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Effectiveness of HIIT (High-Intensity Interval Training) in Improving Gait and Foot Function in Patients with Diabetic Neuropathy: An Observational Approach

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Abstract: ***The primary objective of the present study is to evaluate the effectiveness of High-intensity interval training (HIIT) to improve gait and foot function in diabetic peripheral neuropathy patients. Pre and post evaluation was performed on 30 participants using Foot Function Index (FFI) scores and Estimated Shuttle Walk Test (ESWT) score after a 12-week supervised exercise program. The Study was statistically significant improvements in the mean FFI score declined from 67.07 ± 2.32 at baseline to 34.90 ± 1.83 following the 12-week intervention a mean reduction of 32.17 points. Since lower FFI scores denote superior foot function, this reduction reflects a clinically meaningful improvement in functional foot status among participants with diabetic neuropathy and mean walking distance increased from 204.53 ± 8.39 m at pre-test to 319.17 ± 11.75 m at post-test, a mean gain of 114.63 m. This represents a 56.1% improvement in walking endurance over the 12-week HIIT program.***

Keywords: Diabetic Neuropathy, HIIT (High-Intensity Interval Training), Foot Function Index (FFI) scores, Estimated Shuttle Walk Test (ESWT).

1. Introduction

Diabetic neuropathy has profound impacts on quality of life, especially for middle-aged and older adults. It causes sensory loss, pain, muscle weakness, and foot deformities, leading to disability. For example, one cohort found that neuropathy is a major cause of reduced quality of life in diabetes, due to gait disturbances, foot ulceration, fall-related injuries, and disability. Given that DM prevalence peaks in midlife to older age, the 40–75 age group is particularly at risk (1). Elderly patients accumulate more years of hyperglycemia and are more likely to develop complications. Thus, an understanding of DPN in this age group is critical. Studies routinely report that older diabetic adults have significantly worse nerve conduction and sensory function than controls or younger diabetics, highlighting the age- and duration-dependence of neuropathy (2).

Diabetic neuropathy arises from chronic metabolic and vascular insults to peripheral nerves. Sustained hyperglycemia initiates a complex cascade of increased flux through the polyol pathway, accumulation of advanced glycation endproducts, oxidative stress, mitochondrial dysfunction, and microvascular damage. (3) These processes injure nerve fibers and vasa nervorum. (4) The Toronto consensus defines DPN as "symmetrical, length-dependent sensorimotor polyneuropathy attributable to metabolic and microvascular alterations from chronic hyperglycemic exposure". In early stages, small unmyelinated sensory fibers are most affected, producing numbness, tingling, or pain in a stocking-glove distribution. (5) As neuropathy progresses, larger myelinated sensory and autonomic fibers become involved, and eventually motor fibers are impaired. Overall, half or more of diabetic patients develop significant nerve damage if followed long enough. (6)

The neural damage in DPN profoundly alters foot structure and function. Sensory loss in the feet means minor injuries or abnormal pressures go unnoticed, predisposing to ulcers. Motor denervation leads to muscle weakness and atrophy, particularly in the intrinsic foot muscles and distal leg muscles. Chronic hyperglycemia also stiffens connective tissue: advanced glycation can reduce tendon elasticity, limiting joint range of motion (e.g., the Achilles tendon becomes stiffer). (7) As a result, common structural changes include claw-toe deformities, high or collapsed arches, and decreased ankle dorsiflexion. (8) For instance, diabetic patients often exhibit a collapsed medial longitudinal arch and increased midfoot rigidity, which, in turn, elevates plantar pressure under the forefoot. Equally important, the intrinsic foot muscles atrophy first in neuropathy, reducing the foot's dynamic support and shock absorption. In the lower limb, calf muscle atrophy and weakness lead to foot drop and an impaired push-off phase of gait. (9)

Physical activity is a cornerstone of diabetes management in general, and its role in neuropathy is increasingly recognized. Exercise improves glycemic control, insulin sensitivity, cardiovascular fitness, and body composition in patients with type 2 diabetes. (10) These systemic benefits alone help slow the progression of microvascular complications, including neuropathy. Importantly, past clinical guidelines that cautioned DPN patients against weight-bearing exercise have been revised: randomized trials show that walking and other weight-bearing activities do not increase therisk of foot ulcers in people with diabetes without severe foot deformities. (11) Indeed, regular aerobic exercise is now encouraged even in DPN, provided patients use proper footwear and monitor for injuries.

