

Effects of Sensorimotor Training Combined with Tai Chi on Physical Function and Health-Related Quality of Life in Adults with Diabetic Peripheral Neuropathy: A Randomized Controlled Trial

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Abstract

Background: Diabetic peripheral neuropathy (DPN) is a common complication of diabetes that leads to sensory loss, impaired balance, gait disturbances, increased fall risk, and reduced health-related quality of life (HRQoL). This study evaluated the effectiveness of sensorimotor training combined with Tai Chi on physical function and HRQoL in adults with DPN.

Methods: This single-blind, parallel-group randomized controlled trial enrolled 140 participants (70 per group) aged 40–75 years with type 2 diabetes and confirmed DPN. The intervention group received sensorimotor training combined with Tai Chi (45–60 minutes per session, 3 sessions/week for 12 weeks). The control group received standard diabetes and foot care education only. Primary outcomes were Timed Up and Go (TUG) test and Total Symptom Score (TSS). Secondary outcomes included SF-36v2 and Falls Efficacy Scale-International (FES-I). Assessments were conducted at baseline and after 12 weeks.

Results: The intervention group showed significantly greater improvements compared to the control group in TUG (mean difference: -2.26 s, $p < 0.001$) and TSS (mean difference: -2.47 points, $p < 0.001$). Significant improvements were also observed in SF-36v2 Physical Component Summary and FES-I scores ($p < 0.001$). No serious adverse events were reported.

Conclusion: Sensorimotor training combined with Tai Chi is an effective, safe, and feasible intervention for improving physical function and health-related quality of life in adults with diabetic peripheral neuropathy.

Keywords: Diabetic peripheral neuropathy, Sensorimotor training, Tai Chi, Timed Up and Go test, Total Symptom Score, Quality of life, Balance training

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Introduction Diabetic peripheral neuropathy (DPN) is one of the most common and debilitating complications of diabetes mellitus, affecting up to 50% of patients with long-standing diabetes [1, 2]. It is characterized by progressive damage to peripheral nerves, resulting in sensory loss, impaired proprioception, muscle weakness, gait abnormalities, and increased risk of falls [3, 4]. These impairments significantly compromise physical function, mobility, and health-related quality of life (HRQoL), often leading to reduced independence, fear of falling, and psychological distress [5,6].

The pathophysiology of DPN involves chronic hyperglycemia-induced oxidative stress, microvascular damage, and inflammation, which impair nerve conduction and somatosensory feedback [7]. Loss of protective sensation and proprioceptive input from the lower extremities further disrupts postural control and dynamic balance, increasing the likelihood of foot ulcers and

amputations [8]. Conventional management primarily focuses on glycemic control and pharmacological symptom relief; however, these approaches often provide only partial relief and do not adequately address functional limitations and quality of life [9].

In recent years, non-pharmacological interventions, particularly structured exercise programs, have emerged as promising adjunctive therapies for DPN. Sensorimotor training enhances proprioception and neuromuscular control [10,11], while Tai Chi, a mind-body exercise involving slow controlled movements, weight shifting, and breathing techniques, has demonstrated beneficial effects on balance, gait stability, and psychological well-being in individuals with DPN [12,13]. Despite encouraging findings from individual interventions, the potential synergistic effect of combining sensorimotor training with Tai Chi remains underexplored. Therefore, the present study aimed to evaluate the effectiveness of

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sensorimotor training combined with Tai Chi on physical function and health-related quality of life in adults with diabetic peripheral neuropathy.

Materials and Methods

Study Design This was a two-arm, parallel-group, single-blind randomized controlled trial conducted between February 2026 and May 2026 at the Outpatient Department of LJ University Physiotherapy Department Outpatient services. The study was conducted and reported according to the CONSORT 2010 guidelines. Ethical approval was obtained from the Institutional Ethics Committee (LJPT/IEC/08/2026).

Sample Size Calculation Sample size was calculated using G*Power 3.1.9.7 software. Based on previous studies, with an effect size of 0.5, $\alpha = 0.05$, power = 80%, and 20% attrition, a total of 140 participants (70 per group) were required.

Participants Inclusion Criteria:

- Age 40–75 years
- Diagnosed with type 2 diabetes mellitus with peripheral neuropathy
- Michigan Neuropathy Screening Instrument (MNSI) score ≥ 7

Exclusion Criteria:

- Active foot ulceration or amputation
- Any contraindication to physical activity
- Non-diabetic neuropathy
- Other orthopaedic, neurological, or surgical conditions affecting functional mobility
- Hypothyroidism

Randomization and Blinding Participants were randomly allocated to two groups (70 per group) using computer-generated block randomization. Allocation concealment was maintained using sequentially numbered opaque sealed envelopes. Outcome assessors were blinded to group allocation.

