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RESEARCH ARTICLE

PROPRIOCEPTIVE TRAINING AND CONVENTIONAL PHYSICAL THERAPY ON BALANCE AND QUALITY OF LIFE IN PATIENTS WITH DIABETIC PERIPHERAL NEUROPATHY: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

OBJECTIVE:

To compare the effects of proprioceptive training and conventional physical therapy on balance and health-related quality of life in patients with diabetic peripheral neuropathy versus conventional physical therapy alone.

METHODS:

This single-blinded, randomised controlled trial was conducted at District Headquarter Hospital, Layyah, Punjab, Pakistan. The sample size of 82 participants was selected through a purposive sampling technique. The control group (A) received conventional physical therapy, including strength training and ROM exercises. The experimental group (B) received proprioceptive training along with conventional physical therapy. Balance was measured using the Berg Balance Scale (BBS), and health-related quality of life by using the Short Form-36 (SF-36). Outcome measures were assessed at baseline, 4th week, and 8th week. An independent sample t-test was used to determine the between-group difference of means. Repeated measure ANOVA was used to analyse within-group mean differences.

RESULTS:

The mean age of participants was 50.72 ± 8.24 years with a mean HbA1c of 6.68 ± 0.72. The proprioceptive training group showed significantly greater improvements in balance and most SF-36 domains compared to controls ($p < 0.001$). No significant differences were found in role limitations due to physical or emotional health. Higher partial η^2 values (0.83–0.97) indicated strong intervention effects.

CONCLUSION:

The addition of proprioceptive training to conventional physical therapy in the management of patients with diabetic peripheral neuropathy is more effective in improving balance and health-related quality of life than conventional physical therapy alone.

KEYWORDS

balance, diabetic neuropathy, proprioception, physical therapy, quality of life

INTRODUCTION

Diabetic Peripheral Neuropathy (DPN) is one of the complications of diabetes mellitus (DM) resulting from microvascular dysfunction. Almost 50% of individuals with diabetes develop this condition during their lifetime. Its prevalence varies with age, gender, glycaemic control, and type of diabetes [1]. According to a survey, the prevalence of DPN in people living with diabetes is 26.52% in Pakistan [2]. The manifestations of DPN range from no pain to severe pain and sensory impairments [3] that lead to foot ulcers and may cause non-traumatic amputations. Many recent studies have shown an association of cardiovascular risk factors, including obesity, hypertriglyceridemia, hypercholesterolemia, hypertension, and cigarette smoking, in the pathogenesis of DPN [4]. Identifying the modifiable risk factors for developing neuropathy and effectively controlling them at an early stage is critical for successful management and prevention of serious consequences such as ulcers, gangrene, amputation, and accompanying social burden [5].

Diabetic peripheral neuropathy leads to difficulties in balance and coordination due to damage to sensory nerves, reduced tactile stimulation, and loss of proprioception, as well as motor nerve damage that causes weakness, resulting in frequent falls. The most distal parts of the body are the first to be affected by glove and stocking patterns. Furthermore, cognitive decline, particularly in attention, executive function, and dual-tasking ability, exacerbates these sensorimotor deficits, creating a multifactorial pathway to heightened fall risk [6]. These sensorimotor deficits are more predominant in the lower extremities, specifically in the feet, and they lead to disturbances in gait mechanics and impairments in balance [7]. Peripheral neuropathy, present in 50–70% of older patients with diabetes, increases the risk of postural instability, balance problems, muscle atrophy, limiting physical activity, and increasing the risk of falls, which worsen the health-related quality of life [8]. Furthermore, foot problems, including foot ulcerations, partial foot amputation, and trans-tibial amputations, may exacerbate balance disturbances. These individuals also have reduced walking speed, step length, and rhythmic acceleration patterns at the head and pelvis [9]. Therefore, effective interventions targeting balance and functional status may be beneficial in optimising health and well-being [10].