Recent research specifically highlights exercise-induced adaptations in individuals with neuropathy. Animal models of diabetic neuropathy demonstrate peripheral nerve plasticity in response to overload exercise, suggesting that stressed but healthy neural tissue can regenerate or reinnervate muscle. (12) Early clinical trials report measurable improvements in nerve function after exercise; for example, combined aerobic and resistance training over 10–16 weeks has reduced neuropathic symptoms and even increased nerve fiber density in patients with DPN. Moreover, general strength and foot–ankle exercises have been shown to increase lower-extremity strength and joint mobility in DPN subjects. A recent systematic review found that structured exercise programs (including balance, gait, and strength training) produced significant gains in lower-limb strength and ankle range of motion in adults with neuropathy. (13)

Nonetheless, the optimal exercise prescriptions for DPN – in terms of intensity, modality, and targets – remain under investigation. What is clear is that sedentary behavior accelerates neuropathic deterioration: the presence of neuropathy correlates with significantly lower daily activity levels. Therefore, any intervention that can safely increase activity, improve strength, or enhance balance could have a meaningful clinical impact. This motivates the current interest in high-intensity interval training for patients with neuropathic conditions. (14)

High-intensity interval training (HIIT) is an exercise strategy characterized by brief bursts of vigorous effort interspersed with recovery periods. In practice, a HIIT session might involve short "all-out" or near-maximal efforts, typically exceeding 85–90% of maximal heart rate or oxygen uptake, alternating with passive or low-intensity intervals. (15, 16) For instance, Tabata-style HIIT consists of 8 cycles of 20 seconds of near-maximal effort (≈170% of maximal power output) followed by 10 seconds of rest; classical protocols also include multiple 4-minute bouts at 85–95% VO_2max with a few minutes of active recovery. Sprint interval training (SIT) is an extreme form of HIIT that involves "all-out" 20–30-second sprints (100–120% of maximal running speed) with brief rest. (17)

Physiologically, HIIT imposes a very high metabolic load in a short time. It simultaneously stresses the aerobic and anaerobic energy systems. Compared to moderate continuous exercise, HIIT triggers greater fluctuations in heart rate, blood pressure, and muscle recruitment. The intense bouts recruit fast-twitch (Type II) muscle fibers and greatly increase lactate production, while the repeated recovery segments force rapid cardiovascular adjustments. Over successive weeks, these stimuli induce robust adaptations. HIIT reliably increases maximal oxygen uptake (VO_2max) by improving stroke volume, capillary density, and mitochondrial biogenesis. It also enhances anaerobic enzymes and phosphagen stores. Notably, HIIT is "time-efficient": numerous studies show that low-volume HIIT (≤15 minutes of total high-intensity work per session) can produce similar or even greater gains in cardiorespiratory fitness and metabolic health than traditional 30–60-minute moderate-intensity workouts. (18, 19, 20)

From a metabolic perspective, HIIT has powerful effects on glycemic control and insulin sensitivity. In sedentary adults, just a few HIIT sessions can markedly improve glucose metabolism. For example, Babraj and colleagues showed that only 6 sessions of "all-out" sprint intervals led to a ~23% increase in whole-body insulin sensitivity. Similarly, a low-volume HIIT regimen (10×1-minute intervals at ~90% HR_max, thrice weekly for two weeks) substantially reduced post-meal blood glucose and elevated muscle glucose transporter (GLUT-4) expression in people with T2D. Impressively, 12 weeks of HIIT (10 minutes per session) achieved comparable improvements in peak oxygen uptake and insulin sensitivity as 50 minutes of continuous aerobic exercise, despite requiring only one-fifth the time. These findings are supported by meta-analyses: overall, HIIT protocols consistently improve glucose tolerance, reduce HbA1c, and lower adiposity in diabetic and non-diabetic adults. (21)

HIIT's relevance to diabetes management is now well-recognized. It is often promoted as a "time-saving" alternative for people who find long workouts impractical. In fitness surveys, interval training has ranked among the top global exercise trends, reflecting its popularity and documented efficacy. Importantly, early evidence suggests that HIIT is safe for older or metabolically compromised patients: one randomized trial found that supervised interval walking did not increase hypoglycemia or injury risk in T2D patients, while improving fitness. Taken together, HIIT's physiological principles make it an attractive candidate for diabetic patients: it robustly engages the cardiovascular and muscular systems, augments metabolic regulation, and does so in shorter exercise sessions than conventional regimens. (22)

High-Intensity Interval Training (HIIT) has gained attention as a time-efficient exercise method that alternates short periods of high-intensity activity with rest or low-intensity recovery. HIIT has been shown to improve insulin sensitivity, cardiovascular fitness, and muscle metabolism in people with diabetes morequicklyth another forms of exercise. These physiological benefits suggest that HIIT may also positively influence nerve health, lower-limb strength, and walking ability. However, there is limited evidence regarding the effects of HIIT on gait and foot function in patients with diabetic neuropathy. Concerns regarding safety, fatigue, and tolerance in older individuals further highlight the need for systematic evaluation.

