

ORIGINAL ARTICLE

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Comparison Between the Effect of Frenkel Exercise and Proprioceptive Training on Balance, Walking Distance, and Quality of Life in Patients with Diabetic Neuropathy

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ABSTRACT

Background: Sensorimotor impairments caused by diabetic peripheral neuropathy (DPN) increase the risk of falls, make it challenging to move around, and impair balance. Physiotherapy interventions like Frenkel exercises (focused on voluntary motor control) and proprioceptive training (enhancing sensory feedback for stability) are used to address these deficits. This study compares their efficacy in improving balance, walking distance, and quality of life in individuals with DPN.

Methods: 60 people with a diagnosis of DPN, ranging in age from 45 to 65, participated in a randomized controlled experiment. The participants were split into two groups: Group A (Frenkel exercises) and Group B (Proprioceptive training). Both groups underwent a 6-week intervention program, with outcomes assessed using the Mini-BESTest for balance, the 6-Minute Walk Test (6MWT) for walking distance, and the Diabetes Quality of Life (DQOL) scale. The statistical study used the Mann-Whitney U test and the Wilcoxon signed-rank test, with a significance level of $p < 0.05$.

Results: Balance, mobility, and overall quality of life were all significantly enhanced by both treatments. However, Group B (proprioceptive training) showed significantly greater improvements in Mini-BESTest scores ($p < 0.2$), 6MWT performance ($p < 0.07$), and DQOL scores ($p < 0.5$) compared to Group A.

Conclusion: The results indicate that proprioceptive training is superior to other interventions for improving postural stability, gait performance, and overall functioning in patients with DPN. These results support the integration of proprioceptive-based interventions into physiotherapy management for DPN patients.

Keywords: Diabetic Neuropathy, Frenkel exercises, Proprioceptive training, Balance, Walking Distance, Quality of Life.

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INTRODUCTION

Diabetes mellitus (DM) continues to be a significant global health concern, with India alone reporting over 30 million affected individuals. Worldwide, the number of people with diabetes is predicted to skyrocket, rising from 382 million in 2013 to an anticipated 592 million in 2035 [1,2]. Among the myriad complications associated with diabetes, diabetic peripheral neuropathy (DPN) stands out for its high prevalence and substantial impact on patients' functional abilities [3–5].

DPN mainly targets the long nerves in the lower limbs, which impact the peripheral nervous system. This damage manifests as deficits in proprioception, vibration sense, and motor coordination—factors critical for maintaining balance and mobility. Literature reports that up to half of individuals with long-standing diabetes may develop DPN, particularly those with poor glycemic control [6–10]. These patients often exhibit increased postural sway, impaired gait mechanics, and a fall risk estimated to be 15 times higher than in non-diabetic individuals [11].

Effective postural control relies on the dynamic interplay between somatosensory, visual, and vestibular systems [12]. In patients with DPN, the integrity of sensory input—especially from the somatosensory system—is compromised, necessitating compensatory training strategies. Targeted physiotherapy approaches are essential for restoring equilibrium, improving motor performance, and reducing fall risk.

A range of physiotherapy techniques has been explored to address these deficits. For instance, Allet L et al. (2008) [13] observed notable gait deviations in individuals with DPN, attributing them to sensory-motor impairment. Similarly, Allet et al. [2010] [14] highlighted that balance exercises could yield functional benefits. Despite these findings, a direct comparison of two well-established interventions—Frenkel exercises and proprioceptive training—remains underexplored in the current literature.

Frenkel exercises, developed to enhance voluntary motor coordination, have shown promising results in individuals with neurological impairments [15]. On the other hand, proprioceptive training enhances sensory feedback through variations in surface texture and is effective in neuromuscular rehabilitation [16]. There is still no consensus on whether one modality is more effective than the other in improving balance, endurance, and quality of life in DPN patients, despite both modalities demonstrating efficacy on their own.

