EFFICACY OF BALANCE TRAINING ON QUALITY OF LIFE IN DIABETIC PERIPHERAL NEUROPATHY PATIENTS: A SYSTEMATIC REVIEW

[1]Dr. Roshni Vohra (PT), [2]Dr. Slesha Shah (PT)

[1,2]Assistant Professor, Faculty of Physiotherapy, Sigma University – Vadodara

[1]Email: dr.roshnivohra@gmail.com

[2]Email: slesha108@gmail.com

ABSTRACT

Diabetic peripheral neuropathy (DPN), a frequent complication of diabetes mellitus, significantly impairs balance and increases fall risk, impacting quality of life. This systematic review evaluates the efficacy of balance training in improving quality of life in DPN patients. We conducted a comprehensive search across PubMed, EMBASE, Cochrane Library, and Web of Science, including randomized controlled trials (RCTs) assessing balance training interventions with quality-of-life outcomes in DPN patients. Data extraction and quality assessment were performed using standardized tools.

Our analysis revealed that targeted exercise interventions, including multisystem physical exercise (MPE), proprioceptive training, Swiss ball exercises, aerobic exercise, and multisensory exercise, significantly improved balance, mobility, and reduced pain in DPN patients. Studies utilizing validated outcome measures such as the Berg Balance Scale (BBS), Timed Up and Go (TUG), and Numeric Pain Rating Scale (NPRS) demonstrated significant improvements compared to control groups.

Specifically, MPE, proprioceptive training, and Swiss ball exercises were found to be particularly effective in enhancing postural stability and balance. Aerobic exercise improved overall quality of life by addressing pain and sensory symptoms. While studies varied in sample size and intervention duration, the consistent positive findings underscore the clinical significance of exercise therapy in DPN management.

This review concludes that balance training and targeted exercise interventions are effective in improving quality of life in DPN patients. Tailored exercise programs addressing specific deficits, along with consideration of cognitive factors, are crucial for optimal outcomes.

Keywords: Diabetic peripheral neuropathy (DPN), balance training, quality of life, rehabilitation.

INTRODUCTION

Diabetic peripheral neuropathy (DPN) is one of the enduring complications of diabetes resulting from dysfunction in peripheral motors and sensory nerves. It is the most prevalent chronic complication that can result in mortality and morbidity among people with diabetes.{1} Diabetes mellitus is a long-term metabolic condition marked by hyperglycemia resulting from impaired insulin secretion, insulin absorption, or both. India is second only to China in the worldwide diabetes epidemic, with 77 million individuals affected by diabetes.{1,2} The CDC reports that 463 million adults globally suffer from diabetes. The occurrence of diabetes is greater in urban regions compared to rural ones, peaking in the 55–64 age.{2} This increase is mainly attributable to changes in diet and inadequate or absent physical activity, which result in physiological shifts that cause obesity or obesity as well as diabetes. The onset of diabetic neuropathy is affected by risk factors including extended hyperglycemia, obesity, dyslipidemia, hypertension, smoking, and alcohol intake. Obesity and cardiovascular-related conditions additionally worsen the intensity of neuropathy.{2,3}

Pathogenesis of Diabetes includes a range from the autoimmune destruction of pancreatic beta-cells, resulting in insulin deficiency, to irregularities that contribute to insulin resistance. This results in inadequacies in insulin action on target tissues, causing abnormalities in carbohydrate, fat, and protein metabolism. Diabetic peripheral neuropathy (DPN) refers to a form of polyneuropathy that may lead to damage of the peripheral nerve fibers, sensorimotor, and autonomic system.{4} This leads to deficits in insulin function on target tissues resulting in irregularities in carbohydrate, fat, and protein metabolism.{5}

Symptoms of significant hyperglycemia encompass polyuria, polydipsia, weight loss, occasionally accompanied by polyphagia, and blurred vision. It is distinguished by insulin insensitivity due to insulin resistance, reduced insulin secretion, and ultimately pancreatic beta cell dysfunction. This results in a reduction of glucose transport into the liver, muscle cells, and adipose tissue. There is an elevation in fat breakdown associated with hyperglycemia. Recent developments have acknowledged the role of compromised alpha-cell function in the pathophysiology of type 2 diabetes mellitus. {6,7}