In patients with diabetic peripheral neuropathy (DPN), maintaining good glycemic control and practicing effective self-management are crucial for preserving quality of life. Moreover, factors such as socioeconomic status and education level may also influence overall well-being. Therefore, preventing diabetic complications and effectively managing coexisting chronic conditions remain essential components of comprehensive care for individuals with DPN [11]. Conservative management strategies, including patient education, electrophysical modalities such as transcutaneous electrical nerve stimulation (TENS) and vibration therapy, and therapeutic exercises encompassing range of motion (ROM), strengthening, gait, and balance training, are widely used to reduce neuropathic pain, enhance proprioceptive input, improve muscle strength and joint mobility, and ultimately restore functional balance and mobility in patients with DPN. [12, 13, 14]

Proprioceptive training is a therapeutic exercise intervention designed to improve proprioceptive function. It focuses on using somatosensory signals, such as proprioceptive or tactile afferents, in the absence of information from other modalities such as vision. Its ultimate goal is to improve or restore sensorimotor function to enhance postural balance and control, movement coordination, and reduce the risk of re-injury. [15,16]

Despite established evidence linking proprioceptive training to improved balance and reduced fall risk, its effectiveness relative to conventional physical therapy remains unclear. To address this gap, the present study will compare the effects of a combined proprioceptive and strength training intervention against conventional care on balance and health-related quality of life in a diabetic population.

MATERIALS AND METHODS

This single-blind, randomised controlled trial (RCT) was conducted at the University of Lahore, with data collected from the Department of Physical Therapy at the District Headquarter Hospital in Layyah, Punjab, Pakistan, between December

2021 and September 2022. This study was designed as a superiority trial to evaluate whether proprioceptive training combined with conventional physical therapy is superior to conventional physical therapy alone. Participants were randomised with an allocation ratio of 1:1. This trial was registered on ClinicalTrials.gov (ID: NCT05968131) and follows the Consolidated Standards of Reporting Trials (CONSORT) guidelines as shown in Figure 1 (see appendix). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Research Ethics Committee (REC) of The University of Lahore (REF: REC-UOL-FAHS/997/2021). Informed consent was obtained from all participants after the study's objectives were explained. Data anonymity was ensured, and participants retained the right to withdraw from the study at any time. The sample of 82 participants was calculated using the OpenEpi software by the following formula:

$$n = \frac{2\sigma^2 (z_{1-\alpha/2} + z_{1-\beta})^2}{(\mu_1 - \mu_2)^2}$$

$Z_{1-\alpha/2}$ Level of significance=95%, μ_1 expected mean change in balance in control group= 54.3 [15], μ_2 expected mean change in balance in interventional group= 49.8 [15], δ_1 expected standard deviation in control group= 6.9, δ_2 expected standard deviation in interventional group= 6.2, $z_{1-\beta}$ power of the study= 80%. The calculated sample size in a group was 34, but after adding 20% dropout, it came out to 34+7=41 in each group.

ELIGIBILITY CRITERIA:

The inclusion criteria of the study were participants aged between 35-65 years, both genders, diagnosed patients of peripheral neuropathy having type-II diabetes, by a registered medical practitioner, Michigan Neuropathy Screening Instrument Questionnaire score of seven or greater [13], and the ability to stand on both feet independently. The exclusion criteria were amputation, inner ear infection, neurological illness that affects balance, including multiple sclerosis, Parkinson's disease, Alzheimer's disease, stroke, and cerebral ataxia [15], musculoskeletal problems such as leg length discrepancy, ankle sprain, and severe osteoarthritis of knee and hip joints [15] and the usage of an orthotic device [17]. Participants who met the predefined eligibility criteria were recruited using non-probability consecutive sampling methods and were subsequently randomised into intervention and control groups by the fishbowl method.

INTERVENTION AND TREATMENT GROUPS:

Individuals in the control group (A) received conventional physical therapy consisting of strengthening and range of motion (ROM) exercises. The targeted movements included knee flexion and extension, ankle dorsiflexion and plantarflexion, ankle inversion and eversion, and toe flexion and extension. Exercises were performed actively through the full range of motion, followed by resistance training using TheraBands with progressively increasing resistance based on individual strength improvement. Each movement was initially performed for 10 repetitions per set, two sets per session, with progression by adding five repetitions every two weeks.

