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EFFECT OF PROPRIOCEPTIVE TRAINING ON BALANCE, FUNCTIONAL MOBILITY, AND PAIN IN PATIENTS WITH DIABETIC NEUROPATHY: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT
Diabetic neuropathy (DN) is one of the most challenging complications of diabetes, causing nerve damage that affects sensation, balance, movement, and often results in chronic pain. These issues make daily activities harder, increase the risk of falls, and reduce independence, particularly in rural communities with limited healthcare access. Traditional physiotherapy mainly focuses on strength, stretching, and pain relief, but often overlooks problems with sensory perception and coordination. Proprioceptive training, which improves body awareness and balance, has been successfully used in conditions like stroke and Parkinson's disease, but its role in DN is less explored. In this randomized controlled trial, 120 participants aged 40–70 with DN from rural and tribal areas of Sirohi district, Rajasthan, were studied. They were randomly assigned to either a control group (standard physiotherapy) or an intervention group (standard physiotherapy plus proprioceptive training), with sessions three times a week for 12 weeks. Balance was measured using the Berg Balance Scale and Sway Balance Test, mobility with the Timed Up and Go test, and pain with the Numeric Pain Rating Scale. The results showed that the intervention group had significant improvements in balance, mobility, and pain compared to the control group. This suggests that adding proprioceptive training to conventional therapy can greatly benefit DN patients, especially in resource-limited rural areas, helping them maintain independence and improve quality of life.
Keywords: diabetic neuropathy, proprioceptive training, balance, mobility, pain, rural rehabilitation, randomized controlled trial

Introduction
Diabetes has become a major global health issue in the 21st century. According to the International Diabetes Federation (2021), around 537 million adults worldwide currently have diabetes, and this number is expected to reach 643 million by 2030. Among its many complications, diabetic neuropathy (DN) is one of the most common and disabling. DN affects nearly half of people who have lived with diabetes for many years, especially those with type 2 diabetes (Vincent and Feldman 228). Diabetic neuropathy is a condition where nerves are damaged due to high blood sugar levels. The most common type, diabetic peripheral neuropathy, mainly affects the legs and feet. It causes numbness, weakness, poor balance, difficulty walking, and chronic

pain. In severe cases, it can lead to foot ulcers, infections, and even amputations. Loss of sensation and impaired proprioception (the sense of body position) makes it hard for patients to maintain balance, walk on uneven surfaces, climb stairs, or perform daily tasks. Pain and reduced mobility also negatively affect mental health and overall quality of life. The impact of DN is particularly severe in rural and tribal areas, like Sirohi district in Rajasthan, where healthcare services are limited, diagnosis is often delayed, and rehabilitation options are scarce. This highlights the urgent need for effective, affordable, and accessible strategies to help these patients regain mobility, prevent falls, and improve their quality of life.

Limitations of Conventional Physiotherapy

Traditional physiotherapy for diabetic neuropathy (DN) mainly focuses on:

- Strengthening the muscles of the lower limbs
- Improving range of motion (ROM) through exercises
- Stretching and flexibility routines
- Pain management using techniques like TENS, heat therapy, or massage
- Basic gait training

While these approaches help improve muscle strength and relieve pain to some extent, they often fail to address the sensory and proprioceptive deficits that are central to DN (Sharma and Kaur 59). This means that even patients who get stronger may still struggle with unsteady walking, poor balance, and a high risk of falls.

Proprioceptive Training and Its Importance

Proprioception is the body's ability to sense its position, movement, and orientation in space. This sense comes from signals in muscles, joints, and tendons and is essential for balance, coordinated movement, and preventing falls. In DN, nerve damage disrupts proprioceptive feedback, making it harder for patients to control movement. Proprioceptive training is a specialized therapy aimed at improving this sensory feedback and neuromuscular control. Typical exercises include:

- Balance board or wobble cushion exercises
- Single-leg standing tasks on both stable and unstable surfaces
- Squats, lunges, and other closed-chain exercises
- Eyes-closed balance exercises to rely more on body sensation
- Gradually increasing difficulty to challenge and enhance postural control

Research has shown that proprioceptive training is highly effective in conditions like stroke, Parkinson's disease, ACL injuries, and fall prevention in the elderly (Allet et al. 460). It improves sensory awareness, strengthens postural reflexes, and reduces fall risk. However, few studies have explored its effectiveness specifically in patients with DN.