Peripheral neuropathy refers to a gradual deterioration of the peripheral nerves, particularly in the lower extremities, which impacts the sensory, motor, and autonomic aspects of the peripheral nerves.{5,6} This condition presents as a reduction in protective sensation, dysfunction of the intrinsic here are primarily 2 varieties of Diabetes mellitus: A] Type 1 diabetes, referred to as insulin-dependent diabetes mellitus (IDDM) B] Type 2 diabetes, referred to as non-insulin-dependent diabetes mellitus (NIDDM) TYPE

1: Type 1 diabetes mellitus (T1DM), also termed autoimmune diabetes, is a long-term condition marked by a lack of insulin caused by the loss of pancreatic β-cells and results in hyperglycemia muscles of the foot, and a lack of sweat production in the foot.[7,8,9] Balance issues are also triggered by impairments in movement strategies, biomechanical structural disorders, and disorientation. Postural instability results from peripheral neuropathy. Diabetic peripheral neuropathy (DPN) can cause muscle weakness, a decline in ankle reflexes, and difficulties in balance, coordination, and gait control, which significantly heighten the risk of falling.{10,11}Diabetic neuropathy represents a progressive deterioration of the peripheral nerves, typically commencing as mild sensory symptoms such as pain or paranesthesia. The challenges encountered by patients include pain and paranesthesia localized to the most distal parts of the extremities. Altered sensations occur in the foot and distal leg regions and, very infrequently, in the hand and wrist. Ankle jerks are generally affected due to the involvement of sensory fibers within the reflex pathways.[12] DN may disrupt balance in everyday activities. Individuals with DN face a fivefold greater risk of falling, with repercussions that include reduced mobility, avoidance of activities, admission to care facilities, and increased mortality rates.[13,14] The balance issues in those with DN mainly occur in the medial-lateral direction and are most pronounced when descending stairs. Physiological aspects (like strength and proprioception) and cognitive-behavioral elements (such as fear of falling) must be considered when managing diabetic patients who exhibit gait issues. Diabetic neuropathy (DN) significantly diminishes patients' quality of life and hampers diabetes self-management, thereby exacerbating the outlook for other diabetes-related complications.[15,16,18]

DN has been noted to cause postural instability, a heightened risk of falling, and difficulty in carrying out activities of daily living (ADL). Basic protective reflexes, along with coordinated joint movements, along with balance and postural control, are diminished as DPN decreases. Muscle weakness, a delayed response to postural changes, and the inability to evenly distribute body weight due to impaired proprioception led to a balance issue.[19,20] Furthermore, diminished balance in individuals with diabetic neuropathy is another significant factor that contributes to increased falls and a reduction in quality of life. Therefore, tackling balance deficits through exercises in individuals with diabetic peripheral neuropathies is crucial to lowering the risk of falls and enhancing quality of life. Numerous patients with diabetic neuropathy suffer from neuropathic pain, usually described as burning, tingling, electric, sharp, shooting, and lancinating sensations, which initially begins in both feet and may extend to involve the calves, fingers, and hands (stocking and glove pattern).

Objective:

- To systematically evaluate the efficacy of balance training on improving quality of life in diabetic neuropathy patients.

Research Question:

- Does balance training significantly improve the quality of life in patients with diabetic neuropathy?

METHODS

- **Search Strategy:**
  - Databases to be searched (e.g., PubMed, EMBASE, Cochrane Library, Web of Science).
  - Search terms and keywords (e.g., "diabetic neuropathy," "balance training," "quality of life," "exercise therapy," "postural stability").
  - Search string examples.
  - Date range for the search.
- **Inclusion and Exclusion Criteria:**
  - Population: Patients with diagnosed diabetic neuropathy.
  - Intervention: Studies using balance training as the primary intervention.
  - Comparison: Studies with control groups (e.g., no intervention, standard care).
  - Outcome: Studies measuring quality of life (e.g., using validated questionnaires).
  - Study design: Randomized controlled trials (RCTs), quasi-experimental studies.
  - Exclusion criteria: studies not in english, studies without a control group, studies that do not measure quality of life.
- **Study Selection:**
  - Process of screening titles, abstracts, and full texts.
  - Flowchart of study selection (PRISMA).