The experimental group (B) received proprioceptive training in addition to the conventional strengthening and ROM exercises described above. The proprioceptive training session began with a 5-minute warm-up consisting of gentle stretches and ended with a 5-minute cool-down involving slow walking. The main intervention was a circuit composed of six exercise stations designed to stimulate the sole and improve gait. Participants stepped alternately on marked ground surfaces, with progression achieved by modifying walking speed and direction.

The circuit was arranged in the following order:

- A 10-cm-thick foam surface
- A wooden box filled with beans
- A 2-cm-thick mat with a lower density than the foam
- A wooden box filled with sand
- A balance board to train lateral balance reactions
- A wooden box filled with cotton

Each patient spent four minutes at each station, for a total proprioceptive training time of 24 minutes. A two-minute rest was provided before starting proprioceptive training, after completion of the ROM and strengthening exercises. [17] The exercises in both groups were supervised by two physiotherapists, each with an average of five years of neurological rehabilitation experience. Training was conducted three times per week on alternate days for eight weeks. The total duration of each session was 45–60 minutes for both groups.

Outcome variables were balance and health-related quality of life measured using the Berg Balance Scale and the short-form-36 questionnaire (SF-36). The Berg Balance Scale (BBS) is a 14-item scale scored from 0 to 56, where higher scores indicate better balance and a score below 45 suggests increased risk of falls.[18] The SF-36 questionnaire measures eight health domains and is scored from 0 to 100, with higher scores reflecting better perceived health status and quality of life.[19] The assessments were conducted at baseline, at the 4th week, and at the 8th week. Intention-to-treat analysis was employed, and the participants were analysed in the same group in which they were randomised. The missing data due to loss to follow-up was managed by the last observation carried out method.

STATISTICAL ANALYSIS:

Data were entered and analysed using SPSS version 26. Numerical variables (e.g., age) were presented as mean ± standard deviation (SD), while categorical variables (e.g., gender) were expressed as frequency and percentage. The normality of data distribution was assessed using the Kolmogorov–Smirnov test ($n \geq 50$). For between-group comparisons of the mean score of conventional physiotherapy and proprioceptive training on balance and quality of life in individuals with diabetic peripheral neuropathy, an independent-samples t-test was applied. Repeated measures ANOVA was used to evaluate within-group changes across different follow-up points. A p-value ≤ 0.05 was considered statistically significant.

RESULTS

The mean age of participants was 50.72±824 years. The results regarding the gender of participants showed that there were 12% males and 88% females in group A and 44% males and 56% females in group B. There were 8% of subjects who were obese and 3% of subjects who were not obese in group A, while 8% of subjects were obese, 13% and 6% were not obese in group B. The group-wise comparison of demographic details is given in Table 1, and the results showed that the groups are homogenous in baseline characteristics (p>0.05).

TABLE 1: DEMOGRAPHIC DETAILS OF STUDY GROUPS

Variables	Group-A Mean ± SD	Group-B Mean ± SD	p-value
Age	51.03±7.71	50.41±8.84	0.760
Duration of Diabetes(years)	12.38±2.82	11.71±2.65	0.313
HbA1c	6.68±0.72	6.68±0.68	1.00
Onset of Symptoms (months)	5.53±1.60	5.76±1.82	0.574

The between-group comparisons for balance and health-related quality of life, analyzed using independent sample t-tests, are presented in Table 2. The results revealed that the proprioceptive training group demonstrated statistically significant improvements in balance and several domains of quality of life (p = 0.001). These findings indicate that participants in this group experienced enhanced balance with a reduced risk of falls, as well as improved physical function accompanied by reductions in pain and fatigue, leading to greater confidence in mobility. However, no significant between-group differences were observed in the domains related to role limitations due to physical or emotional health. The control group also showed slight improvements over time; the magnitude of change from baseline was substantially greater in the experimental group, demonstrating that proprioceptive training had a meaningful and positive impact on balance and specific aspects of quality of life.