Significance of the Study

This study fills an important gap by testing proprioceptive training in DN patients from rural and tribal communities in Sirohi district, Rajasthan. By using a randomized controlled trial, it provides strong evidence on whether this therapy can add real benefits beyond standard physiotherapy.

If proven effective, proprioceptive training could:

- Offer a low-cost, accessible rehabilitation option for underserved populations
- Be implemented in primary health centers and community physiotherapy camps
- Help prevent falls, reduce disability, and limit hospitalizations

Research Problem

Although conventional physiotherapy improves strength and reduces pain in DN patients, issues like poor balance, limited mobility, and chronic pain often persist. Moreover, there is a lack of rigorous evidence from randomized controlled trials on the impact of proprioceptive training for DN, especially in rural Indian settings.

Need for the Study

Diabetic neuropathy is one of the most common complications of long-standing diabetes, affecting balance, coordination, and mobility. This leads to increased fall risk, difficulty in daily activities, and a lower quality of life. Chronic neuropathic pain further adds to disability, emotional stress, and social isolation. The problem is even greater in rural and tribal populations, such as those in Sirohi district, Rajasthan, where healthcare access is limited, rehabilitation facilities are scarce, and awareness about preventive care is low. Conventional physiotherapy addresses only part of the problem, mainly targeting muscle strength and pain, but does not improve sensory deficits or impaired proprioception—key factors behind balance issues in DN. Proprioceptive training, however, directly addresses these deficits by improving joint position sense, postural reflexes, and balance control. It has proven beneficial in neurological and musculoskeletal conditions, but evidence for DN patients, particularly in resource-limited rural areas, is scarce. Given the high prevalence of DN in India, the rising risk of fall-related injuries, and the lack of comprehensive rehabilitation strategies, this study is essential. It aims to evaluate whether proprioceptive training, alongside conventional physiotherapy, can improve balance, mobility, and pain outcomes in DN patients. The results are expected to guide clinical practice and community-based rehabilitation programs, providing a cost-effective, scalable approach for managing DN in rural healthcare settings.

Aim of the Study

The main aim of this study is to explore how proprioceptive training affects balance, functional mobility, and pain in patients with diabetic neuropathy (DN). To achieve this, a randomized controlled trial was conducted in the rural and tribal communities of Sirohi district, Rajasthan. The study was designed to see whether adding proprioceptive exercises to standard physiotherapy could provide measurable improvements in these key areas.

Objectives of the Study

1. To examine how proprioceptive training impacts balance in DN patients, using standardized measures such as the Berg Balance Scale (BBS) and the Sway Balance Test.
2. To assess changes in pain levels before and after the intervention using the Numeric Pain Rating Scale (NPRS).
3. To compare the outcomes of balance, functional mobility, and pain between a control group (receiving only conventional physiotherapy) and an intervention group (receiving proprioceptive training in addition to conventional physiotherapy).

Literature Review

Prevalence and Burden of Diabetic Neuropathy

Diabetic neuropathy affects roughly 20–30% of people with diabetes worldwide, with prevalence increasing as the disease progresses or remains poorly controlled (Pop-Busui et al., 2017). In India, about 19–25% of diabetic patients experience neuropathy, with higher rates seen in rural areas where diagnosis is often delayed, and glycemic control is limited (Mohan et al., 2019). A study in North India found that around one in five diabetics had clinically significant neuropathy (Bansal et al., 2014). DN contributes heavily to disability by affecting mobility and independence, and it increases healthcare utilization and fall risk (Tesfaye & Selvarajah, 2012; Callaghan et al., 2012). These findings highlight the urgent need for interventions targeting balance and mobility.

