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Effect of Flexi Bar Active Vibration Training on Postural Deviation, Balance Confidence and Risk of Fall with Eyes Close on Force Plate in Type 2 Diabetes Mellitus Patients with Peripheral Neuropathy

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Abstract

Diabetes may result in peripheral neuropathy, which diminishes sensory perception and proprioception, thereby impairing balance, increasing fear of movement and negatively affecting quality of life. In cases of prolonged or severe neuropathy, balance disturbances tend to worsen. The integration of vibration and balance training may offer improved balance outcomes in individuals suffering from diabetic neuropathy. This study primarily aimed to investigate the effects of combining active vibration training with balance exercises on postural control, fall risk and balance confidence. Methodology- Thirty adults aged 45–65 were split into two groups via convenient sampling-one received Flexi-Bar with balance training, the other balance training alone. Assessments at baseline, week 3 and week 6 used the Ortho-King Pressure Plate, ABC Scale, and MFES. Results- The results clearly demonstrated that Group A (vibration + balance training) showed greater improvements across all outcomes. Balance (AP sway) significantly improved from 4.26±2.40 to 1.56±0.75, while Group B saw a smaller change. Balance confidence (ABC) increased markedly in Group A (62.79±6.64 to 82.38±5.78) compared to Group B, with a significant p-value of 0.001. Fall risk (MFES) also improved more in Group A (6.24±0.28 to 8.27±0.44), while Group B showed minimal change (p=0.058). Aim: Effect of active vibration training, Balance, Balance confidence. Conclusion: Flexi-Bar with balance training improved stability, confidence and fall prevention more than balance exercises alone, proving safe and easy to use.

Keywords: Active Vibration Training, Balance, Diabetes, Polyneuropathy

Introduction

Diabetes mellitus is a serious condition that disrupts how the body uses sugar, fat, and protein. It is a metabolic disorder caused by impaired insulin function, leading to high blood sugar levels and long-term damage to vital organs such as the heart, kidneys, nerves and eyes.[1] These complications make it a leading cause of illness and death worldwide.[2] Diabetes mellitus impairs balance through damage to visual, vestibular and proprioceptive systems. Retinopathy reduces visual input; neuropathy weakens sensory

feedback and motor control. These deficits increase the risk of dizziness and falls, especially in older adults, leading to serious mobility and safety concerns.[3] This study defines exercise as purposeful activity to enhance physical fitness, which encompasses both health- and skill-related elements. Due to the functional impairments in the target population, skill-based measures like balance and coordination are included.[4]

Type 1 diabetes is an autoimmune destruction of pancreatic β-cells causing absolute insulin deficiency and accounts for 5–10% of cases, while type 2 diabetes, characterized by insulin resistance and relative insulin deficiency, makes up 90–95% and is often linked to metabolic syndrome.[1] Gestational Diabetes Mellitus (GDM)- Any level of glucose intolerance that begins or is first noticed during pregnancy is referred to as GDM. Idiopathic diabetes, or type 1B, resembles type 1 diabetes anatomically but involves non-immune β-cell failure without HLA association.[2] The risk factors for type II diabetes mellitus included age, genetics, metabolic issues, a sedentary lifestyle, ethnic background, hypertension, insulin resistance, impaired glucose tolerance, obesity, polycystic ovary syndrome, prothrombotic state, and hyperuricemia.[5]