- Methods for resolving disagreements.

- **Data Extraction:**
  - Variables to be extracted (e.g., study design, participant characteristics, intervention details, outcome measures, results).
  - Use of a standardized data extraction form.
- **Quality Assessment:**
  - Tools for assessing the methodological quality of included studies (e.g., Cochrane Risk of Bias tool, PEDro scale).
  - Process of assessing and reporting bias.
- **Data Synthesis:**
  - Methods of summarizing the data, and if data is homogenous enough, plans for meta-analysis.
  - Methods of handling heterogenity.

RESULTS

Table 1 : A summary table describing the characteristics of the included studies:

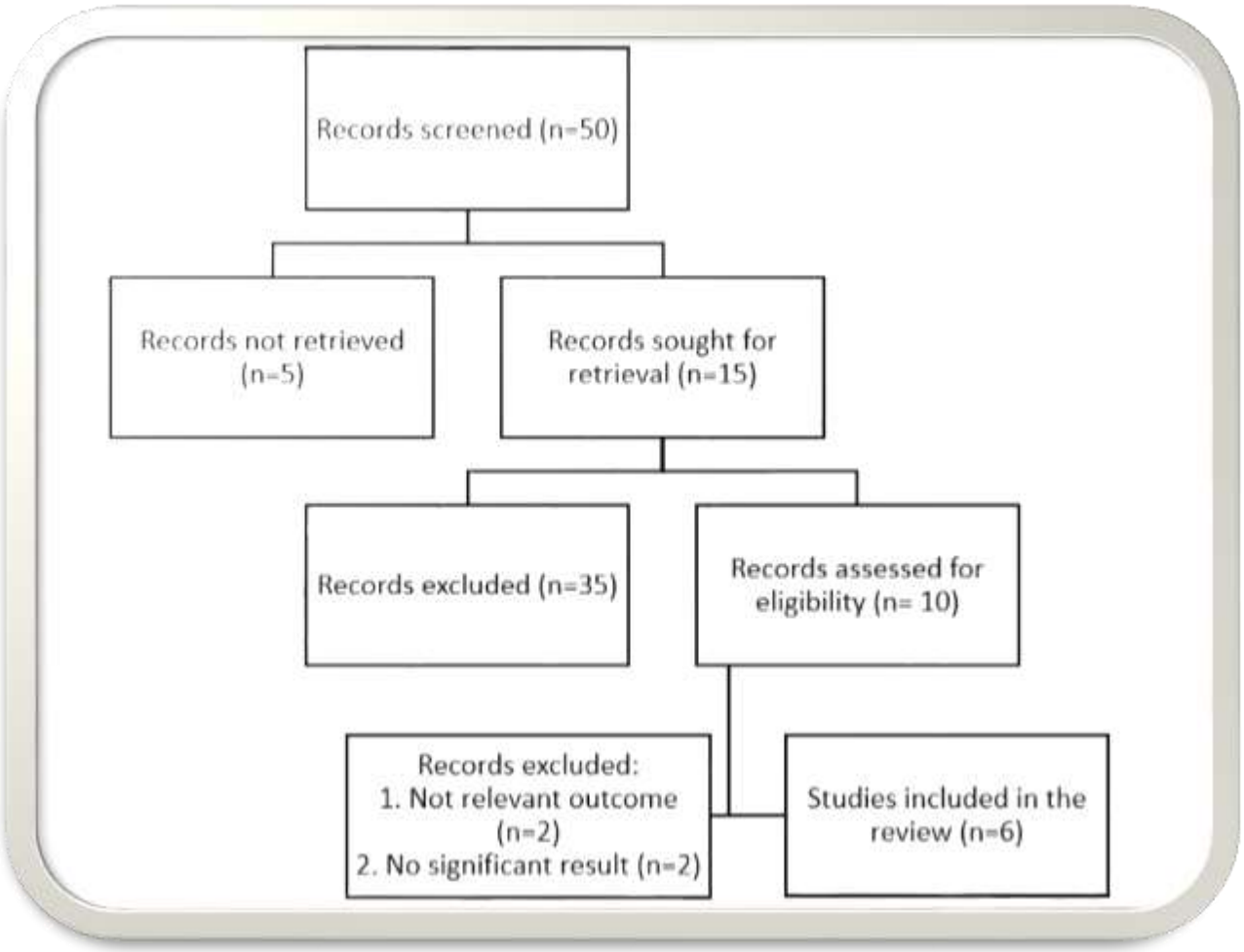
Sr. no.	Author, Year	Sample size	Intervention	Outcome measure	Major finding	Outcome conclusion
1.	Sidra Khurshid et al. (2025)	50	Multisystem Physical Exercise (MPE) group ($n = 26$) and a conventional exercise group ($n = 24$). The MPE program included balance, proprioception, strength, and reaction time training, while the control group received conventional exercises, consisted of strength, balance, stretching, and range of motion exercises. Both groups underwent 30 min intervention sessions, 3 times per week, for 8 weeks.	Berg balance scale (BBS), functional reach test (FRT), time up and go test (TUG), 10 min walk test (10-MWT), and numeric pain rating scale (NPRS).	Significant group and time interactions were observed for all outcome measures including BBS, FRT, TUG, 10-MWT, and NPRS ($p < 0.001$). The between-group analysis also revealed significant differences between the multisystem physical exercise group and the conventional exercise group at both the 4th week and 8th week for BBS, FRT, TUG, 10-MWT, and NPRS ($p < 0.05$).	The study concluded that multisystem exercises resulted in significant improvement in balance, postural stability, mobility, and walking speed, along with reduction in pain, compared to conventional exercises in patients with diabetic peripheral neuropathy.