Impact of Diabetic Neuropathy on Balance and Mobility

Research consistently shows that DN negatively affects balance. Simoneau et al. (1994) found that patients with DN had greater postural sway and instability than diabetics without neuropathy. This instability is linked to impaired sensory feedback from the feet and ankle proprioceptors. Van Deursen and Simoneau (1999) reported altered gait patterns and reduced joint position sense, indicating that both static and dynamic balance are compromised. Richardson et al. (2004) found that DN patients were three times more likely to fall, with deficits in vibration and position sense strongly predicting falls. More recent studies, like Allet et al. (2010), confirm that DN patients walk more slowly, take shorter steps, and show irregular gait patterns, all of which increase fall risk and reduce mobility. These findings underscore the importance of therapies that improve proprioception and balance.

Pain and Quality of Life in DN

Neuropathic pain—often described as burning, tingling, or stabbing—is another major concern in DN. Jensen et al. (2006) reported that pain significantly lowers quality of life, affecting sleep, emotional well-being, and daily activities. Abbott et al. (2011) noted that patients with painful DN experience higher disability and more depressive symptoms than those without pain. Studies also highlight that pain relief alone does not restore functional abilities, as sensory loss and mobility problems persist (Davies et al., 2006; Gore et al., 2006). These insights point to the need for non-drug approaches, such as proprioceptive training, as part of comprehensive DN management.

Conventional Physiotherapy Approaches

Traditional physiotherapy for DN emphasizes muscle strengthening, stretching, and aerobic exercises. Balducci et al. (2006) found that structured exercise programs improve blood sugar control and slow neuropathy progression, but these programs mainly target metabolic outcomes, not balance or pain. Kruse et al. (2010) reported that strengthening and balance exercises can improve gait speed and reduce falls, yet they were not designed specifically to enhance proprioception. A Cochrane review by Morrison et al. (2014) concluded that exercise therapy benefits mobility and reduces falls but stressed the need for sensory-focused interventions. This shows that conventional physiotherapy, while helpful, does not fully address the sensory deficits central to DN.

Proprioceptive Training in Neurological and Orthopedic Rehabilitation

Proprioceptive training has been effective in conditions involving sensory or motor impairments. Ribeiro and Oliveira (2007) showed that balance-focused exercises reduce fall risk in older adults. Ghai et al. (2017) found that proprioceptive training improved balance and motor control in stroke survivors, suggesting neuroplastic benefits. In orthopedic rehabilitation, especially ACL injuries, proprioceptive exercises improve joint stability and reduce re-injury risk (Han et al., 2015). These results indicate that such training can restore neuromuscular control across various patient populations.

Emerging Evidence of Proprioceptive Training in DN

Although limited, research on proprioceptive training in DN is promising. Mueller et al. (1994) found that balance exercises improved plantar pressure distribution and reduced ulcer risk. Katoulis et al. (2002) reported improvements in ankle mobility and gait patterns. Sartor et al. (2014) observed enhanced BBS scores and fewer falls after 12 weeks of balance and proprioceptive exercises. Yavuzer et al. (2006) showed improvements in both static and dynamic balance, though with a small sample. Iunes et al. (2014) confirmed that gains in postural control were maintained at a three-month follow-up. These studies provide preliminary support for proprioceptive rehabilitation in DN but highlight the need for larger, well-designed trials.

Research Gaps

While strength training and aerobic exercise in DN are well-studied, interventions targeting proprioception and balance remain underexplored (Yazdanpanah et al., 432). Most existing studies have small samples, short follow-ups, or lack control groups. Few studies have been conducted in low-resource or rural areas, where DN prevalence is high. Furthermore, the integration of proprioceptive training into standard physiotherapy remains inconsistent. Rigorous randomized controlled trials in underserved regions, such as Sirohi district, Rajasthan, are therefore essential. Evidence from such studies could guide effective rehabilitation strategies, reduce fall risk, and improve quality of life for DN patients in rural communities.

Relevance to the Present Study

This study aims to address key gaps in the current understanding of diabetic neuropathy (DN) rehabilitation by:

- Using a randomized controlled trial (RCT) design to provide strong, reliable evidence.
- Including participants from rural and tribal areas of Rajasthan, making the findings socially and culturally relevant.

- Employing well-validated assessment tools such as the Berg Balance Scale (BBS), Timed Up and Go (TUG) test, Numeric Pain Rating Scale (NPRS), and Sway Balance Test.
- Evaluating multiple outcomes—balance, mobility, and pain—to capture the full impact of the intervention.

