



Neurophysiotherapy

EFFECT OF STRUCTURED INTERVENTION ON BALANCE, GAIT SPEED AND STRENGTH IN PATIENTS WITH DIABETIC PERIPHERAL NEUROPATHY: AN EXPERIMENTAL STUDY

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ABSTRACT **Background:** Diabetic peripheral neuropathy (DPN) leads to sensory loss, muscle weakness, and postural instability, markedly increasing fall risk and compromising functional mobility. **Objectives:** To evaluate the effectiveness of a structured intervention on balance, gait speed, and lower-limb muscle strength in DPN compared to conventional therapy. **Methods:** Forty-four patients with clinically diagnosed DPN were allocated into Group A (conventional intervention, n = 22) and Group B (structured intervention, n = 22); 3 sessions weekly for 6 weeks. Primary outcomes assessed at baseline and post-intervention included static balance (Modified CTSIB), gait speed (10-Meter Walk Test), and lower-limb muscle strength (dynamometry). **Results:** Group B demonstrated significantly greater improvements across all measures compared to Group A ($p < 0.05$). Significant between-group differences favored Group B in static balance across all four mCTSIB conditions (mean differences: 2.45–5.68 s; all $p \leq 0.02$) and gait speed (mean difference: 0.096 m/s; $p < 0.05$). Group B also achieved superior strength gains in bilateral ankle invertors, hip abductors, adductors, and extensors (mean differences: 0.30–0.62; all $p < 0.05$). **Conclusion:** A structured physiotherapy intervention provides superior improvements in balance, gait velocity, and lower-limb strength over conventional exercise, effectively reducing fall risk and enhancing functional independence in DPN.

KEYWORDS : Diabetic Peripheral Neuropathy, Balance, Gait Speed, Muscle Strength, Structured Intervention**INTRODUCTION**

Diabetes mellitus is a group of chronic metabolic diseases characterized by hyperglycemia due to defects in insulin secretion, insulin action, or both, causing long-term damage to the heart, blood vessels, eyes, kidneys, and nerves. [1] In 2024, approximately 589 million adults worldwide were living with diabetes, with global adult prevalence rising from 7% in 1990 to 14% in 2022, and over 81% residing in low- and middle-income countries. [2] India carries the world's largest burden, with 107 million to 212 million affected individuals, and leads globally with approximately 133 million untreated adults over 30 years. [3] Type 2 diabetes mellitus (T2DM) constitutes the vast majority of cases, remaining predominantly asymptomatic in early stages, which delays diagnosis and clinical management. [4]

Diabetic peripheral neuropathy (DPN), defined as the presence of symptoms and/or signs of peripheral nerve dysfunction in people with diabetes after the exclusion of other causes, represents a prevalent microvascular complication affecting up to 50% of patients with long-standing disease. [5,6] In India, DPN prevalence ranges widely from 9.6% to 78% across various cohorts. [6]

DPN predominantly involves distal symmetrical polyneuropathy, characterized by axonal degeneration and demyelination driven by chronic hyperglycemia, oxidative stress, sorbitol pathway activation, microvascular injury, and advanced glycation end-product accumulation. [7] Large fiber dysfunction damages vibration and proprioception, while small fiber involvement alters temperature and pain sensation, predisposing patients to sensory loss, chronic pain, foot ulcers, and lower extremity weakness. [7]

As many as 30% of individuals with DPN experience a loss of ankle reflexes and diminished balance, leading to limitations in walking and heightened fall risks. [8] Deficits in somatosensory feedback disrupt equilibrium during level walking, stair ascent, and stair descent, with maximal instability observed in the mediolateral plane during stair descent. [9] Proprioceptive loss forces an overreliance on visual and vestibular cues; postural sway increases by up to 66% in center of pressure excursions when visual input is eliminated, and loss of plantar sensation directly correlates with reduced preferred walking speed. [10] Resulting gait patterns demonstrate shorter stride lengths, prolonged double support time, and reduced frontal plane torque production. [11]

Neuropathic strength loss in the hip adductors and ankle invertors compromises stability, yet proximally located hip musculature has a dominant effect on gait velocity, indicating that patients with distal

afferent deficits benefit from training focused on rapid hip strength development and frontal plane control. [11,12]