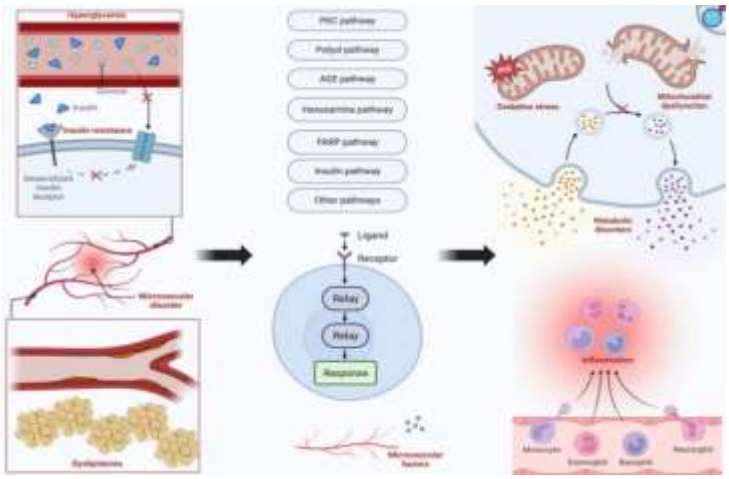

Figure.1 pathway in the mechanism of DPN

Nerve cell damage is commonly caused by metabolic disorders, oxidative stress, and inflammatory responses, involving several key pathways highlights these oxidative and metabolic pathways along with their upstream and downstream factors influencing peripheral nerve function.[6] Diabetic peripheral neuropathy often leads to a higher fall risk, caused by muscular weakness, unsteadiness and anxiety about falling. This investigation considers whether a lack of balance confidence is associated with greater fall susceptibility in DPN sufferers.[7] The Flexi-Bar, measuring 153 cm in length, is a vibrating exercise device that offers an innovative approach to enhancing muscle coordination and balance. Its active vibration technology enables users to regulate both the speed and intensity of the vibrations, providing a dynamic and engaging workout. Research has demonstrated that Flexi-Bar exercises can improve trunk muscle thickness and balance, making it a useful addition to both rehabilitation and general fitness training.[8]

Material and Methods

Eligible participants were enrolled in the study and divided into two groups, Group A underwent active vibration training combined with balance training, while Group B received only balance training. Following consent, patients were selected based on the Michigan Neuropathy Screening Instrument

criteria. The standard 5.07/10g Semmes Weinstein Monofilament Test was used to assess loss of protective sensation and a 128Hz tuning fork was used to evaluate vibration sense.

Participants in the experimental group engaged in both Flexi-Bar and balance training, whereas the control group followed only balance training. The Flexi-Bar sessions lasted 10 minutes daily, five times per week, over a six-week period. Each training session included 5 sets, with 30 seconds of vibration activity and a 90-second rest between sets. Before starting the intervention, patients completed a one-week familiarization period with the Flexi-Bar, which included three practice trials. During the training, patients performed active vibration exercises with the Flexi-Bar, standing with feet shoulder-width apart and moving the bar antero-posteriorly using their dominant hand, held at a 90-degree angle at the shoulder.

Patients performed Flexi-Bar exercises using the highest frequency setting, followed by a 5-minute rest before beginning balance training. Training for balance comprised typical exercises addressing both stationery and movement-based balance control. Stretching, sensory ball massage and step exercises on foam were included in the 10-minute warm-up routine. Balance training included exercises such as standing on both stable and foam surfaces for 4 minutes per set, heel and toe raise, single-leg stands, multidirectional weight shifts and upper limb workouts with Thera-Bands. Rest breaks involved sitting on a Thera-ball with leg support. Exercises in the balance program consisted of single-leg stances, sitting on a Thera-ball, shifting weight and using Thera-Bands. Each 4-minute set of progressive balance training included active activities like football passing on foam and ball throwing and catching on trampoline and foam surfaces. The cool-down phase included relaxation techniques such as deep breathing, abdominal breathing and static abdominal exercises aimed at easing muscle tension.

The control group underwent the identical balance training program as the experimental group, involving standard exercises targeting both static and dynamic balance. A combination of stretching, sensory ball massage and stepping exercises on foam made up the 10-minute warm-up. The balance training included standing exercises on both stable and foam surfaces, with activities like one-leg stances, multidirectional weight shifts and heel-toe raises. Rest periods on a Thera-ball and upper limb Thera-Band exercises were included as part of the regimen. Balance exercises advanced to dynamic tasks such as passing a football on foam and throwing and catching a ball on both trampoline and foam surfaces.

Results

Group A included 11 males and 4 females, while Group B comprised 7 males and 8 females. The mean age was 55.27 ± 6.14 years in Group A and 54.20 ± 5.58 years in Group B ($p = 0.62$). The within-group analysis for Group A (Experimental Group), which received Active Vibration Training (AVT) combined with Balance Training (BT), demonstrated a significant improvement in postural deviation in the Antero-Posterior (AP) direction with eyes closed (EC) over the intervention period, as assessed using Repeated Measures ANOVA. The mean postural deviation scores decreased from 4.26 ± 2.40 on Day 1 to 2.77 ± 1.78 at Week 3 and further to 1.56 ± 0.75 by Week 6, as presented in Table 1. The F-value of 21.89 reflects a substantial treatment effect and the p-value of 0.001 confirms statistical significance. These results underscore the effectiveness of combining AVT with BT in improving balance control in individuals with Diabetic Peripheral Neuropathy (DPN).