2.	Zahra Rojhani-Shirazi et al. (2017)	60	The study was performed on 60 patients with diabetes categorized randomly into three groups: an intervention group (N = 20) that received ball training exercise, another intervention group (N = 20) that received Frenkel exercise and a control group (N = 20) that received no interventions. Exercise training session was performed for 3 weeks.	single leg stance, star excursion test, and Berg balance scale test	Both types of therapeutic exercise programs significantly improved balance in single leg stance, star excursion test, and Berg balance scale test ($P < 0.05$) compared to the control group. Besides, this was more significant in the ball training group ($P < 0.05$).	To improve balance in diabetic neuropathy, Swiss ball exercise is preferred compared to Frenkel training.
3.	Walid Kamal Abdelbasset et al. (2020)	28	They were randomly assigned into two groups, 14 in each group using a random number generator. The proprioceptive exercise group (PEG) received a program of proprioceptive exercise, while the control group (CG) received a conventional treatment without exercise intervention.	Berg Balance Scale (BBS), Six-Minute Walk Test (6MWT), Beck Anxiety Inventory (BAI), and Hamilton Depression Rating Scale (HDRS) were investigated before and after 2 months of the study period.	The findings showed a significant improvement of the BBS, 6MWT, BAI, and HDRS in the PEG ($p = 0.003$, $p < 0.001$, $p = 0.001$, and $p = 0.001$, respectively) while non-significant changes in the CG ($p > 0.05$). Comparison between the two groups showed significant differences between the two groups in the all outcome measures in favor of the PEG at the end of the 2 months (BBS, $p = 0.032$; 6MWT, $p = 0.001$; BAI, p	Proprioceptive exercise may improve postural stability in patients with diabetic neuropathy.