While literature confirms functional gains through 8-week sensorimotor programs [13] and 12-week protocols [14], longer timelines face challenges regarding patient adherence, resource allocation, and clinical feasibility, especially in resource-constrained settings like India. [15] A shorter, 6-week structured intervention targeting proximal and frontal plane musculature may achieve comparable improvements, enhancing compliance and lowering dropout rates. [15] This study evaluates the efficacy of a 6-week structured program compared to conventional balance training on key functional domains to deliver time-efficient, accessible rehabilitation strategies for DPN. [15,16]

Primary Objective:

- 1) To compare the effect of 6 weeks of structured intervention versus conventional intervention balance in patients with diabetic peripheral neuropathy using modified CTSIB.
- 2) To compare the effect of 6 weeks of structured intervention versus conventional intervention on gait speed in patients with diabetic peripheral neuropathy using a 10 meter walk test.
- 3) To compare the effect of 6 weeks of structured intervention versus conventional intervention on isometric strength of hip abductors, hip adductors, hip extensors and ankle inverters in patients with diabetic peripheral neuropathy using microFET-2 hand-held dynamometer.

MATERIALS AND METHODS**MATERIALS**

Pen, Paper, Tuning fork, Reflex hammer, Monofilament, MicroFET-2 hand-held dynamometer, Resistance band, Foam pad, Stopwatch

METHODOLOGY

Study Design: Experimental study

Study Setting: Comparative study

Target Population: patients with diabetic peripheral neuropathy age 45-60 Yrs.

Sample Size: n = 44

Sampling Technique: convenient sampling

Treatment Duration: 6 weeks

Study Duration: 1 year

Inclusion Criteria

- Both males and females
- Age group 45-60 years [13]
- diabetes mellitus type 2 since 5 years [17]

- Body mass index ranging 18.5–29.9kg/m2(normal and overweight classification)[18]
- Clinically diagnosed diabetic polyneuropathy using Toronto clinical neuropathy score:6-11
- Hb1ac levels<7

Exclusion Criteria

- Patients having intermittent claudication [19]
- Patients with uncontrolled hypertension
- Recent history of fall one-month back
- Patient with foot ulceration
- Patients with Severe retinopathy or severe nephropathy

Subject Withdrawal Criteria:

- If patient falls during the intervention period
- Patient unable to understand exercise protocol.
- Patient unable to comply with exercise program.

Intervention

Both the groups were given exercises for 6 weeks, 3 times a week for about 30-45 mins.

Group A: Conventional Balance Training

1. Warm Up
2. Conditioning
3. Cool Down

Group B: Structured Intervention

1. Warm Up
2. Conditioning
3. Cool Down

Warm up and Cool Down exercises were same for both Group A and Group B, both for about 5 mins each.

Warm up:

Hip movements

Knee movements

Ankle movements

Cool down:

TA Stretch

Hamstring Stretch

Quadriceps Stretch

Intervention:

Both groups received a warm-up of duration 5 mins which included stretching and mobility exercises for lower limbs.

Conventional Intervention: The exercise protocol was designed in consideration with multiple systematic reviews. [20,21]

a) Balance and Gait Exercise

Table 1 - Balance and Gait Exercise

First 3 weeks	Duration	Last 3 weeks	Duration
Standing on heel	10 reps, 1 set	Standing on heel	10 reps, 2 sets
Standing on toes	10 reps, 1 set	Standing on toes	10 reps, 2 sets
Tandem stance	30 sec, 1 set	Tandem stance	30 sec, 2 set
One leg stance	15 sec, 2 sets	One leg stance	30 sec, 2 sets
Walking forward	10 steps	Walking forward	20 steps
Walking backward	10 steps	Walking backward	20 steps
Walking sideways	10 steps	Walking sideways	20 steps

b) Functional Strength Training

Table 2 - Functional Strength Training

First 3 weeks	Duration	Last 3 weeks	Duration
Sit-to-stand	10 reps, 1 set	Sit-to-stand	10 reps, 2 sets
Walking up the slope	10 steps	Walking up the slope	10 steps, 2 sets
Walking down the slope	10 steps	Walking down the slope	10 steps, 2 sets
Stair climbing	10 steps	Stair climbing	10 steps, 2 sets
Mini hops	10 reps, 1 set	Mini hops	10 reps, 2 sets

Structured Intervention

Considering affected medial-lateral weight shifting, unilateral stance and ankle strategy and reduced gait speed following exercise protocol was designed under structured intervention.[22,23,24]