To address this gap, the current study aims to compare the clinical outcomes of Frenkel and proprioceptive training interventions among individuals with DPN. Outcome measures include the Mini-BESTest for assessing dynamic balance [17], the 6-Minute Walk Test (6MWT) for functional mobility [18], and the DQOL Brief Clinical Inventory for health-related quality of life [19]. Through this comparative analysis, the study seeks to inform clinical decision-making and improve rehabilitation strategies for this growing population.

METHODS

A randomized controlled trial was conducted at the Physiotherapy Outpatient Department, Parul Sevashram Hospital, Limda, between March and November 2020. We used predetermined inclusion and exclusion criteria to recruit sixty people with diabetic peripheral neuropathy (DPN). Participants included those aged 45–65 years. Confirmed by dates of clinical and laboratory evidence to have type 2 diabetes mellitus for more than five years, the capability to maintain bipedal and unipedal stance, and both male and female participants. Patients were excluded from the study if they had diabetic foot ulcers, Vestibular disorders or inner ear infections, Neurological conditions unrelated to DPN, recent traumatic injuries affecting balance, Complete sensory loss, or known cardiac disease. Before the study's initiation, ethical permission was obtained from the Parul University Institutional Ethics Committee for Human Research, and all participants provided signed informed consent. Randomization and Group Allocation, Two equal groups, each with thirty participants, were randomly assigned from a pool of sixty using computer-generated random numbers:

- Group A: Received Frenkel exercise protocol [25].
- Group B: Received proprioceptive training protocol [26].

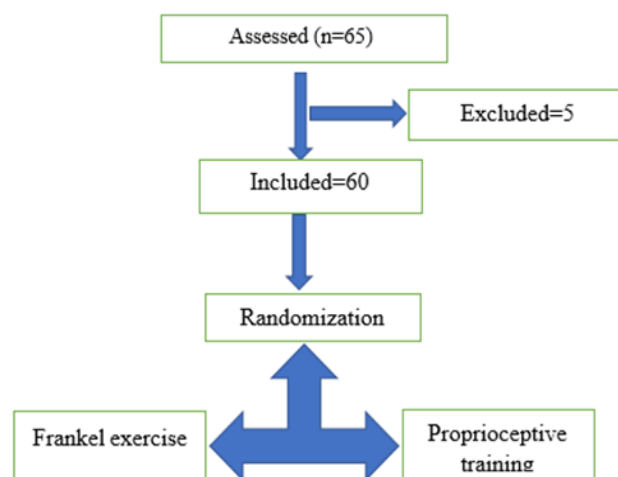


Figure 1: Sample size and Randomization



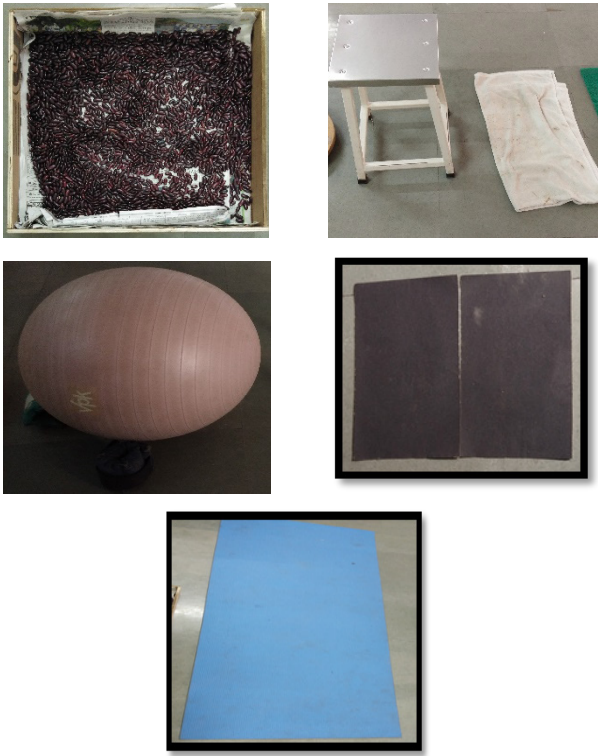


Figure 2: Materials Used

Group A: (Frenkel Exercises) Participants in Group A engaged in coordination-focused exercises based on the Frenkel method. The regimen included: Weight shifting in standing, Sideways ambulation following marked paths, Straight-line walking using visual markers, Directional changes around physical cues. Exercises were delivered in a progressive circuit format, emphasizing precision and control. Sessions were held three times per week, each lasting approximately 30 minutes, for a total of six weeks.