					= 0.031; and HDRS, p = 0.013).	
4.	Gurtej Singh Grewal et al. (2015)	39	Intervention (IG) or a control (CG) group. The IG received sensor-based interactive exercise training tailored for people with diabetes (twice a week for 4 weeks). The exercises focused on shifting weight and crossing virtual obstacles. Body-worn sensors were implemented to acquire kinematic data and provide real-time joint visual feedback during the training.	Outcome measurements included changes in center of mass (CoM) sway, ankle and hip joint sway measured during a balance test while the eyes were open and closed at baseline and after the intervention.	Compared with the CG, the patients in the IG showed a significantly reduced CoM sway (58.31%; p = 0.009), ankle sway (62.7%; p = 0.008) and hip joint sway (72.4%; p = 0.017) during the balance test with open eyes. The ankle sway was also significantly reduced in the IG group (58.8%; p = 0.037) during measurements while the eyes were closed. The number of steps walked showed a substantial but nonsignificant increase (+27.68%; p = 0.064) in the IG following training.	The results of this randomized controlled trial demonstrate that people with DPN can significantly improve their postural balance with diabetes-specific, tailored, sensor-based exercise training.
5.	Nizar Abdul Majeed Kutty et al. (2013)	32	2 groups - an experimental group of 16 participants with diabetes and a control group of 16 participants with diabetes. For 6 weeks, both groups were given health education on diabetes for 30 minutes a week. In addition, the experimental group practised a multisensory exercise programme for 30	'timed up and go' test for assessing balance and '6-minute walk' test	By the end of the trial period, the intervention group showed a significant improvement in scores of the 'timed up and go' test (t= 14.7092), but there was no statistically significant difference in the '6-minute walk' test scores	The findings suggest that along with physiological sensory factors, cognitive-behavioral factors and strengthening of the lower limb muscles should be considered when treating diabetic persons with gait alterations.

			minutes, 3 times a week over 6 weeks.		(p=0.7206, t= 0.3644).	
6.	Snehil Dixit et al. (2014)	47	8-week moderate intensity aerobic (heart-rate reserve 40-60%) exercise on neuropathy quality of life in type 2 diabetes.	Michigan diabetic neuropathy score	The two groups had a significant difference, pre-post intervention in scores of pain ($F = 7$, $p = 0.01$), sensory symptoms ($F = 4.60$, $p = 0.04$), restricted activities of daily living ($F = 4.97$, $p = 0.03$), disruptions in social relationships ($F = 5.43$, $p = 0.02$), specific impact on quality of life ($F = 9.28$, $p < 0.001$) overall quality of life ($F = 28.72$, $p < 0.001$), and total score ($F = 31.10$, $p < 0.001$). Degrees of freedom for all the components were 1, 62.	Moderate intensity aerobic exercise is cornerstone in improving the quality of life of individuals with peripheral neuropathy in type 2 diabetes.

Figure 1: The Study selection process flow chart



DISCUSSION

- **Improved Proprioception:**
  - Diabetic neuropathy often damages the sensory nerves in the feet, leading to impaired proprioception (the body's awareness of its position in space).
  - Balance training stimulates these sensory pathways, helping to improve the brain's ability to receive and interpret sensory information.
  - This leads to better body awareness and increased stability.
- **Enhanced Neuromuscular Control:**
  - Balance exercises activate and strengthen the muscles responsible for maintaining posture and balance.
  - This improved neuromuscular control allows for quicker and more effective responses to changes in balance, reducing the risk of falls.
  - This includes improved motor coordination.
- **Increased Muscle Strength and Endurance:**
  - Balance training often incorporates exercises that strengthen the lower extremity muscles, particularly those in the ankles and legs.
  - Increased muscle strength and endurance provide better support and stability, further reducing the risk of falls.
- **Improved Postural Stability:**
  - Regular balance training helps to improve both static (standing still) and dynamic (moving) postural stability.
  - This translates to better balance during everyday activities, such as walking, climbing stairs, and reaching for objects.

- **Reduction of Fall Risk:**
    - By improving proprioception, neuromuscular control, muscle strength, and postural stability, balance training significantly reduces the risk of falls, a major concern for individuals with diabetic neuropathy.
- **Positive Impacts on the Nervous System:**
    - While nerve damage from diabetic neuropathy is hard to reverse, the stimulation from balance training can help to maximize the function of the remaining healthy nerve pathways.
    - This can potentially improve nerve signalling related to balance.