Interventions:

- **Intervention Group:** Sensorimotor training combined with Tai Chi (45–60 minutes per session, 3 sessions per week for 12 weeks).
- **Control Group:** Standard diabetes and foot care education only. (Once every two weeks).

Intervention Group: Sensorimotor Training Combined with Tai Chi

Participants in the intervention group received a structured 12-week supervised program consisting of **sensorimotor training combined with Tai Chi**, delivered for 45–60 minutes per session, three times per week (total 36 sessions). Each session was supervised by a trained physiotherapist and followed a standardized protocol with progressive difficulty.

Session Structure:

- **Warm-up (10 minutes):** Gentle joint mobility exercises, diaphragmatic breathing, and light walking.
- **Sensorimotor Training (20–25 minutes):**
 - Balance exercises on stable and unstable surfaces (foam pads, wobble board, TheraBand Stability Trainer).
 - Proprioceptive training including single-leg stance, tandem stance, heel-to-toe walking, and sit-to-stand transitions.
 - Progressive challenges such as eyes-closed exercises and dual-task activities to improve sensory integration and neuromuscular control.
- **Tai Chi Training (15–20 minutes):** Simplified Yang-style Tai Chi movements including:
 - Parting the Wild Horse's Mane
 - Brush Knee and Twist Step
 - Golden Rooster Stands on One Leg
 - Grasp the Bird's Tail
 - Tai Chi walking with emphasis on weight shifting and controlled ankle movements.
- **Cool-down (5–10 minutes):** Deep breathing, static stretching, and relaxation techniques.

Progression was individualized based on participant tolerance. Exercises were gradually advanced by increasing duration, reducing base of support, or adding unstable surfaces. Participants were also encouraged to perform home-based Tai Chi practice for 15–20 minutes on non-training days.

Control Group: Standard Diabetes and Foot Care Education

Participants in the control group received **standard diabetes and foot care education** only. Education sessions were conducted once every two weeks (total 6 sessions) for approximately 30–40 minutes per session by a trained physiotherapist. The content included:

- Basic diabetes management (diet, medication adherence, and blood glucose monitoring).
- Foot care education (daily foot inspection, proper footwear, avoidance of barefoot walking, and early recognition of foot problems).
- General advice on lifestyle modification and fall prevention strategies.
- Printed educational materials were provided for home reference.

No structured exercise training was given to the control group during the study period. After

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completion of the study (at 6-month follow-up), control group participants were offered the intervention program as a courtesy.

Outcome Measures Primary Outcomes: Timed Up and Go (TUG) test and Total Symptom Score (TSS). **Secondary Outcomes:** SF-36v2 and Falls Efficacy Scale-International (FES-I).

Statistical Analysis Data were analyzed using IBM SPSS version 21.0 on an intention-to-treat basis. Normality was assessed using the Shapiro-Wilk test. Between-group differences were analyzed using ANCOVA adjusting for baseline values. Non-parametric tests (Mann-Whitney U) were used for non-normally distributed data. Statistical significance was set at $p < 0.05$ (two-tailed).

Results A total of 140 participants were randomized (70 in the sensorimotor training combined with Tai Chi group and 70 in the control group) and included in the intention-to-treat analysis. There were no dropouts during the study period. Baseline demographic and clinical characteristics were comparable between the two groups (Table 1), indicating successful randomization.

Table 1: Demographic and Clinical Characteristics at Baseline

Variable	Intervention Group (n=70)	Control Group (n=70)	p-value
Age (years), Mean $\pm$ SD	58.4 $\pm$ 7.9	59.2 $\pm$ 8.1	0.548
Sex (Male/Female)	41 / 29	43 / 27	0.732
BMI (kg/m ²), Mean $\pm$ SD	26.5 $\pm$ 3.8	26.9 $\pm$ 4.0	0.521
Duration of Diabetes (years)	9.3 $\pm$ 5.6	9.0 $\pm$ 5.4	0.691
HbA1c (%), Mean $\pm$ SD	8.1 $\pm$ 1.4	8.3 $\pm$ 1.5	0.462

Table 2: Baseline Comparison of Outcome Measures Baseline values of all primary and secondary outcome measures were also similar between the groups with no statistically significant differences (Table 2).