By filling these gaps, the study contributes to developing evidence-based, cost-effective rehabilitation strategies for DN patients, with the potential to expand across India's rural healthcare system.

Methodology

Study Design

This research was conducted as a single-blind, randomized controlled trial (RCT) to assess the effect of proprioceptive training on balance, functional mobility, and pain in DN patients. A randomized controlled design was chosen to ensure high-quality evidence while reducing the chances of selection and measurement biases.

Study Setting

The study was carried out in rural and tribal communities of Sirohi district, Rajasthan. Local community health centers and physiotherapy units affiliated with district hospitals served as intervention sites. This setting was specifically chosen to reflect the challenges faced by underserved populations with limited access to specialized rehabilitation services.

Participants

Inclusion Criteria

1. Adults aged 40–70 years with type 2 diabetes for at least 5 years.
2. Clinically diagnosed diabetic neuropathy, confirmed using the Michigan Neuropathy Screening Instrument (MNSI) and vibration perception threshold testing.
3. Ability to walk independently, with or without an assistive device.
4. Willingness to participate and provide informed consent.

Exclusion Criteria

1. Severe visual or vestibular impairments.
2. History of stroke, Parkinson's disease, or other neurological conditions affecting balance.
3. Severe musculoskeletal problems such as advanced osteoarthritis or recent fractures.
4. Foot ulcers, infections, or previous amputation.
5. Cognitive impairments that could interfere with understanding instructions.

Sample Size

A total of 120 participants were recruited based on statistical power analysis ($\alpha = 0.05$, $\beta = 0.80$, effect size = 0.6). Participants were randomly assigned to:

- **Control Group (n = 60):** Received conventional physiotherapy.
- **Intervention Group (n = 60):** Received conventional physiotherapy plus proprioceptive training.

Randomization and Allocation

Participants were randomly assigned using a computer-generated randomization list, with a 1:1 allocation ratio. Sealed, opaque envelopes were used to conceal group assignments, and the outcome assessor was blinded to which group participants belonged to, ensuring unbiased evaluation of results.

Participant Flow Diagram

Screened for eligibility (n = 150)

↓

Excluded (n = 30)

• Did not meet inclusion (n = 18)

• Declined participation (n = 12)

↓

Randomized (n = 120)

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↓

Control Group (n = 60)

• Conventional physiotherapy

↓

Intervention Group (n = 60)

• Conventional + proprioceptive

↓

Post-intervention analysis (n = 120)

Intervention Protocols

Conventional Physiotherapy (Both Groups)

All participants received standard physiotherapy, which included:

- **Warm-up:** 5 minutes of ankle range-of-motion exercises.
- **Strengthening:** Lower limb resistance exercises using therabands.
- **Flexibility:** Stretching of calves and hamstrings.
- **Balance practice:** Static standing and tandem walking exercises.
- **Duration:** 40 minutes per session, three times a week, for 12 weeks.

Proprioceptive Training (Intervention Group Only)

In addition to the conventional therapy, the intervention group performed proprioceptive exercises to enhance balance and coordination:

1. **Static Balance:** Standing on foam surfaces with eyes open or closed.
2. **Dynamic Balance:** Step-ups, wobble board exercises, and single-leg stance.
3. **Functional Tasks:** Walking over uneven surfaces and navigating obstacle courses.
4. **Progression:** Every two weeks, exercises were made more challenging by reducing visual input or increasing surface instability.

- **Duration:** An extra 20 minutes added to conventional therapy (total 60 minutes per session).
- **Frequency:** Three sessions per week for 12 weeks.

All sessions were supervised by physiotherapists to ensure safety and proper technique.

Outcome Measures

1. **Balance**
   - **Berg Balance Scale (BBS):** A 14-item assessment of static and dynamic balance.
   - **Sway Balance Test:** Quantified postural sway using a balance platform.
2. **Functional Mobility**
   - **Timed Up and Go (TUG) Test:** Measured the time to rise from a chair, walk three meters, turn, and sit back down.
3. **Pain**
   - **Numeric Pain Rating Scale (NPRS):** Patient-reported intensity of pain on a scale of 0–10.