Impact on Quality of Life:

These physiological improvements directly contribute to an enhanced quality of life by:

- Increasing confidence and independence.
- Reducing fear of falling.
- Improving mobility and participation in daily activities.
- Reducing pain and discomfort associated with instability.

In essence, balance training helps to counteract the negative effects of diabetic neuropathy on the nervous and musculoskeletal systems, leading to significant improvements in physical function and overall well-being.

- **Exercise Benefits:**
    - All studies demonstrate that targeted exercise interventions, compared to control groups or conventional treatments, result in significant improvements in various outcome measures.
    - These improvements span across balance (BBS, FRT, single leg stance, star excursion test), mobility (TUG, 10-MWT, 6MWT), pain (NPRS, Michigan diabetic neuropathy score), and even psychological aspects (BAI, HDRS).
- **Specific Exercise Modalities:**
    - **Multisystem Physical Exercise (MPE):** Khurshid et al. (2025) highlights the effectiveness of MPE, which incorporates balance, proprioception, strength, and reaction time training, demonstrating superior results compared to conventional exercises.
    - **Proprioceptive Exercises:** Abdelbasset et al. (2020) and Grewal et al. (2015) emphasize the importance of proprioceptive training, showing significant improvements in postural stability and balance. Grewal et al. also showed the benefits of sensor based training.
    - **Ball Training:** Rojhani-Shirazi et al. (2017) found that Swiss ball exercises were more effective than Frenkel exercises in improving balance.
    - **Aerobic Exercise:** Dixit et al. (2014) demonstrates the positive impact of moderate-intensity aerobic exercise on neuropathy quality of life, addressing pain, sensory symptoms, and social aspects.
    - **Multisensory Exercise:** Kutty et al. (2013) showed that multisensory exercise improved the timed up and go test, which suggests an improvement in balance.
- **Outcome Measures:**
    - The studies utilize a range of validated outcome measures, including the Berg Balance Scale (BBS), Functional Reach Test (FRT), Timed Up and Go (TUG), 6-Minute Walk Test (6MWT), and Numeric Pain Rating Scale (NPRS), among others.
    - This diverse set of measures provides a comprehensive assessment of the impact of interventions on various aspects of DPN.
- **Sample Size and Study Design:**
    - The studies vary in sample size, ranging from 28 to 60 participants.
    - Most studies employ randomized controlled trial (RCT) designs, which strengthen the validity of the findings.
    - The duration of the interventions also varied, from 3 weeks to 8 weeks.

- **Limitations:**
    - Variability in sample sizes and intervention durations makes it difficult to directly compare the effectiveness of different exercise modalities.
    - Some studies had relatively small sample sizes, which may limit the generalizability of the findings.
    - Further research with larger sample sizes and standardized intervention protocols is needed to establish definitive guidelines for exercise therapy in DPN.
    - The study of Kutty et al. (2013) showed improvement in the timed up and go test, but not the 6 minute walk test. This suggests that some exercise programs may improve balance more than endurance.
    - The study of Grewal et al. (2015) showed a substantial but nonsignificant increase in the number of steps walked. This result suggests that further studies with a larger sample size may show a significant result.

Clinical Implications:

- Exercise therapy should be considered a cornerstone of DPN management.
- Tailored exercise programs that address specific deficits, such as balance, proprioception, and strength, are likely to be most effective.
- Healthcare professionals should consider incorporating a variety of exercise modalities, including MPE, proprioceptive training, and aerobic exercise, into DPN rehabilitation programs.
- Sensor based exercise programs can be very beneficial.
- When creating exercise programs for those with DPN, it is important to consider the cognitive and behavioural factors, in addition to the physiological factors.

CONCLUSION

This review confirms that targeted balance training and exercise significantly improve quality of life in diabetic peripheral neuropathy (DPN) patients by enhancing balance, mobility, and reducing pain. Various exercise modalities, including multisystem, proprioceptive, and aerobic training, demonstrate efficacy.

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