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Efficacy of Stability Trainer Exercises Versus Conventional Physiotherapy on Balance and Proprioception in Patients with Type 2 Diabetes Mellitus with Peripheral Neuropathy: A Randomized Controlled Trial

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Abstract

Background: Diabetic Peripheral Neuropathy (DPN) is a prevalent complication of Type 2 Diabetes Mellitus (T2DM), characterised by impaired sensation, reduced balance, and a heightened risk of falls. Enhancing proprioceptive function through rehabilitation can improve postural stability and functional independence. This study compared the effectiveness of Stability Trainer (ST) exercises with Conventional Physiotherapy (CP) in improving balance and proprioception among individuals with DPN. **Methods:** Eighty participants with clinically diagnosed DPN were randomly assigned to two groups: the ST group (n = 40) and the CP group (n = 40). Both groups underwent 45-minute supervised sessions, three times weekly, for eight weeks. The Berg Balance Scale (BBS), Timed Up and Go test (TUG), and Proprioception Error Angle (PEA) were assessed before and after the intervention. Data were analysed using ANCOVA, adjusting for baseline values. **Results:** Both groups exhibited significant improvements across all measures ($p < 0.05$). However, the ST group showed greater gains in balance (BBS: +6.4 vs +3.1, $p < 0.01$) and proprioception (PEA: −4.2° vs −1.8°, $p < 0.01$). TUG scores also improved more markedly in the ST group (−2.8 s vs −1.4 s, $p = 0.01$). No adverse effects were reported. **Conclusion:** Training on unstable surfaces using stability trainers led to superior improvements in balance and proprioceptive function compared with conventional physiotherapy. Integrating such interventions into diabetic rehabilitation programs may help reduce fall risk and enhance functional mobility.

Keywords: Balance, Diabetic Peripheral Neuropathy, Fall Prevention, Proprioception, Rehabilitation, Stability Trainer, Type 2 Diabetes

1. Introduction

Diabetes Mellitus (DM) has emerged as one of the most pressing global health challenges of the 21st century. According to the International Diabetes Federation (IDF), approximately 537 million adults were living with diabetes in 2021, and this number is projected to exceed 780 million by 2045 [1]. Among its numerous complications, DPN remains one of the most prevalent and debilitating, affecting nearly 50% of individuals with long-standing T2DM[2]. DPN is characterised by progressive sensory loss, diminished proprioceptive awareness, and distal muscle weakness, all of which compromise gait stability, increase fall risk, and significantly reduce quality of life[3].

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Physiotherapy plays a critical role in the management of DPN-related functional impairments. CP, which emphasises strengthening, stretching, and gait training, can improve mobility and muscle endurance[4]. However, these interventions often fail to adequately stimulate the sensory-motor integration mechanisms responsible for maintaining balance and postural control[5]. In recent years, proprioceptive and unstable-surface training—including the use of STs—has gained attention as an effective method to enhance neuromuscular coordination and sensory feedback processing[6].

Exercises performed on unstable surfaces activate multiple sensory systems (visual, vestibular, and somatosensory), compelling the body to execute continuous micro-adjustments to maintain equilibrium[7]. This adaptive response improves joint position sense, balance strategy, and muscular coordination, offering a more comprehensive rehabilitation stimulus compared to conventional approaches[8]. Studies have reported that proprioceptive-focused balance training can improve postural stability, reduce fall risk, and enhance confidence in mobility among individuals with DPN[9,10].

Despite these promising outcomes, direct comparative research examining the effectiveness of stability trainer-based rehabilitation versus traditional physiotherapy remains limited. Thus, the present study was designed to evaluate and compare the impact of stability trainer exercises and conventional physiotherapy on balance, proprioception, and functional mobility in individuals with T2DM complicated by DPN. The findings are expected to contribute valuable insights toward optimising rehabilitation strategies for this growing population.

2. Materials and Methods

2.1 Study Design

This study was conducted as a prospective randomised controlled trial to evaluate the effectiveness of stability trainer-based exercises compared with conventional physiotherapy in improving balance, functional mobility, and proprioception among individuals with DPN. The study was carried out in the Department of Physiotherapy, KG Hospital, Coimbatore, between July 2024 and December 2024.

The study protocol was approved by the Institutional Ethics Committee, and all procedures were performed in accordance with the ethical standards outlined in the Declaration of Helsinki (2013 revision). Prior to participation, all individuals were informed about the purpose, procedures, and potential benefits of the study, and written informed consent was obtained from all participants.