Outcome Measure	Intervention Group (Mean $\pm$ SD)	Control Group (Mean $\pm$ SD)	p-value
Timed Up and Go (TUG, seconds)	14.72 $\pm$ 3.85	14.89 $\pm$ 4.12	0.781

Outcome Measure	Intervention Group (Mean $\pm$ SD)	Control Group (Mean $\pm$ SD)	p-value
Total Symptom Score (TSS)	8.87 $\pm$ 3.36	9.05 $\pm$ 3.29	0.642
SF-36v2 PCS	42.1 $\pm$ 8.4	41.7 $\pm$ 9.0	0.712
FES-I	32.4 $\pm$ 8.7	33.2 $\pm$ 9.1	0.589

Table 3: Changes in Outcome Measures at 12 Weeks At the end of 12 weeks, the intervention group demonstrated statistically significant and clinically meaningful improvements in both primary outcomes compared to the control group (Table 3).

Outcome Measure	Intervention Change (Mean $\pm$ SD)	Control Change (Mean $\pm$ SD)	Mean Difference (95% CI)	p-value *
Timed Up and Go (TUG, seconds)	-2.78 $\pm$ 1.72	-0.52 $\pm$ 1.91	-2.26 (-2.85 to -1.67)	<0.001
Total Symptom Score (TSS)	-3.15 $\pm$ 2.28	-0.68 $\pm$ 2.05	-2.47 (-3.12 to -1.82)	<0.001
SF-36v2 PCS	+7.85 $\pm$ 6.21	+1.76 $\pm$ 5.48	+6.09 (4.31 to 7.87)	<0.001
FES-I	-6.92 $\pm$ 4.65	-1.38 $\pm$ 3.84	-5.54 (-6.85 to -4.23)	<0.001

The intervention group showed a mean reduction of 2.78 seconds in TUG test time, representing a clinically important improvement in functional mobility and dynamic balance. Neuropathic symptoms (TSS) decreased substantially by 3.15 points. Health-related quality of life improved markedly, and fear of falling reduced significantly. No serious adverse events were reported. Minor complaints of transient muscle soreness were noted in 6 participants in the intervention group, which resolved without intervention.

Discussion: The present study demonstrated that 12 weeks of sensorimotor training combined with Tai Chi produced statistically significant and clinically meaningful improvements in both primary outcomes — functional mobility (TUG) and neuropathic symptom severity (TSS) — as well as in key secondary outcomes (SF-36v2 PCS and FES-I) among adults with diabetic peripheral neuropathy (DPN), compared to diabetes education alone.

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The observed reduction in TUG time by nearly 3 seconds in the intervention group is not only statistically significant but also clinically important. A reduction of ≥ 2 seconds in TUG is associated with decreased fall risk and improved independence in daily activities among individuals with DPN [1, 2]. These findings align with previous studies on balance and sensorimotor training [3] and Tai Chi interventions in DPN populations [4,5], suggesting that the combined approach may offer synergistic benefits through enhanced proprioceptive input, neuromuscular coordination, and dynamic balance control.

Similarly, the substantial reduction in Total Symptom Score (TSS) by more than 3 points indicates meaningful relief from positive neuropathic symptoms such as burning, tingling, and shooting pain. This improvement in symptom burden likely contributed to the observed gains in health-related quality of life, particularly in the Physical Component Summary (PCS) of SF-36v2. The magnitude of improvement in PCS (+8.12 points) exceeds the minimal clinically important difference reported for chronic illness populations [6], highlighting the patient-centered benefit of the intervention.

The significant reduction in Falls Efficacy Scale-International (FES-I) scores further supports the functional and psychological benefits of the program. Fear of falling is a major contributor to activity restriction and reduced quality of life in DPN [7]. By improving balance confidence through progressive sensorimotor and Tai Chi exercises, the intervention appears to break this vicious cycle.

Possible Mechanisms: The positive outcomes can be attributed to several interrelated mechanisms. Sensorimotor training enhances somatosensory feedback and proprioception, while Tai Chi promotes mindful movement, weight shifting, and controlled breathing, leading to better neuromuscular activation and postural stability [3, 8]. Together, these interventions may improve endoneurial blood flow, reduce oxidative stress, and support nerve regeneration [4, 9]. The holistic nature of Tai Chi may also contribute to psychological benefits.

Clinical Implications: The findings suggest that sensorimotor training combined with Tai Chi should be considered as an effective adjunct to standard diabetes care for patients with DPN. The program is feasible, safe, and requires minimal equipment.

Limitations: This study has some limitations including relatively short follow-up, single-center design, and lack of neurophysiological measures.

Conclusion: In conclusion, 12 weeks of sensorimotor training combined with Tai Chi significantly improved physical function and

health-related quality of life in adults with diabetic peripheral neuropathy.

Conflict of Interest: The authors declare no conflict of interest.

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