Table 1. The comparison of outcome measures on (Baseline) Day 1, Week 3 and week 6 in Intra-group for GA and GB

Mean	Groups	(Baseline) Day 1	Week 3	Week 6	F-test	T-Value	P-Value
PD (EC)	GA	4.26±2.40	2.77±1.78	1.56±0.75	21.89	3.34	0.001
	GB	3.28±1.66	3.07±1.65	2.65±1.65	5.95	3.34	0.007
ABC (Score)	GA	62.79±6.64	71.75±6.74	82.38±5.78	273.6	3.34	0.001
	GB	64.75±2.88	67.53±4.83	70.76±7.86	8.36	3.34	0.001
MFES (Score)	GA	6.24± 0.29	7.20± 0.43	8.27± 0.44	281.5	3.34	0.001
	GB	6.47± 0.47	6.80± 0.95	6.93± 1.11	3.16	3.34	0.058

Table 2. The comparison for Postural Deviations (eye close) between GA and GB

Mean	Groups	(Baseline) Day 1	Week 3	Week 6
PD (EC)	GA	4.26±2.40	2.77±1.78	1.56±0.75
	GB	3.28±1.66	3.07±1.65	2.65±1.65
Unpaired t-test		1.300	0.479	2.335
P-value		0.2042	0.6355	0.0270
T-value		2.05	2.05	2.05

Group B demonstrated a statistically significant improvement in postural deviation in the Antero-Posterior (AP) direction with eyes closed (EC) over the intervention period. The mean postural deviation reduced from 3.28 ± 1.66 mm on Day 1 to 3.07 ± 1.65 mm at Week 3, and further to 2.65 ± 1.65 mm by Week 6. This trend indicates a progressive enhancement in postural control. The consistency of participants' responses also improved, as reflected by the steady standard deviation. The F-test value of 5.95 suggests that the changes over time are meaningful and the p-value of 0.007 ($p < 0.05$) confirms that the observed improvements are statistically significant, as shown in Table 1.

Group A exhibited a significant improvement in Balance Confidence over the course of the intervention ($p < 0.05$). The high F-test value of 273.6, as shown in Table 2, indicates a strong statistical effect. The mean Balance Confidence scores increased from 62.79 ± 6.64 on Day 1 to 71.75 ± 6.74 at Week 3 and further to 82.38 ± 5.78 by Week 6. These findings suggest that the combination of active vibration and balance training is highly effective in boosting Balance Confidence among patients with Type 1 Diabetes Mellitus and peripheral neuropathy.

Group B demonstrated a significant improvement in Balance Confidence over time, as revealed by Repeated Measures ANOVA. The F-test value of 8.36, presented in Table 2, indicates a statistically significant effect. The mean scores on the Activities-Specific Balance Confidence (ABC) Scale increased from 64.75 ± 2.88 on Day 1 to 67.53 ± 4.83 at Week 3, and further to 70.76 ± 7.86 at Week 6. This upward trend highlights the positive impact of the intervention over time, suggesting that balance training alone contributed to enhanced Balance Confidence over the six-week period.

Group A demonstrated a significant improvement in scores on the Modified Falls Efficacy Scale over the six-week intervention period. the F-test value of 281.5 reflects a highly significant effect. The mean scores increased progressively from 6.24 ± 0.29 on Day 1 to 7.20 ± 0.43 at Week 3 and further to 8.27 ± 0.44 by Week 6, indicating enhanced balance confidence, as presented in Table 1. These findings suggest that the intervention led to a marked improvement in balance confidence over time. If the p-value is <0.001, it further confirms that this change is statistically significant.

In Group B, the Modified Falls Efficacy Scale did not exhibit statistically Not significant changes over the intervention period. The mean scores showed a slight increase from 6.47 ± 0.47 on Day 1 to 6.80 ± 0.95 at Week 3 and to 6.93 ± 1.11 at Week 6, suggesting a modest improvement in balance confidence. However, the p-value of 0.058 exceeds the conventional significance threshold ($\alpha = 0.05$), and the F-test value of 3.16 indicates some variability across time points, though not statistically meaningful. Therefore, the observed changes in Modified Falls Efficacy Scale scores over time are not considered significant, as reflected in Table 1.