Group A



Stride standing.



Walking, placing feet on the mark.



Standing, turn around.



Walking to avoid obstacles.



Walking sideways, placing the foot on marks.

Figure 3: Frenkel's Exercises

Group B: (Proprioceptive Training) Participants in this group underwent sensory stimulation exercises involving 13 different textured surfaces (e.g., cotton, grains, beans, sandpaper, balance boards). The training emphasized dynamic foot stimulation and postural control through rhythmic stepping activities. Each session incorporated Alternating step patterns on variable textures, Directional and speed modulation, and Movement synchronized with music cues (slow and fast-paced rhythms). Each session lasted 30 minutes and was performed three times per week over six weeks.

Group B



March on 10cm thick foam.



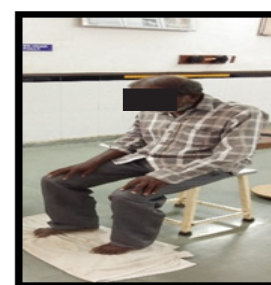
March on the wooden box with a bean.



March on mat



Lateral balance reaction



Towel grasping by the feet flexors
Figure 4a: Proprioceptive Training



March on a proprioceptive texture.



March on grains.



Hip movement with a medicine ball, slide feet on sand paper



Figure 4b: Proprioceptive Training

Both the beginning and end of the six-week intervention periods were used to evaluate outcomes. Three standardized outcome tools were used- Mini-BESTest – to evaluate the capacity to maintain a steady stride, as well as reactive and anticipatory control, sensory orientation, and dynamic balance. 6-Minute Walk Test (6MWT) – to measure submaximal functional endurance. Diabetes Quality of Life (DQOL) – Brief Clinical Inventory – to evaluate perceived quality of life in relation to diabetic complications.

All assessments were administered individually by trained assessors under standardized conditions. The statistical package SPSS (version XX) was used to analyze the data. The Shapiro-Wilk test was used to assess whether the data were normally distributed. For demographic factors, descriptive statistics were used.

- To assess differences within groups (both before and after the intervention), the Wilcoxon signed-rank test was used.
- To name a few: For comparisons between groups, the U-test was used.
- Statistical significance was determined at a p-value less than 0.05.

RESULTS

All data passed the normality test ($P > 0.05$) and follow a Gaussian distribution. All statistical analyses were calculated using alpha levels of 0.05. To ensure normalcy, the Shapiro-Wilk test was used. The demographic baseline data were validated using descriptive statistics and a chi-

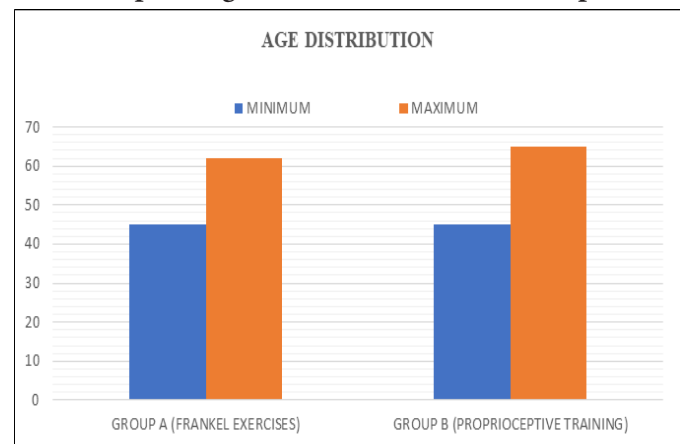
square test. When comparing pre- and post-test parameters for significance, the Wilcoxon signed-rank test is used. For non-parametric data, the Mann-Whitney U test was used to compare the two groups.