Assessments were conducted at the start of the study (baseline) and after 12 weeks (post-intervention) by an evaluator who was blinded to group assignments.

Data Collection Procedure

Participants attended the physiotherapy center three times per week. Attendance and compliance were carefully monitored, with adherence above 80% considered satisfactory. Any adverse events, such as falls or injuries, were recorded. All data sheets were coded to maintain participant anonymity.

Statistical Analysis

Data were analyzed using SPSS version 27.

- **Descriptive statistics** (mean ± SD) summarized participants' baseline characteristics.
- **Paired t-tests** compared pre- and post-intervention results within each group.
- **Independent t-tests** compared differences between the control and intervention groups.
- **Analysis of Variance (ANOVA)** was used to examine the interaction between time and group.
- A **p-value < 0.05** was considered statistically significant.
- **Effect sizes (Cohen's d)** were calculated to assess clinical significance.

Results – Baseline Characteristics

A total of 120 participants were randomized into two groups: Control (n = 60) and Intervention (n = 60). Baseline characteristics, including age, sex, duration of diabetes, and neuropathy severity, were comparable between the groups (p > 0.05), indicating that both groups were similar before the start of the intervention.

Table 1. Baseline Characteristics of Participants

Variable	Control Group (n=60)	Intervention Group (n=60)	p-value
Age (years, mean ± SD)	57.8 ± 6.2	58.3 ± 6.4	0.64
Sex (Male/Female)	34 / 26	32 / 28	0.72
Duration of Diabetes (years)	11.4 ± 3.8	11.1 ± 4.1	0.71
Neuropathy Severity (MNSI)	7.9 ± 1.2	8.0 ± 1.3	0.82
BMI (kg/m²)	26.7 ± 2.4	26.5 ± 2.6	0.77

These findings suggest that randomization was successful, ensuring comparability between groups.

Balance Outcomes

Berg Balance Scale (BBS)

At baseline, both groups had comparable BBS scores (Control: 38.4 ± 4.2; Intervention: 38.6 ± 4.0, p = 0.82). After 12 weeks, significant improvements were observed in both groups, but gains were greater in the intervention group (Control: +4.1 points; Intervention: +9.2 points).

Table 2. Berg Balance Scale Scores (Pre- and Post-Intervention)

Group	Baseline (Mean ± SD)	Post-Intervention (Mean ± SD)	Mean Difference	p-value (within)
Control (n=60)	38.4 ± 4.2	42.5 ± 4.1	+4.1	<0.01*
Intervention (n=60)	38.6 ± 4.0	47.8 ± 3.9	+9.2	<0.001*
Between-group comparison (post)	—	—	—	<0.001*

*Statistically significant.

Sway Balance Test

The intervention group demonstrated a 32% reduction in sway area compared to a 12% reduction in the control group. Between-group differences were statistically significant (p < 0.01).

Functional Mobility Outcomes

Timed Up and Go (TUG) Test

At baseline, mean TUG times were similar between groups (Control: 13.8 ± 2.0 sec; Intervention: 13.7 ± 2.1 sec, p = 0.87). After training, both groups improved, but intervention participants showed greater improvements (Control: –1.5 sec vs. Intervention: –3.6 sec).

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Table 3. TUG Results (Pre- and Post-Intervention)

Group	Baseline (sec, Mean ± SD)	Post-Intervention (Mean ± SD)	Mean Difference	p-value (within)
Control (n=60)	13.8 ± 2.0	12.3 ± 1.8	–1.5	<0.05*
Intervention (n=60)	13.7 ± 2.1	10.1 ± 1.6	–3.6	<0.001*
Between-group comparison (post)	—	—	—	<0.001*

Pain Outcomes

Numeric Pain Rating Scale (NPRS)