Table 3 - Structured Intervention

First 3 weeks	Duration	Last 3 weeks	Duration
Bridging with ball squeeze	10 reps, 1 set	Unilateral bridging with ball squeeze	10 reps, 1 set
Hip adduction in side lying	10 reps, 1 set	Hip adduction in side lying	10 reps, 2 sets

Wide stance squats	10 reps, 1 set	Wide stance squats	10 reps, 2 sets
Side lunges	10 reps, 1 set	Side lunges	10 reps, 2 sets
Lateral weight shifts	10 reps, 1 set	Lateral weight shifts	10 reps, 2 sets
Hip adduction in sitting	10 reps, 1 set	Hip adduction in sitting with resistance band	10 reps, 1 set
One leg stand	15 sec, 2 sets	One leg stand	30 sec, 2 sets
Heel raises	10 reps, 1 set	Heel raises	10 reps, 2 sets
Toe raises	10 reps, 1 set	Toe raises	10 reps, 2 sets
Hip adduction in standing	10 reps, 1 set	Hip adduction in standing with resistance band	10 reps, 1 set



Side lunges



One leg stand

Statistical Analysis

Demographic data including name, age, gender was taken. Data was collected from outcome measure: Modified CTSIB, 10-metre walk test, FET2 Hand-held dynamometer. Microsoft Excel (version 2019) and G-Power 3.1.9.2 Software was used for statistical analysis. Quantitative data was summarized using Mean and Standard Deviation. Data was initially explored to find out normal distribution, Shapiro-Wilk test was used for this analysis. In all the tests performed, $p < 0.05$ was considered to be statistically significant, i.e. level of significance was set at 5%.

RESULTS

A total of 44 participants with diabetic peripheral neuropathy were enrolled and equally allocated to Group A (conventional intervention, $n = 22$; mean age: 53.73 ± 4.14 years) or Group B (structured intervention, $n = 22$; mean age: 51.86 ± 3.35 years). Both groups were comparable at baseline with respect to age, sex distribution, diabetes duration, and baseline balance, gait velocity, and muscular strength measures ($p > 0.05$).

Within-group Changes:

Balance: Following 6 weeks of intervention, both groups showed significant within-group improvements across all four mCTSIB conditions ($p < 0.001$). Group A (conventional exercise) improved by mean differences of 3.181 (EO firm), 3.091 (EC firm), 3.136 (EO foam), and 3.137 (EC foam) ($p < 0.0001$). In contrast, Group B (structured intervention) achieved substantially greater gains, with corresponding mean improvements of 7.227, 7.363, 7.045, and 7.000 ($p < 0.001$).

Gait Speed: The results in the study showed that Gait Speed values increased in Group A with mean difference between pre intervention and post intervention after 6 weeks of sessions is 0.069, with p value of < 0.05 and in Group B is 0.210, with p value of < 0.01 respectively.

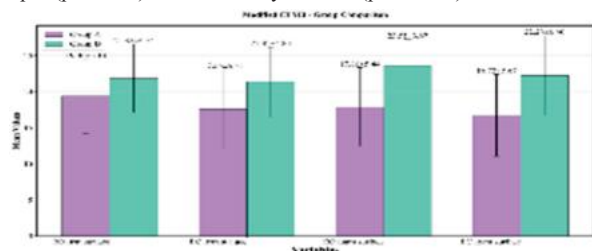
Lower Limb Muscle Strength: Following 6 weeks of intervention, both groups demonstrated statistically significant within-group improvements across all evaluated muscle groups bilaterally ($p < 0.001$). However, Group B consistently exhibited substantially greater strength gains than Group A:

- **Ankle Invertors:** Pre-to-post mean differences in Group A were 0.296 (left) and 0.304 (right) ($p < 0.0001$), whereas Group B achieved mean improvements of 0.763 (left) and 0.750 (right) ($p < 0.001$).

- **Hip Abductors:** Group A improved by 0.296 (left) and 0.336 (right) ($p < 0.0001$), compared to 0.741 (left) and 0.800 (right) in Group B ($p < 0.001$).
- **Hip Adductors:** Mean gains were 0.323 (left) and 0.291 (right) in Group A ($p < 0.0001$), versus 0.741 bilaterally in Group B ($p < 0.001$).
- **Hip Extensors:** Group A showed improvements of 0.314 (left) and 0.291 (right) ($p < 0.0001$), while Group B yielded gains of 0.714 (left) and 0.828 (right) ($p < 0.0001$).