TABLE 2: BETWEEN-GROUP COMPARISON OF BALANCE & HEALTH-RELATED QUALITY OF LIFE

Variables		Measurement	Control Group	Experimental Group	Mean Difference	p-value
Balance		Baseline	13.35±4.07	12.09±4.40	1.267	0.22
		4th week	18.12±3.50	26.12±2.87	-8.14	0.001
		8th Week	25.62±2.65	45.38±3.13	-19.76	0.001
Health-Related QoL*	**Physical Function**	Baseline	34.94±14.67	32.88±6.79	2.05	0.460
		4th week	42.26±14.59	55.18±11.14	-12.91	0.001
		8th Week	49.79±14.45	64.53±12.25	-14.74	0.001
	Limitation due to PH*	Baseline	63.03±10.77	65.41±11.41	-2.38	0.38
		4th week	56.71±9.73	56.09±11.41	0.62	0.81
		8th Week	49.47±11.81	45.18±10.85	4.29	0.12
	Limitation due to EH*	Baseline	74.62±7.17	74.79±7.83	-0.18	0.92
		4th week	53.68±4.76	52.91±4.43	0.77	0.50
		8th Week	36.79±4.32	37.44±5.20	-0.65	0.58
	Fatigue	Baseline	33.59±12.69	33.06±9.43	0.529	0.846
		4th week	40.76±13.41	55.94±11.37	-15.18	0.001
		8th Week	46.29±12.29	65.26±11.39	-18.97	0.001
	Emotional Wellbeing	Baseline	46.85±13.63	44.32±6.68	1.85	0.476
		4th week	54.00±13.42	63.65±10.64	-9.65	0.001
		8th Week	60.16±12.97	72.85±10.13	-12.71	0.001
	Social functioning	Baseline	51.43±11.14	54.84±11.12	-3.41	0.21
		4th week	59.09±10.01	64.15±10.23	-5.06	0.04
		8th Week	64.82±9.62	73.18±9.82	-8.35	0.001
	Pain	Baseline	74.32±7.31	73.09±9.97	1.235	0.562
		4th week	55.76±8.48	49.41±5.99	6.35	0.001
		8th Week	38.29±12.85	29.38±5.54	8.91	0.001
	General Health	Baseline	52.29±11.72	55.00±11.56	-2.71	0.34
		4th week	59.91±11.55	64.44±10.54	-4.53	0.10
		8th Week	66.12±11.00	73.44±9.97	-7.32	0.01

*QoL= Quality of Life, *PH = Physical Health, *EH = Emotional Health

Table 3 presents the results of the repeated measures ANOVA, indicating that both groups demonstrated significant improvements over time in balance and all domains of the SF-36 ($p < 0.001$ for all comparisons). Pairwise comparisons revealed that the experimental group exhibited greater improvements between baseline and the 8th week compared to the control group. Consistently, the experimental group showed higher partial eta squared (η^2) values (ranging from 0.83 to 0.97) than the control group (ranging from 0.64 to 0.90), suggesting a stronger effect of the intervention. The magnitude of change across all SF-36 domains, including physical function, role limitations, emotional well-being, fatigue, pain, and general health, was markedly superior in the experimental group, demonstrating large effect sizes and greater clinical relevance of the intervention.