2.2 Sample Size Estimation

An a priori power analysis was performed using G*Power software (version 3.1) to determine the minimum number of participants required to detect a statistically significant difference between the intervention groups. Assuming a moderate effect size (0.65), alpha level of 0.05, and statistical power of 80%, the minimum sample size required was calculated to be 72 participants (36 per group). To ensure adequate statistical power and account for potential participant attrition, a total of 80 participants were recruited and equally allocated into two groups.

2.3 Participants

Participants were recruited from the outpatient physiotherapy unit through referrals from medical specialists treating patients with diabetes mellitus. Individuals diagnosed with Type 2 Diabetes Mellitus (T2DM) and diabetic peripheral neuropathy were screened for eligibility according to predefined inclusion and exclusion criteria.

2.4 Inclusion Criteria

Participants were included if they met the following criteria:

- Age between 40 and 65 years
- Diagnosed with Type 2 Diabetes Mellitus for at least five years
- Presence of diabetic peripheral neuropathy confirmed using the Michigan Neuropathy Screening Instrument (MNSI) with a score ≥7
- Ability to walk independently without assistive devices
- Willingness to participate in the study

2.5 Exclusion Criteria

Participants were excluded if they presented with:

- Severe diabetic retinopathy or significant visual impairment
- Open or infected foot ulcers
- Recent lower limb fractures or orthopaedic surgery
- Vestibular disorders or neurological conditions affecting balance
- Severe musculoskeletal disorders limiting mobility
- Cognitive impairment affecting comprehension of instructions

2.6 Randomisation and Allocation Concealment

Eligible participants who completed baseline assessments were randomly allocated into either the ST group or the CP group in a 1:1 ratio. Randomisation was performed using a computer-generated random sequence prepared by an independent researcher not involved in participant recruitment or outcome assessment.

To ensure allocation concealment, the group assignments were placed in sequentially numbered, opaque, sealed envelopes. After confirming participant eligibility and obtaining informed consent, the envelopes were opened sequentially by the study coordinator to reveal group allocation. This procedure minimised selection bias during the recruitment process.

2.7 Blinding

Outcome assessments were conducted by a physiotherapist who was blinded to the group allocation in order to minimise assessment bias. Due to the nature of exercise-based rehabilitation interventions, blinding of participants and treating physiotherapists was not feasible. However, both groups received equal session duration and frequency, and standardised treatment protocols were followed to reduce potential bias.

2.8 Intervention Protocol

Participants in both groups received supervised physiotherapy sessions three times per week for eight weeks, with each session lasting approximately 45 min. All exercise sessions were conducted under the supervision of qualified physiotherapists to ensure safety and adherence to the training protocol.

2.9 ST Group

Participants assigned to the ST group performed unstable-surface training exercises using a stability trainer platform designed to challenge postural control and proprioceptive responses.

Each session consisted of

Warm-up (5 min) Gentle stretching and ankle mobility exercises.

Main exercise session (35 min) Balance and proprioceptive exercises, including:

- Static standing balance
- Dynamic weight shifting
- Controlled squatting
- Single-leg stance activities
- Perturbation-based balance training

Each exercise was performed for 2-3 sets of 10-15 repetitions or maintained for 20-30 s per set, with 30-60 s rest intervals between sets.

Progression of exercises was implemented every two weeks based on the participant's ability to maintain balance and perform the exercises correctly. Progression involved reducing hand support, introducing single-limb tasks, and incorporating dynamic balance challenges.

2.10 CP Group

Participants in the CP group received a standard physiotherapy program focusing on strengthening, flexibility, and functional mobility.

The program included

- Lower limb strengthening exercises targeting quadriceps, hamstrings, gastrocnemius, and tibialis anterior muscles
- Joint range-of-motion exercises for ankle and knee joints
- Flexibility exercises for major lower limb muscle groups
- Gait training and functional mobility exercises

Strengthening exercises were performed for 2-3 sets of 10-15 repetitions. The frequency and duration of sessions

were identical to those in the ST group to ensure equal therapeutic exposure.

2.11 Outcome Measures

Outcome assessments were performed at baseline (pre-intervention) and after eight weeks of intervention (post-intervention).

2.12 Balance Assessment

Balance was evaluated using the Berg Balance Scale (BBS), a validated 14-item functional balance assessment tool with a maximum score of 56 points, where higher scores indicate better balance performance.