The impact of Active Vibration Training combined with Balance Training on postural deviation in the antero-posterior (AP) direction with eyes closed was assessed across three time points-Day 1, Week 3 and Week 6-between Group A and Group B. On Day 1, Group A recorded a slightly higher mean postural deviation (4.26 ± 2.40) compared to Group B (3.28 ± 1.66). However, by Week 3, Group A demonstrated a more substantial reduction (2.77 ± 1.78) than Group B (3.07 ± 1.65). This trend continued at Week 6, with Group A showing a marked improvement (1.56 ± 0.75) compared to Group B (2.65 ± 1.65). These results were statistically significant ($p < 0.05$), confirming that Group A achieved greater improvement over time. Although both groups showed progress, a statistically significant difference between the groups emerged only at Week 6, with Group A ($p = 0.001$) and Group B ($p = 0.007$). Unpaired t-test values for Day 1 ($p = 0.6853$) and Week 3 ($p = 0.0924$) indicate that earlier differences were not statistically significant, as shown in Table 2.

The impact of Active Vibration Training combined with Balance Training on Activities-Specific Balance Confidence (ABC) Scale scores was evaluated at three time points-Day 1, Week 3 and Week 6-between Group A and Group B. Initially, Group B had a slightly higher mean ABC score (64.75 ± 2.88) compared to Group A (62.79 ± 6.64). However, by Week 3, Group A exhibited a more notable increase (71.75 ± 6.74) compared to Group B (67.53 ± 4.83), and this improvement was even more pronounced by Week 6, with Group A reaching 82.38 ± 5.78, whereas Group B reached 70.76 ± 7.86. These findings indicate a statistically significant difference ($p < 0.05$), with Group A demonstrating greater enhancement in balance confidence over time. While both groups improved, statistical significance ($p = 0.001$) was achieved only at Week 6. The unpaired t-test results for Day 1 ($p = 0.3039$) and Week 3 ($p = 0.0584$) suggest that early improvements were not statistically significant, as presented in Table 3. The significant outcome at Week 6 supports the hypothesis that vibration training enhances balance confidence in individuals with diabetic peripheral neuropathy, with Group A showing a markedly greater improvement than Group B by the end of the intervention.

The mean ± SD scores for the Modified Falls Efficacy Scale (MFES) were compared between Group A and Group B across three time points: Day 1, Week 3, and Week 6. On Day 1, Group B had a slightly higher mean score (6.47 ± 0.47) compared to Group A (6.24 ± 0.29). However, by Week 3, Group A demonstrated a greater increase in mean MFES scores (7.20 ± 0.43) than Group B (6.80 ± 0.95). This trend continued at Week 6, with Group A reaching 8.27 ± 0.44, showing more improvement than Group B's

6.93 ± 1.11, Although both groups showed balance improvements over time, a statistically significant difference (p = 0.001) was observed only at Week 6. The unpaired t-test results for Day 1 (p = 0.1120) and Week 3 (p = 0.1389), shown in Table 4, indicate that earlier changes were not statistically significant. These findings suggest that while active vibration training combined with balance training may contribute to improvements, a longer duration of intervention may be necessary to achieve clinically meaningful outcomes.

Table 3. The comparison for ABC between GA and GB

	Groups	Day 1	Week 3	Week 6
ABC (Score)	GA	62.79±6.64	71.75±6.74	82.38±5.78
	GB	64.75±2.88	67.53±4.83	70.76±7.86
Unpaired t-test		1.047	1.973	4.611
P-value		0.3039	0.0584	0.0011
T-value		2.05	2.05	2.05

Table 4. Values represented as Mean±SD; MFES GA: Group A, GB: Group B.

	Groups	Day 1	Week 3	Week 6
MEFS Score	GA	6.24± 0.29	7.20± 0.43	8.27± 0.44
	GB	6.47± 0.47	6.80± 0.95	6.93± 1.11
Unpaired t-test	1.641		1.523	4.341
P-value	0.1120		0.1389	0.0012
T-value	2.05		2.05	2.05

Discussion

According to Holmes CJ et al[4], diabetes mellitus is among the most common metabolic disorders worldwide, affecting populations in both developing and developed countries. Chronic diabetes leads to various complications involving the nervous, vascular and lymphatic systems, often resulting in neuropathy. Diabetic Peripheral Neuropathy (DPN) is the most common complication of diabetes mellitus, causing damage to both motor and sensory nerves in the upper and lower limbs due to prolonged high blood glucose levels. It also leads to pain, muscle wasting with fat infiltration, impaired or reduced sensation and muscle dysfunction in the limbs. Damage to motor and sensory nerves disrupts the nerve and blood supply to muscle fibers, resulting in muscle atrophy and balance impairments, which increase the risk of falls in patients.