TABLE 3: WITHIN-GROUP DIFFERENCE IN BALANCE AND QUALITY OF LIFE

Outcome Measure		Group	Mean Differences with 95% CI	Partial η^2 (group-wise)	p-value
Balance		Control	BL→4th: -4.76, CI: –5.58 to –3.95 4th→8th: -7.50, CI: –8.84 to –6.16 BL→8th: -12.26, CI: –13.96 to –10.57	0.87	<0.001
		Experimental	BL→4th: -14.17, CI: -15.48 to -12.867 4th→8th: -19.11, CI: -20.56 to -17.67 BL→8th: -33.29, CI: -35.36 to -31.22	0.97	<0.001
Health-Related QoL	**Physical Function**	Control	BL→4th: -7.32, CI: -8.30 to -6.34 4th→8th: -7.52, CI: -8.73 to -6.32 BL→8th: -14.85, CI: -16.56 to -13.13	0.90	<0.001
		Experimental	BL→4th: -22.29, CI: -26.62 to -17.96 4th→8th: -9.35, CI: -10.31 to 8.38 BL→8th: -31.64, CI: -36.04 to -27.24	0.94	<0.001
	Role limitations due to Physical health	Control	BL→4th: 6.32, CI: 4.71 to 7.93 4th→8th: 7.23, CI: 4.86 to 9.60 BL→8th: 13.55, CI: 9.74 to 17.37	0.68	<0.001
		Experimental	BL→4th: 9.32, CI: 8.35 to 10.29 4th→8th: 10.91, CI: 10.01 to 11.80 BL→8th: 20.23, CI: 19.07 to 21.39	0.97	<0.001
	Role limitations due to emotional health	Control	BL→4th: 20.94, CI: 17.82 to 24.05 4th→8th: 16.88, CI: 14.80 to 18.95 BL→8th: 37.82, CI: 35.04 to 40.59	0.96	<0.001
		Experimental	BL→4th: 21.88, CI: 18.45 to 25.31 4th→8th: 15.47, CI:12.67 to 18.26 BL→8th: 37.35, CI: 34.27 to 40.43	0.94	<0.001
	Fatigue	Control	BL→4th: 5.52, CI: 3.28 to 7.77 4th→8th: 7.17, CI: 5.82 to 8.53 BL→8th: 12.70, CI: 10.00 to 15.40	0.80	<0.001
		Experimental	BL→4th: 9.32, CI: 8.35 to 10.29 4th→8th: 22.88, CI: 19.01 to 26.74 BL→8th: 32.20, CI: 28.58 to 35.82	0.96	<0.001
	Emotional Wellbeing	Control	BL→4th: -7.82, CI: -9.13 to -6.51 4th→8th: -6.14, CI: -6.59 to -5.70 BL→8th: -13.97, CI: -15.45 to -12.48	0.96	<0.001
		Experimental	BL→4th: -19.32, CI: -22.51 to -16.13 4th→8th: -9.20, CI: -10.11 to -8.29 BL→8th: -28.52, CI: -31.61 to -25.44	0.95	<0.001
	Social Functioning	Control	BL→4th: -7.66, CI: -8.67 to -6.64 4th→8th: -5.73, CI: -6.21 to -5.25 BL→8th: -13.39, CI: -14.64 to -12.14	0.95	<0.001
		Experimental	BL→4th: -9.30, CI: -10.11 to -8.50 4th→8th: -9.02, CI: -9.91 to -8.14 BL→8th: -18.33, CI: -19.74 to -16.92	0.95	<0.001
	Pain	Control	BL→4th: 18.55, CI: 15.36 to 21.75 4th→8th: 17.47, CI: 12.77 to 22.16	0.89	<0.001

			BL→8th: 36.02, CI: 31.17 to 40.88		
		Experimental	BL→4th: 23.67, CI: 20.50 to 26.84 4th→8th: 20.02, CI: 17.79 to 22.26 BL→8th: 43.70, CI: 39.89 to 47.51	0.94	<0.001
	General Health	Control	BL→4th: -7.61, CI: -8.50 to -6.72 4th→8th: -6.20, CI: -6.83 to -5.58 BL→8th: -13.82, CI: -14.95 to -12.68	0.95	<0.001
		Experimental	BL→4th: -9.44, CI: -10.25 to -8.62 4th→8th: -9.00, CI: -9.88 to -8.11 BL→8th: -18.44, CI: -19.85 to -17.03	0.95	<0.001

DISCUSSION

This study aimed to compare the effects of proprioceptive training in addition to conventional physical therapy on balance and quality of life in patients with diabetic peripheral neuropathy (DPN). The findings demonstrated significant improvements in both groups after intervention; however, participants receiving proprioceptive training showed greater gains in balance control and in several domains of health-related quality of life, including general health, physical functioning, emotional well-being, pain, and fatigue. These results indicate that proprioceptive training enhances postural stability and overall functional confidence during daily activities.