Table 1: Distribution of Ages in the Two Categories

Characteristic	Group	Minimum age	Maximum age	Mean \pm SD
Age	Group A	45	62	57 \pm 4.87
	Group B	45	65	56.8 \pm 5.56

Table 1: Shows the mean age of both groups, respectively, Group A 57 and Group B 56.8 Years. The SD are Group A: ± 4.87 , and Group B: ± 5.56 , respectively.

Graph 1: Age Distribution of Both Groups



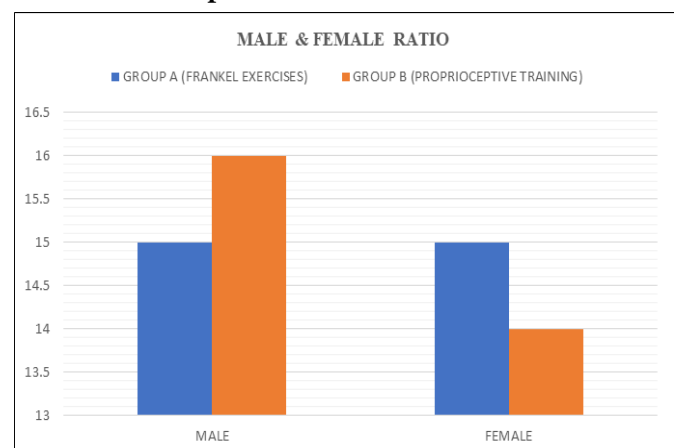
Graph 1: Both groups were comparable, as no difference was seen statistically. A p-value less than 0.05 was considered significant.

Table 2: Subject Division by Gender

Characteristic	A - Group	B - Group	Total	
Gender	Man	15	16	31(51.7%)
	Women	15	14	29(48.3%)
	Total	30	30	60(100%)

Table 2 for the breakdown by sex in each category. Within Group A, there were 15 men and 15 women, whereas within Group B, there were 16 men and 14 women.

Graph 2: Gender Distribution



Both groups were comparable; no difference was observed. A p-value less than 0.05 was considered significant.

Table 3: Analysis Of the Quality-of-Life Scale for Diabetics (Inside Groups)

Group	Pre-treatment	Post-treatment	Z-value	p-value
	Mean ± SD	Mean ± SD		
Group-A	62.30 ± 8.65	62.90 ± 8.58	-3.21	0.001
Group-B	62.93 ± 5.41	70.13 ± 3.93	-4.8	0.00

Table 3: After six weeks of the intervention, both groups showed a significant increase in quality of life, as determined by the Wilcoxon signed-ranks test ($p < 0.0001$). Group A showed a slight increase in mean scores (62.30 to 62.90), while Group B demonstrated a more substantial improvement (62.93 to 70.13).

Graph 3: Analysis of Diabetic Quality of Life Scale (In Groups)

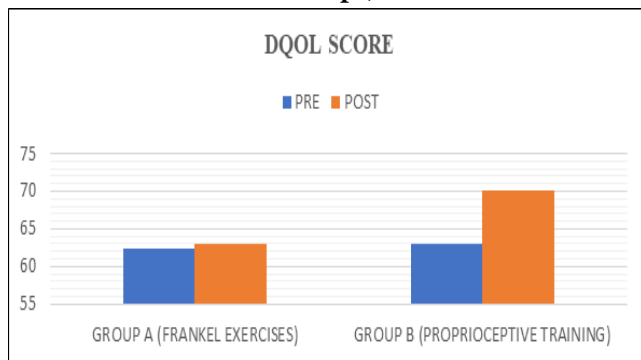


Table 4: Mean Difference in Diabetic Quality of Life Scale (Between Groups)

Group	Mean ± SD	Z-value	p-value
Group-A	62.90 ± 8.58	-0.55	0.5
Group-B	70.13 ± 3.93		

Table 4 displays the comparison of Diabetic Quality of Life scores between Group A and Group B after the intervention. Despite Group B having a higher mean score (70.13 ± 3.93) than Group A (62.90 ± 8.58), the difference was not statistically significant ($Z = -0.55$, $p = 0.5$), suggesting no clear between-group effect.