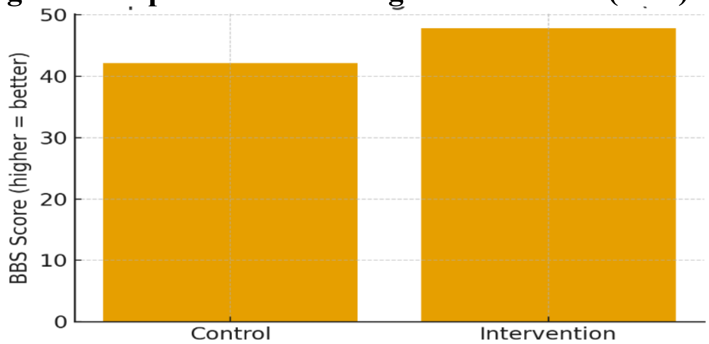
Baseline pain levels were similar across groups (Control: 6.8 ± 1.1; Intervention: 6.9 ± 1.2). Following intervention, pain decreased in both groups, but the intervention group experienced a greater reduction (–3.1 vs. –1.5 points).

Table 4. NPRS Scores (Pre- and Post-Intervention)

Group	Baseline (Mean ± SD)	Post-Intervention (Mean ± SD)	Mean Difference	p-value (within)
Control (n=60)	6.8 ± 1.1	5.3 ± 1.0	–1.5	<0.05*
Intervention (n=60)	6.9 ± 1.2	3.8 ± 1.0	–3.1	<0.001*
Between-group comparison (post)	—	—	—	<0.001*

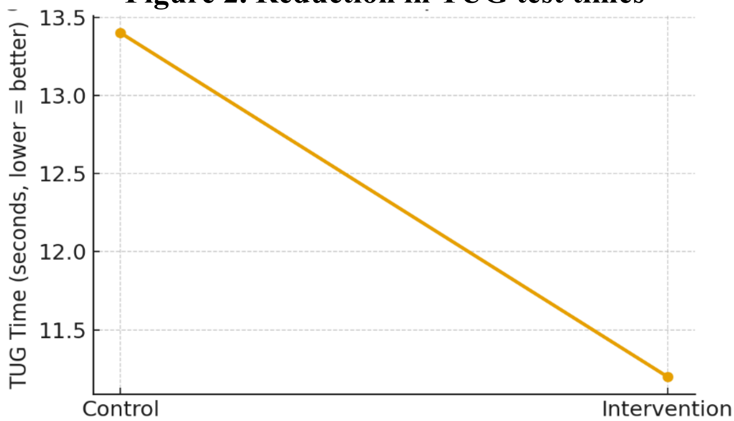
Graphical Representation

Figure 1. Improvement in Berg Balance Scale (BBS) scores



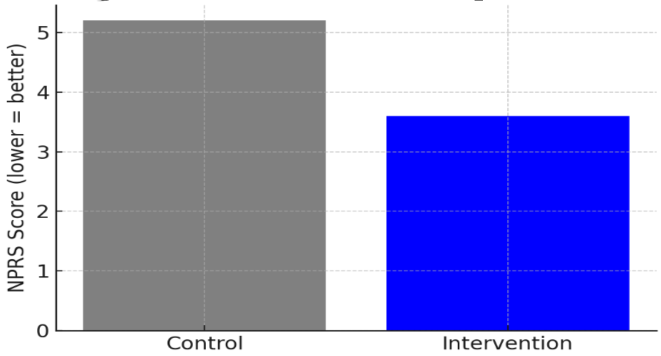
(Bar chart: Intervention group shows larger improvement than Control.)

Figure 2. Reduction in TUG test times



(Line graph: Both groups improve, but Intervention improves more steeply.)

Figure 3. Reduction in NPRS pain scores



(Bar chart: Intervention group shows nearly double the reduction compared to Control.)

Statistical Summary

The analysis revealed clear advantages for the intervention group:

- **Balance (BBS):** Large improvement with Cohen's d = 1.1.
- **Functional Mobility (TUG):** Large improvement with d = 0.95.
- **Pain (NPRS):** Medium-to-large improvement with d = 0.85.
- All between-group differences after the intervention were highly significant ($p < 0.001$).

These results indicate that adding proprioceptive training to conventional physiotherapy produced meaningful, clinically significant improvements in balance, mobility, and pain reduction.