This study demonstrated that four weeks of Active Vibration Training with the Flexi-Bar, combined with balance training, enhanced balance, reduced fall risk and increased balance confidence in patients with diabetic peripheral neuropathy. The findings of our study revealed statistically significant improvements in balance, fall risk and balance confidence, as assessed by the Ortho King Pressure Plate, Modified Falls

Efficacy Scale, and Activities-Specific Balance Confidence Scale, respectively. Um KM et al[9] conducted a study to examine the effects of a six-week Flexi-Bar exercise program on balance and postural alignment in individuals with asymmetric posture. They noted that the Flexi-Bar generates low-frequency vibrations (around 5 Hz), which are believed to travel from the hands to other parts of the body; however, this effect has not been definitively proven or quantified by existing research. Mileva KN et al[10] demonstrated that during a single-leg squat, the Flexi-Bar transmits low-frequency vibration stimuli from the upper limbs to the trunk and subsequently to the lower limbs. The observed improvement in balance may be attributed to the vibrations generated by the Flexi-Bar, which stimulate proprioceptors and enhance the sense of joint movement through the external load created by intense stimulation. The postural or tonic muscles in the abdominal, waist and pelvic regions contribute to lumbar stability and postural control, playing a vital role in enhancing overall balance and stability. Chung JS et al[11] conducted a study to examine and compare the effects of Flexi-Bar and non-Flexi-Bar exercises on trunk muscle activation across three different postures: quadruped, side bridge and standing.

Muscle activation was evaluated using EMG, focusing on the rectus abdominis, erector spinae, external oblique and internal oblique muscles. Among the three postures, Flexi-Bar exercises performed in the standing position elicited the highest activation of the external oblique muscle, likely due to the need to stabilize the trunk on a narrower base of support. Seo DK et al[12] demonstrated that the deep abdominal muscles play a key role in stabilizing the lumbopelvic region during functional movements. The findings of our study cannot be directly compared with existing literature, as no prior research has specifically examined the effects of Flexi-Bar training on balance confidence and fall risk. However, several observational studies have explored the relationship between these factors and balance impairments. Riandini T et al[8] conducted a study to explore the relationship between fall risk and balance confidence in individuals with diabetes-induced neuropathy. The authors found that balance confidence, measured by the total ABC score, was inversely related to fall risk, indicating that higher balance confidence was linked to a lower likelihood of falls and reduced fall risk. A decrease in balance confidence and fear of falling significantly restrict an individual's ability to carry out daily functional tasks.

This leads to physical deconditioning and eventually, greater disability and reduced independence in daily activities, thereby raising the risk of falls. Additional studies have also found that diabetes and diabetes-related neuropathy are associated with balance impairments, which in turn elevate the risk of falls. People with a longer duration of diabetes have been shown to experience muscle weakness and a higher rate of hospitalizations due to increased fall incidents. Richardson JK et al[13] reported that a three-week balance exercise program enhanced both static and dynamic balance, as well as activity-specific balance confidence in older adults. Thus, the current literature indicates a lack of studies specifically targeting individuals with diabetic peripheral neuropathy (DPN) to enhance balance confidence and reduce fall risk. Hence, this study is the first to directly address both balance confidence and fall risk. The findings of our study revealed that incorporating Flexi-Bar exercises with traditional balance training enhances balance confidence and lowers fall risk in individuals with diabetic peripheral neuropathy (DPN). A study by Winter DA et al[14] reported comparable improvements of 27.43% in individuals with diabetes, suggesting that the enhancement in antero-posterior sway could be attributed to the use of the ankle strategy for maintaining balance. Ankle strategy contributes to the improvement of antero-posterior sway.

Future Scope

This study's small sample size limits how broadly its conclusions can be applied and larger studies are

needed for confirmation. Additionally, the lasting impact of Flexi-Bar exercises has yet to be established. Because the study lacked randomization and blinding, selection bias may have influenced the results. The absence of a control group without any intervention and a group trained exclusively with the Flexi-Bar also restricts the depth of comparison.

Clinical Implication

The study demonstrated a reduction in antero-posterior postural sway, including both peak and average sway, in patients with Type 2 Diabetes Mellitus and polyneuropathy. Hence, routine assessment of postural sway in these patients is crucial for early detection and intervention.

Conclusion

Conducted to compare the impact of combined Flexi-bar and balance training with balance training alone, this study found improvements across both groups. However, those using Flexi-bar showed more pronounced benefits. The device offers gentle vibrations, is safe and can be used without supervision. Additionally, the combined approach produced quicker outcomes than balance exercises alone, which typically require a longer duration for similar benefits.

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