Graph 4: Mean Difference in Diabetic Quality of Life Scale (Between Groups)

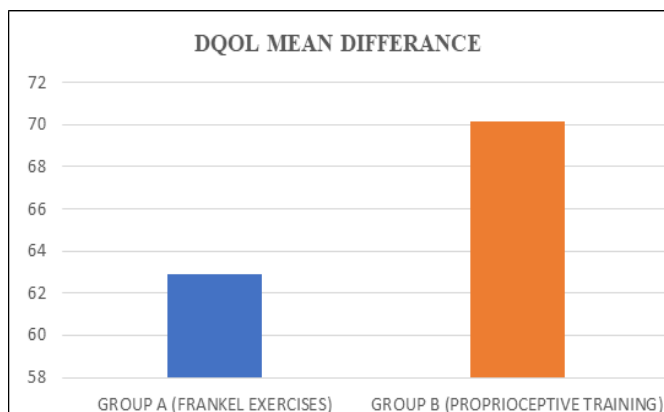


Table 5: Analysis Of 6-Minute Walking Distance Scale (In Both Groups)

Group	Pre-treatment	Post-treatment	Z-value	p-value
	Mean ± SD	Mean ± SD		
Group-A	546.67 ± 54.07	553.00 ± 53.47	-4.72	0.00
Group-B	546.37 ± 43.80	603.00 ± 48.69	-4.705	0.00

Table 5. After 6 weeks of the intervention, there was a substantial improvement in 6-minute walking distance in both groups, as indicated by the Wilcoxon signed-rank test ($p < 0.0001$). Group A's mean distance increased from 546.67 m to 553.00 m, while Group B showed a greater improvement from 546.37 m to 603.00 m.

Graph 5: Analysis of the 6 Minute Walking Distance Scale (In Groups)

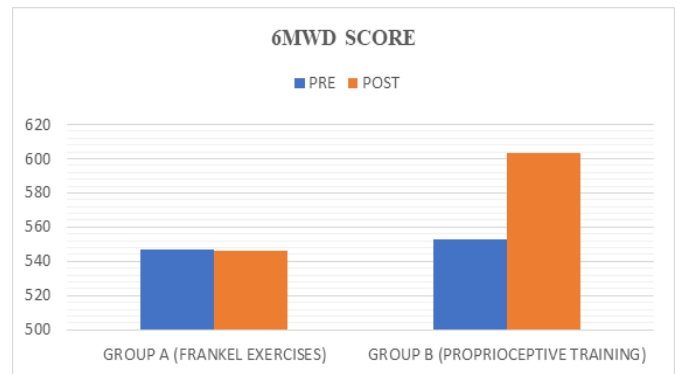


Table 6: Mean Difference In 6 Minute Walking Distance Scale (Between Groups)

Group	Mean ± SD	Z-value	p-value
Group-A	553.00 ± 53.47	-1.7	0.07
Group-B	603.00 ± 48.69		

Table 6: A comparison of post-intervention 6-minute walking distance between both groups shows higher mean values in Group B (603.00 m) than in Group A (553.00 m). Although the Wilcoxon rank-sum test indicated a trend toward significance ($z = -1.7$, $p < 0.07$), Group B (proprioceptive training) demonstrated greater improvement.

Graph 6: Mean Difference In 6 Minute Walking Distance Scale (Between Group)