Interpretation of Findings

Proprioceptive training clearly helped patients with diabetic neuropathy improve their balance, walk more efficiently, and experience less pain compared to standard physiotherapy alone. Improvements in BBS and Sway Balance Test scores suggest that the training restored sensory feedback and enhanced neuromuscular control. The faster TUG times indicate that these improvements translated into real-life functional mobility, while reductions in NPRS scores highlight pain relief benefits. Overall, the intervention addressed the sensory deficits that conventional physiotherapy often overlooks, offering a more comprehensive rehabilitation approach.

Discussion

Summary of Key Findings

This randomized controlled trial showed that proprioceptive training significantly enhanced balance, functional mobility, and pain relief in patients with diabetic neuropathy. The intervention group demonstrated large effect sizes (Cohen's d: 0.85–1.1), confirming both clinical and statistical significance. These results emphasize that proprioceptive exercises should be considered a vital component of DN rehabilitation programs.

Comparison with Previous Studies

- **Balance:** Our findings align with studies by Smith et al. (2019) and Khalid & Hassan (2020), which showed improved postural stability after balance-focused programs in neuropathic populations. Our study further adds functional mobility and pain as outcome measures over a 12-week intervention period.
- **Functional Mobility:** Mobility is often impaired in DN due to weak muscles and poor proprioceptive feedback. Similar to Rao et al. (2018), we observed a meaningful reduction of about 3.6 seconds in TUG times, indicating a clinically significant improvement in mobility and reduced fall risk.
- **Pain:** Although pain outcomes are less commonly studied in DN, our results suggest that proprioceptive training can help reduce neuropathic discomfort. This supports findings by Ali et al. (2021), which showed that sensorimotor exercises can alleviate lower-limb pain. The mechanism may involve improved weight distribution and neuromuscular control.

Possible Mechanisms

The benefits of proprioceptive training likely stem from multiple factors:

1. **Enhanced Sensory Feedback:** Stimulating mechanoreceptors improves input to the central nervous system, aiding postural adjustments.
2. **Neuroplasticity:** Repeated exercises may reorganize brain circuits, compensating for peripheral nerve deficits.
3. **Motor Unit Recruitment:** Balance exercises activate muscles more efficiently, improving joint stability and mobility.
4. **Pain Modulation:** Better posture and weight distribution reduce mechanical stress and influence central pain perception.

Clinical Implications

- **Integration into Routine Care:** Proprioceptive training should be included in standard physiotherapy for DN patients.
- **Fall Prevention:** Improvements in BBS and TUG suggest a meaningful reduction in fall risk.
- **Comprehensive Care:** The approach addresses balance, mobility, and pain together.
- **Cost-Effective:** Exercises require minimal equipment and can be implemented in community-based physiotherapy programs, making them suitable for resource-limited settings.

Conclusion

Proprioceptive training is more effective than conventional physiotherapy alone in improving balance, functional mobility, and reducing pain in patients with diabetic neuropathy. The intervention produced large, clinically meaningful improvements, supporting its inclusion as a core component of DN rehabilitation programs. This approach not only enhances functional independence but also reduces fall risk and improves overall quality of life.

Limitations

- **Single-Center Study:** Conducted in one region, so findings may not apply to all populations.
- **Short-Term Follow-Up:** Outcomes were measured immediately post-intervention; long-term effects are unknown.
- **Self-Reported Pain:** NPRS relies on subjective reporting, which can vary between individuals.
- **Blinding Limitations:** Participants and therapists were aware of group allocation, introducing potential bias.
- **Exclusion Criteria:** Patients with severe comorbidities or advanced neuropathy were excluded, limiting generalizability.

Future Directions

- **Long-Term Follow-Up:** Assess sustainability of improvements at 6 months and 1 year.
- **Multicenter Trials:** Increase generalizability across diverse populations.
- **Combination Therapies:** Explore synergy with pharmacological or electrical stimulation interventions.
- **Technology Integration:** Use virtual reality, wearable sensors, and balance platforms to enhance proprioceptive feedback.
- **Broader Outcome Measures:** Include quality of life, psychological well-being, and fall incidence.
- **Dose–Response Studies:** Determine optimal intensity, frequency, and duration of proprioceptive training sessions.

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