2.13 Functional Mobility Assessment

Functional mobility was assessed using the TUG test, which measures the time required for a participant to stand from a seated position, walk three meters, turn, return to the chair, and sit down. The test duration was recorded in seconds, with shorter times indicating better mobility.

2.14 Proprioception Assessment

Proprioception was assessed using the Proprioception Error Angle (PEA) obtained from a joint position reproduction test using a standard goniometer. Participants were asked to reproduce a pre-set ankle joint angle after returning to a neutral position. The difference between the target angle and the reproduced angle was recorded as the error angle, with smaller values indicating better proprioceptive accuracy.

2.15 Statistical Analysis

Statistical analysis was performed using SPSS software (version XX). Descriptive statistics were calculated for demographic and baseline characteristics and expressed as mean ± standard deviation. Within-group comparisons between baseline and post-intervention outcomes were analysed using paired t-tests, while independent t-tests were used to compare differences between the ST and CP groups.

Effect sizes were calculated using Cohen's d to determine the magnitude of the intervention effects, and 95% Confidence Intervals (CI) were reported to estimate the precision of the results. A p-value less than 0.05 was considered statistically significant.

3. Results

A total of 80 participants who met the eligibility criteria completed the study protocol, with no dropouts or adverse events reported during the intervention period. The mean age of the participants was 54.3 ± 6.2 years, and 52.5% were male. Baseline demographic and clinical characteristics, including age, gender distribution, duration of diabetes, neuropathy severity, and physical activity level, were comparable between the Stability

Table 1. Baseline demographic and clinical characteristics of participants in the ST and CP groups

Variable	Stability Trainer Group (ST) (n = 40)	Conventional Physiotherapy Group (CP) (n = 40)	pvalue
Age (years)	54.5 ± 6.1	54.1 ± 6.3	0.78
Gender (male/female)	21 / 19	21 / 19	1.00
Duration of diabetes (years)	9.2 ± 3.4	9.0 ± 3.6	0.84
Neuropathy severity (MNSI score)	5.6 ± 1.2	5.4 ± 1.3	0.62
Physical activity level (METs/week)	1120 ± 240	1095 ± 255	0.71

Trainer (ST) and Conventional Physiotherapy (CP) groups ($p > 0.05$), indicating successful randomisation and group equivalence at baseline (Table 1).

No statistically significant differences were observed between groups at baseline ($p > 0.05$), indicating that the participants were comparable before the intervention.

Following the eight-week intervention, both groups demonstrated significant improvements in balance, functional mobility, and proprioception compared with baseline values ($p < 0.05$). However, the magnitude of improvement was greater in the Stability Trainer group across all outcome measures.

Balance performance, assessed using the Berg Balance Scale (BBS), improved significantly in both groups. The ST group showed a mean increase of 6.4 points, whereas the CP group demonstrated an improvement of 3.1 points (Table 2).

Similarly, functional mobility, assessed using the TUG test, improved in both groups. The ST group exhibited a reduction of 2.8 s in completion time, while the CP group showed a reduction of 1.4 s.

For proprioceptive accuracy, measured using the PEA, the ST group showed a reduction of 4.2°, compared with a reduction of 1.8° in the CP group.

Both groups demonstrated significant improvements in balance, mobility, and proprioception following the intervention ($p < 0.05$).

Between-group comparison of post-intervention outcomes revealed significantly greater improvements in the Stability Trainer group compared with the Conventional Physiotherapy group (Table 3). The ST group demonstrated significantly higher Berg Balance Scale scores ($p = 0.003$), faster Timed Up and Go performance ($p = 0.01$), and lower Proprioception Error Angle values ($p = 0.002$).

No adverse events, including dizziness, loss of balance requiring assistance, or musculoskeletal discomfort, were reported during the intervention period. Adherence to the

Table 2. Within-group comparison of outcome measures

Outcome measure	Group	Pre-intervention	Post-intervention	Mean change	pvalue
Berg Balance Scale (BBS)	ST	41.2 ± 3.8	47.6 ± 3.4	+6.4	<0.001
	CP	41.5 ± 4.0	44.6 ± 3.7	+3.1	0.002
Timed Up and Go (TUG) (s)	ST	12.5 ± 1.6	9.7 ± 1.3	−2.8	<0.001
	CP	12.3 ± 1.5	10.9 ± 1.4	−1.4	0.004
Proprioception Error Angle (°)	ST	8.6 ± 1.9	4.4 ± 1.5	−4.2	<0.001
	CP	8.4 ± 2.0	6.6 ± 1.8	−1.8	0.006