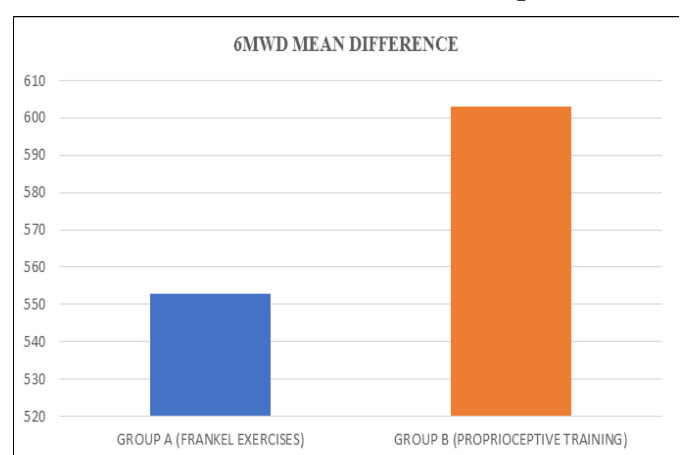


Table 7: Analysis of Mini Best Test

Group	Pre-treatment	Post-treatment	Z-value	p-value
	Mean ± SD	Mean ± SD		
Group-A	10.00 ± 3.07	10.87 ± 2.62	-3.12	0.002
Group-B	15.20 ± 7.65	22.20 ± 3.86	-4.8	0.000

Table 7: A significant improvement in balance (Mini-BESTest scores) was observed in both groups after six weeks of intervention, as analyzed using the Wilcoxon signed-rank test ($p < 0.0001$). Group A's mean score increased from 10.00 to 10.87, while Group B showed a greater improvement from 15.20 to 22.20.

Graph 7: Analysis of Mini Best Test (In Group A&B)

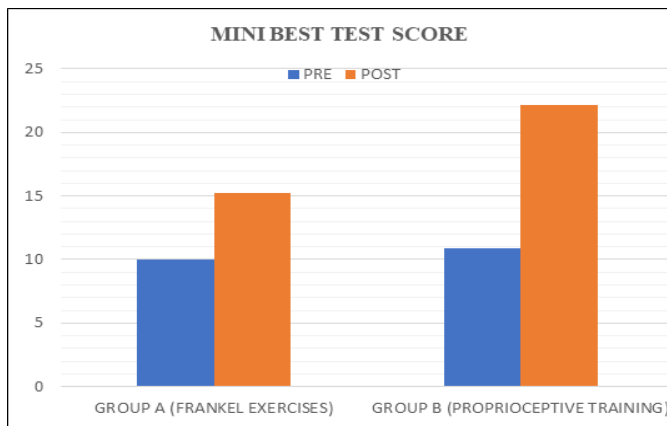
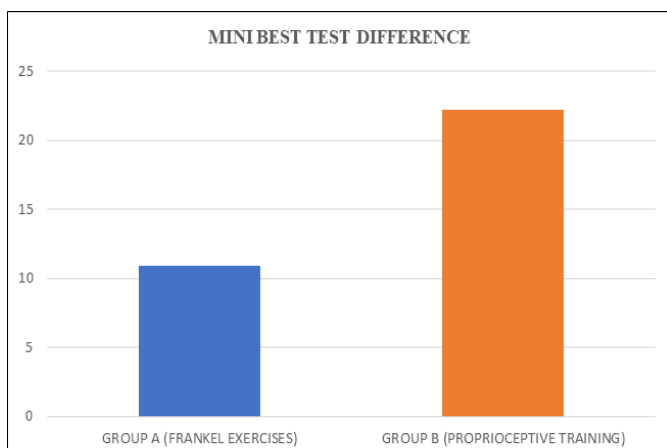


Table 8: Mini-Best Test Mean Difference (Between Groups)

Group	Mean ± SD	Z-value	p-value
Group-A	10.87 ± 2.62	-1.2	0.2
Group-B	22.20 ± 3.86		

Table 8: A comparison of post-intervention Mini-BESTest scores between the two groups. Higher mean values in Group B (22.20) compared to Group A (10.87). Although the Wilcoxon rank-sum test presented no significance ($z = -1.2, p < 0.2$), Group B (proprioceptive training) demonstrated greater improvement in balance than Group A (Frenkel exercises).

Graph 8: Mean Difference in Mini Best Test (Between Groups)



Throughout the six weeks of the intervention, both groups showed considerable improvements in their mobility, balance, and overall quality of life. However, Group B demonstrated superior outcomes in all three domains:

- Balance (Mini-BESTest): Group B showed a mean increase of 7 points, whereas Group A demonstrated only a 0.87-point improvement.
- Walking Distance (6MWT): Group B exhibited a 57m increase, significantly greater than the 6.33m improvement in Group A.
- Quality of Life (DQOL): Group B experienced a 7.2-point enhancement, compared to a 0.6-point improvement in Group A.