The observed benefits align with previous literature highlighting the value of proprioceptive training in restoring sensorimotor function. Exercises performed on unstable or varied surfaces stimulate reweighting of sensory inputs and improve somatosensory integration, ultimately enhancing balance and motor learning. El-Wishy and Elsayed [20] conducted a randomized controlled trial in Egypt and reported a highly significant improvement in balance ($p < 0.001$) following eight weeks of proprioceptive training delivered through multiple exercise stations. Similarly, Ahmad et al. [21] found significant improvements in both static and dynamic balance ($p < 0.05$) among middle-aged and older adults with diabetic neuropathy after eight weeks of proprioceptive and sensorimotor interventions. Consistent results were also observed by Malwanage et al. [22], who reported that 12 weeks of proprioceptive training effectively restored static and dynamic proprioceptive deficits of the lower limb.

Evidence from prior studies also supports the effectiveness of conventional therapeutic exercises such as strengthening, gait, and balance training in improving function among individuals with DPN. A Japanese trial involving 53 participants demonstrated that eight weeks of home-based strengthening exercises improved activities of daily living and functional independence [23]. Likewise, a 12-week program focusing on gait, balance, and fear of falls in 71 participants with diabetic neuropathy led to significant improvements in walking speed, muscle strength, and balance ($p < 0.002$) compared with controls [24]. These findings emphasize the importance of distal muscle strengthening in reducing fall risk and enhancing postural stability.

Taken together, the evidence suggests that both strengthening and proprioceptive training independently enhance balance and quality of life in patients with DPN. However, when combined, as in the present study, they appear to produce superior outcomes by targeting both muscular strength and sensorimotor control. Clinically, this integrated approach may reduce fall risk, promote functional independence, and improve overall well-being in individuals with diabetic peripheral neuropathy.

There are a few limitations to this study. It was conducted in a single center, which may limit the generalizability of the findings. Moreover, the intervention period and assessments were limited to eight weeks, with no long-term follow-up to determine the sustainability of improvements. The outcome measures used were primarily subjective in nature. Therefore, future research is recommended to evaluate the long-term effects of proprioceptive training on additional aspects of lower limb function, including gait, using objective measurement tools and exploring its applicability to other types of neuropathies.

CONCLUSION

Proprioceptive training combined with conventional physical therapy was more effective than conventional therapy alone in improving balance, physical function, fatigue, and overall quality of life in patients with diabetic peripheral neuropathy.

Healthcare professionals can incorporate these interventions into rehabilitation or prevention strategies, particularly for individuals at risk of falls. This dual intervention approach holds the potential for holistic enhancements in diverse health aspects, thereby positively influencing the overall quality of life for those undergoing such interventions.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE:

The ethical approval of the study was obtained from the Ethical Review Committee of The University of Lahore (Ref No.: IRB-UOL-FAHS/997/2021). Consent to participate in the study was obtained from all the participants at the time of recruitment.

CONSENT FOR PUBLICATION:

Permission to publish the findings of the study was sought from every participant.

AVAILABILITY OF DATA AND MATERIALS:

All the available data can be shared upon request with the authors of the study.

COMPETING INTERESTS:

There are no competing interests in the study.

FUNDING:

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AUTHORS' CONTRIBUTIONS:

SN contributed to the Study concept, design, and data collection. AJ provided the Concept of Study, Literature Review, Data Analysis, Writing the Manuscript, and the Final review. SA contributed to Data Analysis and Interpretation, and approval of the final version. ST contributed to the Literature Review and finalisation of the manuscript. SA (Akram) contributed to the Literature Review and finalisation of the manuscript. All authors have reviewed and approved the final version of the manuscript.

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APPENDIX

FIGURE 1: CONSORT 2025 FLOW DIAGRAM