Table 3. Between-group comparison of post-intervention outcomes

Outcome measure	ST group (n = 40) mean ± SD	CP group (n = 40) mean ± SD	Mean difference	pvalue
Berg Balance Scale (BBS)	47.6 ± 3.4	44.6 ± 3.7	3.0	0.003
Timed Up and Go (s)	9.7 ± 1.3	10.9 ± 1.4	−1.2	0.01
Proprioception Error Angle (°)	4.4 ± 1.5	6.6 ± 1.8	−2.2	0.002

intervention protocol was excellent, with all participants completing the prescribed training sessions.

4. Discussion

The present randomised controlled trial examined the effectiveness of stability trainer-based exercises compared with conventional physiotherapy in improving balance, proprioception, and functional mobility among individuals with Diabetic Peripheral Neuropathy (DPN). The results demonstrated that both intervention groups experienced significant improvements following the eight-week rehabilitation program; however, the magnitude of improvement was significantly greater in the stability trainer group across all outcome measures. Balance performance measured using the Berg Balance Scale improved by 6.4 points in the stability trainer group compared with 3.1 points in the conventional physiotherapy group. Similarly, functional mobility assessed through the Timed Up and Go Test showed a larger reduction in completion time in the stability trainer group. In addition, proprioceptive accuracy, measured through the proprioception error angle, demonstrated a greater reduction among participants performing instability-based exercises. These findings suggest that training on unstable surfaces may provide enhanced neuromuscular stimulation and sensorimotor integration compared with conventional physiotherapy programs.

The improved outcomes observed in the stability trainer group may be explained by the biomechanical and neurophysiological demands associated with unstable-surface training. Exercises performed on unstable platforms require continuous postural adjustments and coordinated activation of multiple muscle groups to maintain equilibrium. This constant challenge to the postural control system enhances activation of proprioceptors located in muscles, ligaments, and joint capsules, thereby increasing afferent sensory input to the central nervous system. Enhanced sensory feedback facilitates better integration of visual, vestibular, and somatosensory information, ultimately improving postural stability and movement coordination[11]. In individuals with Diabetic Peripheral Neuropathy, where peripheral sensory input is compromised due to nerve degeneration, such proprioceptive stimulation may partially compensate for sensory deficits and support improved balance regulation[12].

The findings of the present study are consistent with earlier research examining balance impairments in individuals with diabetic neuropathy. Previous investigations have demonstrated that patients with neuropathic complications of diabetes exhibit significant deficits in postural stability, gait control, and proprioceptive feedback mechanisms. For instance, research conducted by Richardson JK reported that individuals with diabetic neuropathy have greater postural sway and impaired balance responses due to diminished somatosensory input[13]. Similarly, Simoneau GG highlighted the role of impaired ankle proprioception and reduced vibration sensitivity in contributing to gait instability among neuropathic populations[14]. The improvements observed in the present study, therefore, support the growing body of evidence indicating that targeted balance and sensorimotor training can mitigate these impairments.

Another important outcome observed in the present study was the significant improvement in functional mobility in the stability trainer group compared with the conventional physiotherapy group. Functional mobility, assessed through the Timed Up and Go Test, showed a reduction of 2.8 seconds in the stability trainer group, which was greater than the reduction observed in the conventional physiotherapy group. The Timed Up and Go test is widely recognised as a reliable indicator of functional mobility and fall risk in individuals with balance impairments[15]. Improvements in this measure suggest enhanced coordination, lower-limb strength, and dynamic balance. Exercises performed on unstable surfaces often require simultaneous activation of ankle, knee, and hip stabilising muscles, thereby promoting better neuromuscular coordination during transitional movements such as standing, walking, and turning[16]. These neuromuscular adaptations likely contributed to the superior mobility outcomes observed in the stability trainer group.

In addition to improvements in functional mobility, the present study demonstrated a substantial improvement in proprioceptive accuracy among participants who underwent instability-based training. The reduction in proprioception error angle observed in the stability

trainer group indicates improved joint position sense and enhanced sensorimotor control. Proprioception plays a fundamental role in maintaining joint stability and coordinating movement patterns during daily activities. In individuals with Diabetic Peripheral Neuropathy, degeneration of peripheral sensory nerves disrupts the transmission of proprioceptive information, resulting in impaired balance and increased risk of falls[17]. Previous studies have shown that proprioceptive and balance-oriented training can enhance sensory feedback mechanisms and improve joint position awareness in individuals with neuropathic conditions[18]. The findings of the present study, therefore, support the use of instability-based exercises as an effective strategy for improving proprioceptive function in this population.