(Refer to graphs and tables for more information)

DISCUSSION

Researchers aimed to determine how people with diabetic peripheral neuropathy (DPN) responded to either Frenkel exercises or proprioceptive training to improve balance, walking endurance, and overall quality of life. After six weeks of intervention, both groups showed improvements across all outcome measures, but participants in the proprioceptive training group experienced significantly greater gains.

The improvement in both groups supports the idea that targeted exercises can enhance physical function in people with DPN. However, the more notable progress in the proprioceptive training group can be explained by the nature of the intervention itself. Proprioceptive training challenges the sensory systems more directly by stimulating the skin, muscles, and joints through textured surfaces and unstable platforms [20]. These inputs likely helped retrain the body's ability to detect changes in position and movement, which is often compromised in people with neuropathy [21]. Abeer El-Wishy and Enas Elsayed (2012) support this mechanism, showing that proprioceptive training using different floor textures for sensory stimulation, along with conventional physiotherapy for balance, improves postural control in diabetic patients [22].

In contrast, Frenkel exercises focus more on voluntary movement coordination, using visual feedback and repetition. While they are helpful—particularly in improving motor planning and limb coordination—their sensory input component is limited. That could explain why the Frenkel group (Group A) showed smaller improvements in balance and quality of life. Still, the significant statistical difference in 6-minute walk distance suggests that Frenkel exercises were effective in improving coordination and basic mobility. Previous research, such as that by Zahra Rojhani-Shirazi et al. (2017), also found Frenkel exercises helpful for improving function in patients with diabetic neuropathy [23, 24].

From a theoretical standpoint, the success of proprioceptive training could be linked to its ability to engage multiple systems—musculoskeletal, vestibular, and sensory. For instance, Shah C. (2016) reported that using unstable surfaces, such as wobble boards, can increase ankle joint mobility and muscle activation, which are essential for

maintaining postural balance [27]. Moreover, Horak (2006) emphasized that dynamic balance training, particularly that which stimulates lateral trunk control and postural strategies, is key for fall prevention in populations with sensory loss [28]. Our study's proprioceptive training incorporated these elements, which accounted for the superior results in that group.

Interestingly, while balance and walking distance were clearly similar between the groups, the improvement in quality of life also followed the same pattern. This suggests a strong link between physical function and emotional or psychosocial well-being in people with DPN. When patients feel more stable and mobile, they are likely to feel more confident, independent, and socially engaged—factors that contribute to a higher perceived quality of life.

CONCLUSION

In individuals with diabetogenic peripheral neuropathy, this study found that proprioceptive training was superior to Frenkel exercises in terms of quality of life, balance, and walking distance. Given the substantial benefits observed, clinicians should prioritize proprioceptive training as a key component of physiotherapy management for DPN.

Study Limitations and Future Recommendations

The study's main flaw was that it couldn't compare gender differences in outcomes due to an uneven distribution of male and female participants. Additionally, long-term follow-up was not conducted, limiting the understanding of sustained benefits beyond the intervention period. Future research could address these limitations by ensuring an equal representation of male and female participants to analyse gender-specific effects. Studies with extended intervention durations and prolonged follow-ups would give deeper insights into the sustained impact of these training programs. Further, conducting similar research with a larger sample size could enhance the statistical reliability of findings. Expanding the study to older populations may yield valuable insights into balance training in geriatric patients. Additionally, applying these interventions to other balance-deficient disorders, such as Parkinson's disease or stroke, could help explore their broader clinical applicability.

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Conflict of Interest: There are no reported conflicts of interest by the writers.

Ethical Approval: The Parul University Institutional Ethics Committee for Human Research (PU-IECHR) granted ethical approval for the project, as it involves human subjects.

Informed Consent: All individuals provided written consent before taking part in the study.

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