Currently, there is a lack of studies evaluating the effectiveness of HIIT in patients with diabetic neuropathy. Most available studies either combine multiple exercise approaches or focus mainly on metabolic outcomes rather than functional outcomes such as gait and foot performance. This gap in the literature makes it difficult for physiotherapists and clinicians to choose the most appropriate exercise intervention to improve mobility and prevent disability in this population.

Therefore, this study is needed to observe the effectiveness of HIIT in improving gait and foot function in patients with diabetic neuropathy. The findings may help develop evidence-based rehabilitation protocols, guide physiotherapists in clinical decision-making, and ultimately improve mobility, independence, and quality of life for individuals with diabetic neuropathy.

2. Aim & Objectives of the Study

To evaluate the effect of High-Intensity Interval Training (HIIT) on gait endurance and foot function in patients with diabetic peripheral neuropathy.

3. Materials and Methodology

The cross- sectional research design was used in study. Which is a type of an observational study in which data is collected at a single moment in time to evaluate the relationship between variables. The study used randomized sampling as its sample design. The participants were individuals those who had symptoms of diabetic peripheral neuropathy related gait and foot mechanics or functional limitation issues. These people were involved in the study to see how High-Intensity Interval Training (HIIT) affected their condition. Paper and pencil for data recording, chair for participants to sit on during assessment and treatment, a treatment couch, assessment form, consent form, towel for comfort or support were all used in the study.

Selection Criteria

Inclusion Criteria:
- Aged between 30 and 65 years.
- Patient with both types of DM
- Independent walking ability for at least 10 m

Exclusion Criteria:
- History of cerebrovascular accident
- Lower limb nerve injury
- Presence of an active planter ulcer
- History of surgical procedure at the knee, ankle, or hip, or indication of surgery throughout the intervention period
- Arthroplasty and/or orthosis of the lower limb
- Dementia or inability to give consistent information
- Major vascular complication
- Other neurological disorders

Sample Size and Study Duration
For this study the sample size was 30 people the individual were chosen at random from the research population to ensure representativeness and adequate data for analysis. The Study was carried out (3 times a week) for 12 weeks, individuals in a clinical environment had therapy as part of the study in pacific college of physiotherapy, pacific medical university (Udaipur), after obtaining ethical committee approval dated 6-10-2025, **PMU/IEC/MPT/2025**. All participants completed information and consent form at recruitment. This time frame allowed for evaluation of subjects response to the therapy as well as any changes in their pain, range of motion and functional ability. Each session was scheduled for 40-45 minutes. This period was set aside to ensure the patient had enough time to execute the procedure correctly.

4. Procedure

Permission for conduct Study is taken from the institutional ethical committee of PMCH **(PMU/IEC/MPT/2025)**, Pacific medical university bhilo ka bedla Udaipur (RAJ).

Individuals Diagnosed with diabetic peripheral neuropathy related gait and foot mechanics or functional limitation issues by the Physiotherapy department, Neurosciences department OPD; initially assessed for the inclusion or exclusion criteria. Prior to the treatment procedure, all participants were informed about the purpose, procedures, potential benefits, and possible risks of the study. Written informed consent was obtained from each participant prior to enrollment.

30 subjects were selected on the basis on inclusion criteria treated with High-Intensity Interval Training (HIIT).

HIIT Program

Exercise Training Protocol
Phase 1 (Weeks 1–3)
5 min warm-up → 20 min continuous aerobic exercise → 5 min recovery
Phase 2 (Weeks 4–8)
5 min warm-up → 1-min sprint + 5-min active recovery (×4 sets) → 5 min cool-down
Phase 3 (Weeks 8–12)
5 min warm-up → 6 × 1-min sprints with 4-min active recovery → cool-down

Exercise Components

Exercise Category	Description
Foot Exercises	Sitting foot exercises using a ball
Core Training	Core stabilization exercises
Lower Limb Strengthening	Partial squats and functional lower-limb exercises

5. Results

A total of 30 participants were included in the study, 16 females and 14 males. In the 45-50 years age group 13 participants, 51–55 years age group,8 participants, 56-60years age group, 6 participants,61-65 years age group, 3 participants were participated.