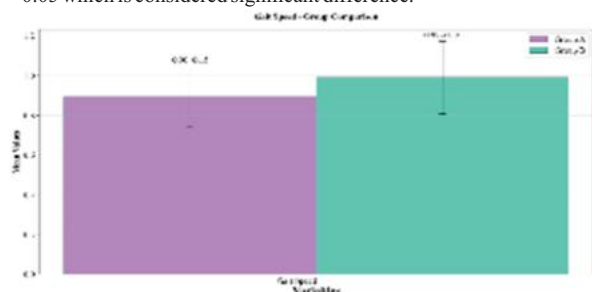
Between-group Comparison

Balance: Between-group analyses demonstrated that Group B achieved significantly greater balance improvements across all four modified CTSIB conditions compared to Group A. Specifically, Group B showed superior gains in the eyes-open firm condition (mean difference = 3.773, $p = 0.020$) and the eyes-closed firm condition (mean difference = 2.454, $p = 0.010$). These between-group differences were even more pronounced under foam-surface conditions, with mean differences favoring Group B of 5.500 for eyes open ($p = 0.002$) and 5.681 for eyes closed ($p < 0.0001$).



Graph 1 - Comparison Between Group A and Group B in Post Intervention Values of Modified CTSIB

Gait Speed: The Gait Speed compared between Group A and Group B, shows that Group B showed more improvement in gait speed, compared with Group A, with mean difference of 0.096, with p value < 0.05 which is considered significant difference.



Graph 2 - Comparison Between Group A and Group B for Gait Speed

Lower Limb Muscle Strength: Between-group analyses demonstrated that Group B achieved significantly greater bilateral strength gains across all evaluated muscle groups compared to Group A:

- **Ankle Invertors:** Group B demonstrated superior improvement over Group A, with mean differences of 0.504 (left) and 0.619 (right) ($p < 0.0001$).
- **Hip Abductors:** Gains favored Group B, showing mean differences of 0.536 (left) and 0.460 (right) ($p < 0.0001$).
- **Hip Adductors:** Group B outperformed Group A with mean differences of 0.300 (left) and 0.541 (right) ($p < 0.05$).
- **Hip Extensors:** Significant differences favoring Group B were observed, with mean differences of 0.391 (left) and 0.455 (right) ($p < 0.0001$).

DISCUSSION

Diabetic peripheral neuropathy (DPN) significantly compromises postural stability, thereby reducing mobility, safety, and independence. The neuropathy results in sensory deficits in the lower extremities, muscle weakness, and impaired proprioception, which heighten the risk of falls. This increased fall risk engenders a fear of falling, leading to avoidance of routine activities, social isolation, and diminished quality of life. Fundamental self-care tasks become challenging, often necessitating assistive devices or caregiver support. Moreover, falls may cause severe injuries, such as fractures, exacerbating both

physical and emotional burdens.[17,18,25,26]

A 2020 Journal of Diabetes Research study notes that 20–30% of DPN patients fall annually with balance deficits driving 80% of cases and emphasizes that balance training and glycaemic control can improve stability while slowing disease progression. [18]

The Within-Group analysis showed improvements in Group B across all parameters of modified CTSIB ($p < 0.001$ for paired t-tests). Limited literature is available in the population of diabetic peripheral neuropathy patients for values of minimal clinical important difference in modified CTSIB scores. Although a study done by Mullin R et. al. suggest that Standard Estimated Measure was 3.48 s in the mCTSIB composite score, with 9.66 s Minimal Detectable Change, the results of this study were inconclusive. Also we found a change of 3s in scores of modified CTSIB in this study which is statistically significant but this may not be clinically significant. [27]

Gait speed increased by an average of 0.2 m/s in Group B, exceeding the minimal clinically important difference of 0.1 m/s for DPN populations, reflecting improved stride efficiency and reduced fear of falling. [28]

Isometric strength improvements were bilateral and symmetric, with hip adductors and ankle invertors showing mean gains of 0.7–0.9 kgf ($p < 0.001$). This emphasizes focus of structured intervention on frontal plane control, which is critical for mediolateral stability during gait perturbations which is a common deficit in DPN leading to falls. [9,23,28,29]

