intervention, utilizing the advanced ProKin 252 balancing platform, yielded statistically significant improvements in various balance measures for these patients. Our findings reveal that while the level surface balance training did not produce a significant change in postural control for individuals with DPN, the inclined surface training led to a significant improvement. These results highlight the potential benefits of incorporating challenging balance tasks into rehabilitation programs for individuals with DPN to enhance postural control and stability.

Consistent improvements in balance measures, particularly for the Tilted Bipodalic Stabilometric Training Group, underline the importance of targeted interventions. This finding is in line with the study by Iram et al. (2014), which indicated the superiority of combining proprioceptive training with conventional physiotherapy over physiotherapy alone in functional balance enhancement. Furthermore, Akbari et al. (2012) and the research by Cuesta-Vargas AI, González-Sánchez M. (2013) support the efficacy of balance training in improving stability in individuals with DPN.

Contrasting with the significant enhancements observed in our tilt-platform intervention, Kruse (2010) reported minimal impact on balance and lower-extremity strength from an exercise and walking intervention. This suggests that the effectiveness of balance-related therapies may vary, and our study contributes to this dialogue by demonstrating substantial improvements in balance following a specialized training regimen.

The positive effects of the balance training observed in our study align with Grewal's (2015) findings, where sensor-based interactive balancing training reduced sway and improved postural stability. This is further corroborated by Lee's (2013) study, which presented enhancements in balance and muscle strength following a different modality—whole-body vibration therapy. The diversity of these interventions, including the use of specialized equipment like the Biodex Stability System as explored by Eftekhar-sadat (2015), all point towards the beneficial impact of multifaceted balance training approaches.

Moreover, Allet's (2009) research, which examined comprehensive training programs targeting gait speed, balance, muscle strength, and joint mobility, presents favorable outcomes that complement the results of the current study. It highlights the potential for a well-rounded training approach to yield improvements in overall mobility and stability.

Considering the existing literature and the findings from our study, there is strong support for the premise that varied training regimens can effectively enhance balance in individuals with DPN. Interventions such as proprioceptive training, balance training, sensor-based interactive training, and the use of different therapy modalities show promise in managing DPN. Health care providers may consider these findings when designing personalized treatment plans aimed at mitigating fall risks and improving the quality of life for those affected by DPN.

Despite the encouraging insights provided by this study, further research with larger cohorts and more rigorous methodologies is essential to determine the long-term efficacy of these interventions and their suitability for specific patient demographics. Additionally, assessing the cost-effectiveness and accessibility of these treatment options in clinical practice is crucial for ensuring widespread adoption and maximizing the benefits for a broader patient population.

A limitation of this study was the small sample size, which may affect the generalizability of the results. Furthermore, the outcome may have been influenced by the participants' motivation levels and their adherence to the training instructions.

Conclusion

The present study's findings indicate that a four-week specialized balance training program can significantly enhance balance control in patients with diabetic peripheral neuropathy. The data demonstrate notable improvements in post-treatment trajectory lengths for patients participating in the Tilted Bipodalic Stabilometric Training Group, reflecting the potential benefits of including challenging balance tasks in training regimens. While the Level Bipodalic Stabilometric Training Group did not show a statistically significant change, the overall results suggest that the intervention may aid in reducing the risk of falls and improving the quality of life for patients with DPN.

The significance of these results is underscored by their alignment with existing research, which collectively advocates for the inclusion of proprioceptive and balance-focused exercises in the treatment of DPN. Our study contributes to the body of evidence supporting the use of multifaceted balance training as a therapeutic option.

Healthcare professionals may consider these findings when developing treatment plans, keeping in mind that individualized approaches are crucial for the management of DPN. The positive response to the inclined platform balance training encourages further exploration into similar or more challenging interventions to maximize the therapeutic benefits.

While the study demonstrates promising directions for clinical practice, it is also a call for additional research. Larger-scale studies with varied demographics are necessary to validate these findings and ensure that the interventions are effective across the broader spectrum of DPN patients. Moreover, future research should evaluate the cost-effectiveness and practicality of implementing such training programs in different clinical settings to enhance their accessibility.

In conclusion, this study advocates for the importance of innovative balance training interventions in enhancing the stability and mobility of patients with DPN, potentially leading to improved clinical outcomes in the management of this condition.

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