Table 1: Group A (HIIT) – Foot Function Index (FFI) Pre and Post Intervention

Variable	N	Mean	SD	Mean Difference	t-value	p-value
FFI Pre-test	30	67.07	2.32	32.17	252.08	<0.001 Significant
FFI Post-test	30	34.90	1.83			

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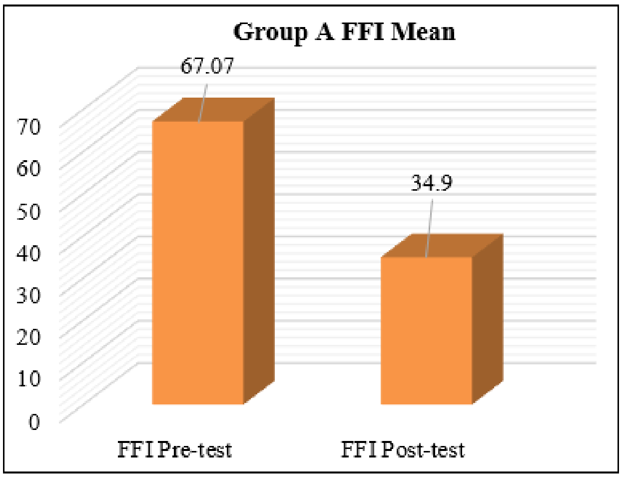


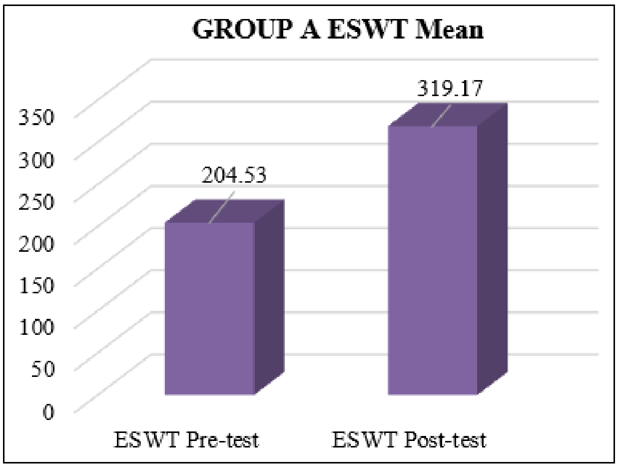
Graph 1: Group A (HIIT) – Foot Function Index (FFI)

Table 1 presents the within-group comparison of FFI scores for the HIIT group. The mean FFI score declined from 67.07 ± 2.32 at baseline to 34.90 ± 1.83 following the 12-week intervention a mean reduction of 32.17 points. Since lower FFI scores denote superior foot function, this reduction reflects a clinically meaningful improvement in functional foot status among participants with diabetic neuropathy.

The paired t-test yielded t(29) = 252.08, $p < 0.001$, confirming that the improvement was highly significant. These findings provide strong evidence that HIIT substantially enhanced foot function over the intervention period.

Table 2: Group A (HIIT) – Estimated Shuttle Walk Test (ESWT) Pre and Post Intervention

Variable	N	Mean	SD	Mean Difference	t-value	p-value
ESWT Pre-test	30	204.53	8.39	114.63	171.44	<0.001 Significant
ESWT Post-test	30	319.17	11.75			



Graph 2: Group A (HIIT) – Estimated Shuttle Walk Test (ESWT)

Table 2 presents within-group ESWT performance for Group A. Mean walking distance increased from 204.53 ± 8.39 m at pre-test to 319.17 ± 11.75 m at post-test, a mean gain of 114.63 m. This represents a 56.1% improvement in walking endurance over the 12-week HIIT program.

The paired t-test yielded t(29) = 171.44, $p < 0.001$, indicating a highly significant improvement in aerobic walking capacity. These results suggest that HIIT is an effective modality for enhancing functional mobility in individuals with diabetic peripheral neuropathy.