Between-group comparisons confirmed the structured intervention's superiority with Group B outperforming Group A by 20%–30% post-treatment ($p < 0.01$). Group A's modest gains (p approx 0.006 – 0.022) highlight the limitations of conventional exercises in targeting proximal compensations, such as hip-strategy recruitment for distal sensory deficits. [14]

These findings align with existing literature. Alissa et al. demonstrated that weight-shifting and base-of-support modifications reduce fall risk, corroborating the improvements in mCTSIB scores elicited by our frontal-plane exercises. Furthermore, while Jiang et al. and Wang et al. documented reduced gait velocity and altered biomechanics in early DPN [25], our proximal-strengthening regimen effectively counteracted these impairments. Similarly, Ravand et al. reported enhanced stability following ankle proprioceptive training [30]. Collectively, these data substantiate the efficacy of targeted strength and balance interventions in addressing DPN-induced locomotor deficits [31].

Adrienne Henderson et al. (2019) and Aline Gomes et al. (2017) highlight distal-to-proximal shifts in workload, explaining why hip-focused exercises mitigated ankle deficits [32,13]. Laleh Abadi et al. noted reduced hip torques in DPN, which our intervention addressed through adductor/invertor strengthening. Studies by Brown et al. and Handsaker et al. link neuropathy to mediolateral instability during dynamic tasks, reinforcing our focus on frontal-plane control [9,29]. Repeated sensorimotor challenges enhance afferent feedback from mechanoreceptors, thereby driving somatosensory cortical reorganization and promoting neuroplasticity.

Physiologically, the intervention may stimulate neurotrophic factors (NGF, BDNF) that promote axonal regeneration and attenuate neurodegeneration [33]. Moderate-intensity exercise upregulates heat shock protein 72 (Hsp72), conferring neuroprotection by mitigating hyperalgesia, allodynia, and tactile hypersensitivity via calcium-channel modulation [34]. Furthermore, frontal-plane resistance training improves muscle-specific glucose uptake and microvascular perfusion, attenuating oxidative stress and pro-inflammatory signaling (e.g., TNF- α , IL-1 β) within dorsal root ganglia [35]. These anti-inflammatory effects normalize ion-channel dynamics (TRPV1, TRPM8), thereby elevating pain thresholds and enhancing nerve conduction velocity. Finally, exercise may modulate aberrant peripheral microRNA expression to favor neuronal survival and suppress inflammation, though translational human evidence remains limited [36].

Biomechanically, the focus on hip adductors and ankle invertors addresses mediolateral instability, a hallmark of DPN gait alterations characterized by wider base of support, prolonged double-support

phases, and reduced stride velocity. [28] Moreover, symmetrical bilateral strength gains suggest systemic neuromuscular remodeling, likely driven by improved insulin sensitivity, endothelial function, and vasa nervorum perfusion promoting nerve repair [36].

Both the treatment strategies have shown improvements in balance, gait speed and strength with 6 weeks of intervention in patients with diabetic peripheral neuropathy. By strengthening proximal muscles, the structured intervention facilitates a distal-to-proximal shift in workload, compensating for distal sensory deficits and enhancing center-of-mass control during dynamic tasks like walking or stair negotiation. This proximal strategy not only improves gait speed (as seen in our 0.2 m/s increase) but also reduces compensatory adaptations like shortened strides, which exacerbate energy inefficiency and fall risk.

Limitations

The Limitation of this study is that carry over effect was not checked. Also the lower limb dominance was not taken into consideration. Any advanced measure was not used for assessment of balance.

Future Scope

More research is needed to see the long-term effects (e.g., 12–24 months) to assess the durability of structured interventions, such as frontal plane training in improving balance, reducing fall risk, and enhancing quality of life, while also evaluating patient adherence in real-world contexts. Further research could also compare different types of structured interventions and incorporate home-based and technology-assisted training modules to enhance accessibility and adherence.

CONCLUSION

A structured physiotherapy intervention programme produced greater improvements in balance, gait speed, and lower limb muscle strength compared with conventional intervention in patients with diabetic peripheral neuropathy. Incorporating such structured, progressive, and task-oriented protocols into routine clinical practice may help reduce fall risk and improve functional independence in this population.

Conflict of Interest

The authors declare no conflict of interest.

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