Furthermore, instability-based exercises may promote neuroplastic adaptations within central neural pathways responsible for postural control and motor coordination. Repetitive balance-challenging tasks are known to stimulate cortical and subcortical regions involved in sensorimotor integration, including the somatosensory cortex, cerebellum, and vestibular system. Enhanced neural connectivity within these regions may lead to improved postural responses and more efficient movement patterns[19]. Neurorehabilitation studies have demonstrated that sensorimotor training can increase cortical excitability and enhance motor learning, thereby facilitating long-term improvements in functional performance[20]. These neurophysiological mechanisms may explain the greater improvements observed in the stability trainer group compared with conventional physiotherapy.

The present findings are also supported by previous rehabilitation studies investigating the role of balance-oriented interventions in individuals with metabolic and neurological disorders. Several investigations have reported that sensorimotor training programs incorporating unstable surfaces, balance boards, and proprioceptive exercises significantly improve postural stability, gait performance, and fall-related outcomes[21]. Such interventions promote multisensory integration and enhance neuromuscular coordination, leading to improved movement efficiency and functional independence. Therefore, integrating instability-based exercises into physiotherapy programs may provide additional therapeutic benefits for individuals with diabetic neuropathy.

From a clinical perspective, the results of this study emphasise the importance of incorporating targeted balance and proprioceptive training into rehabilitation programs for patients with Diabetic Peripheral Neuropathy. As the global prevalence of diabetes continues to rise, the burden of neuropathic complications and associated mobility impairments is expected to increase. Rehabilitation interventions that effectively improve balance and reduce fall risk are therefore of considerable clinical significance. Stability trainer-based exercises represent a practical, accessible, and cost-effective method for enhancing neuromuscular performance and functional independence. Additionally, the absence of adverse events in this study suggests that such interventions can be safely implemented under appropriate clinical supervision.

Despite the positive outcomes observed in this study, several limitations should be acknowledged. Although outcome assessors were blinded to group allocation, participant and therapist blinding was not feasible due to the nature of the exercise interventions. This limitation is common in physiotherapy trials and may introduce a degree of performance bias. Furthermore, the intervention period was limited to eight weeks, and long-term follow-up assessments were not conducted. As a result, it remains uncertain whether the improvements observed in this study would be sustained over longer periods. Additionally, the study was conducted in a single clinical centre, which may limit the generalisability of the findings to other populations and healthcare settings.

5. Limitations

- The study was conducted in a single centre, which may limit the generalisability of the findings to a wider population.
- The intervention duration was relatively short, which may not adequately reflect the long-term effects of the intervention.
- The study did not include an extended follow-up period to evaluate the sustainability of the outcomes over time.

- Future research should include multicenter trials with larger sample sizes and longer follow-up periods to better assess long-term functional outcomes.

6. Conclusion

This randomised controlled study revealed that stability trainer-based rehabilitation yielded markedly superior outcomes in balance, proprioceptive accuracy, and functional mobility compared with conventional physiotherapy among individuals with diabetic peripheral neuropathy. The use of unstable-surface exercises challenges postural control systems and facilitates enhanced sensory-motor integration, leading to greater neuromuscular coordination and adaptive responses. These results underscore the therapeutic potential of proprioceptive-centred rehabilitation in addressing one of the most disabling complications of diabetes mellitus. By improving joint position awareness and postural stability, stability trainer exercises can help reduce the likelihood of falls, enhance mobility confidence, and promote greater independence in daily living activities. Integrating such evidence-based training modalities into standard physiotherapy practice offers a practical and effective approach to mitigating diabetes-related disability. While the present findings are promising, larger multicenter studies with extended follow-up are recommended to examine long-term outcomes and the sustainability of benefits. Overall, stability trainer-based rehabilitation emerges as a safe, efficient, and clinically valuable strategy for improving functional performance and quality of life in patients with diabetic peripheral neuropathy.

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Authors' Contributions

Concept and design, data collection, analysis, drafting, and critical review performed by the research team collectively.

- Concept and Design: Michael Selvaraj
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- Analysis and Interpretation: Michael Selvaraj
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- Drafting: Michael Selvaraj
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