6. Discussion

The present study aimed to observe the effectiveness of High-Intensity Interval Training (HIIT) in improving gait performance and foot function in individuals with diabetic peripheral neuropathy. Diabetic neuropathy often causes reduced walking ability, foot pain, muscle weakness, and functional limitations, which can affect daily activities and quality of life. Therefore, this study evaluated changes in walking endurance using the Estimated Shuttle Walk Test (ESWT) and foot function using the Foot Function Index (FFI) after a 12-week supervised exercise program and finally the data suggest that the application of High-Intensity Interval Training (HIIT) is an effective intervention.

The findings of the present study are also supported by ***Holmes and Hastings (2021)***, who discussed the role of exercise training in managing impairments associated with diabetic peripheral neuropathy. The authors explained that diabetic neuropathy leads to muscle atrophy, muscle weakness, sensory deficits, and impaired balance, particularly in the lower extremities. These impairments reduce patients' ability to maintain stable posture and walk efficiently, ultimately affecting gait performance and overall functional mobility. Holmes and Hastings (2021) highlighted that exercise training can help address these impairments by improving neuromuscular strength, coordination, balance, and overall physical function. Aerobic exercise was reported to improve cardiovascular fitness and endurance, while resistance training was shown to enhance lower-limb muscle strength and stability. As a result, exercise interventions can play an important role in improving walking ability and reducing functional limitations in individuals with diabetic peripheral neuropathy.

Holmes and Hastings (2021) further explained that different types of exercise provide different functional benefits for individuals with diabetic peripheral neuropathy. According to their review, aerobic exercise primarily improves cardiovascular fitness and endurance, thereby enhancing walking ability and overall mobility. In contrast, resistance-based exercise focuses on improving muscle strength and joint stability, which are important for maintaining proper foot support, balance, and control during gait. These explanations align closely with the findings of the present study, which showed that both HIIT and anaerobic training significantly improved gait endurance and foot function. HIIT may have improved walking endurance through cardiovascular and metabolic adaptations, while anaerobic training may have enhanced foot function by strengthening the lower-limb and intrinsic foot muscles. Therefore, the improvements observed in both groups are consistent with the mechanisms described by Holmes and Hastings (2021), supporting the use of different exercise approaches to address multiple functional deficits in patients with diabetic peripheral neuropathy.

High-Intensity Interval Training (HIIT) involves short periods of high-intensity exercise alternated with recovery periods, which challenge both aerobic and anaerobic energy systems. The improvement in walking endurance observed in the HIIT group in the present study may be related to better cardiovascular efficiency, improved muscle oxygen utilization, and improved metabolic regulation developed during the training program. Similar findings were reported by ***Alarcón-Gómez et al. (2020)***, who investigated the effects of a short-term HIIT program in individuals with diabetes. Their study reported improvements in lower-limb muscle power, ankle mobility, and dynamic balance following the HIIT intervention. Although their research was conducted in patients with type 1 diabetes, the physiological adaptations observed in their study support the functional improvements seen in the HIIT group of the present study.

7. Conclusion

The present study was conducted to observe the effectiveness of High-Intensity Interval Training (HIIT) in improving gait performance and foot function in patients with diabetic peripheral neuropathy. Diabetic neuropathy is a common complication of diabetes that affects the peripheral nerves, especially in the lower limbs. Due to nerve damage, patients often experience reduced sensation in the feet, muscle weakness, poor balance, and changes in foot structure and biomechanics. These problems can make walking difficult, leading to a slow gait, instability, an increased risk of falls, and difficulty performing daily activities. Over time, these limitations can reduce mobility and independence. Therefore, identifying safe and effective exercise programs that can improve gait and foot function is very important for the rehabilitation of individuals with diabetic peripheral neuropathy.

The present study found that HIIT resulted in significant improvements in gait endurance and foot function following a 12-week exercise program. Participants demonstrated a reduction in Foot Function Index (FFI) scores, indicating decreased foot pain, disability, and activity limitations related to foot problems. A lower FFI score reflects better foot function and improved ability to perform daily activities without discomfort.

Similarly, walking endurance improved in both groups, as evidenced by increased Estimated Shuttle Walk Test (ESWT) distance after the intervention period. This means that participants were able to walk longer distances and tolerate physical activity better after completing the training program. The improvement in walking performance may be related to greater muscle strength, improved joint mobility, increased cardiovascular endurance, and enhanced neuromuscular coordination, allof which are developed through regular exercise training.

Overall, these findings indicate that structured and supervised exercise programs can play an important role in improving functional mobility in individuals with diabetic peripheral neuropathy. Regular exercise may help improve walking ability, physical endurance, and foot function, which are essential for maintaining independence and improving quality of life in patients with this condition.

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