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Effects Of Interval Walking Training And Nordic Walking On Balance, Lower Extremity Muscle Strength, And Anxiety In Individuals With Diabetic Peripheral Neuropathy: A Randomized Clinical Trial

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Abstract: Type 2 Diabetes Mellitus (T2DM) is a major global health concern associated with multiple complications, among which Diabetic Peripheral Neuropathy (DPN) is highly prevalent and disabling. DPN leads to impaired balance, reduced lower extremity muscle strength, and increased anxiety levels, thereby increasing fall risk and reducing quality of life. Exercise therapy is widely recommended as a non-pharmacological intervention to improve both physical and psychological outcomes in individuals with DPN. This randomized clinical trial aimed to compare the effects of Interval Walking Training (IWT) and Nordic Walking (NW) on balance, lower limb muscle strength, and anxiety levels in individuals with DPN. A total of 66 participants aged 45–60 years were randomly allocated into two groups: Interval Walking Training (n = 33) and Nordic Walking (n = 33). Both groups underwent supervised training sessions for a specified duration. Outcome measures included the Berg Balance Scale (BBS) for balance, Manual Muscle Testing (MMT) for lower extremity strength, and the Generalized Anxiety Disorder-7 (GAD-7) scale for anxiety. Statistical analysis was performed using paired t-tests for within-group comparisons and independent t-tests for between-group comparisons. The results demonstrated that both groups showed statistically significant improvements in balance, muscle strength, and anxiety levels following the intervention ($p < 0.05$). Within-group analysis revealed significant improvements in BBS, MMT, and GAD-7 scores in both groups. However, between-group comparison demonstrated no significant difference in balance ($p = 0.945$) and anxiety levels ($p = 0.531$), while Interval Walking Training showed significantly greater improvement in lower extremity muscle strength compared to Nordic Walking ($p < 0.05$). In conclusion, both Interval Walking Training and Nordic Walking are effective in improving balance and reducing anxiety in individuals with Diabetic Peripheral Neuropathy; however, Interval Walking Training is superior in enhancing lower extremity muscle strength, supporting its inclusion in rehabilitation protocols for individuals with DPN.

Keywords **-** Type 2 Diabetes Mellitus, Diabetic Peripheral Neuropathy, Interval Walking Training, Nordic Walking, Balance, Muscle Strength, Anxiety.

I. INTRODUCTION

Type 2 Diabetes Mellitus

Type 2 Diabetes Mellitus (T2DM) is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from defects in insulin secretion, insulin action, or both. According to the World Health Organization, diabetes mellitus leads to long-term damage, dysfunction, and failure of various organs including the eyes, kidneys, nerves, heart, and blood vessels. Diabetes mellitus is a condition characterized by elevated blood glucose levels due to the body's inability to produce adequate insulin or effectively utilize it. [1]

Over the past few decades, the global prevalence of diabetes has increased dramatically, making it one of the most significant public health concerns worldwide. India has experienced a rapid rise in the number of individuals diagnosed with T2DM. Epidemiological evidence indicates that India is among the countries with the highest burden of diabetes. Several studies have been conducted to estimate the prevalence of diabetes in India. Among these, the India Diabetes (INDIAB) study conducted by the Indian Council of Medical Research (ICMR) is one of the largest nationally representative studies designed to estimate the prevalence of diabetes and prediabetes across different regions of the country. Findings from this study highlight the growing burden of diabetes and the urgent need for effective prevention and management strategies. [1]

Type 2 diabetes is associated with numerous microvascular and macrovascular complications that significantly affect physical function and overall quality of life. Among these complications, diabetic peripheral neuropathy (DPN) is one of the most common and disabling conditions. DPN involves progressive damage to peripheral nerves, particularly those supplying the lower extremities, leading to symptoms such as numbness, tingling, burning pain, and muscle weakness. [2] the pathogenesis of DPN is complex and multifactorial, involving chronic hyperglycemia, oxidative stress, lipid metabolism disorders, and impaired insulin signaling, all of which contribute to nerve injury and dysfunction. [2]

The presence of DPN has significant clinical implications. Individuals with this condition often experience reduced sensation in the feet, impaired proprioception, and decreased muscle strength. These impairments may lead to gait disturbances, poor balance, and an increased risk of falls. In severe cases, DPN may contribute to foot ulcers and lower limb amputations, further reducing functional independence and quality of life. [2]

Balance Impairment in Diabetes

Balance capacity is defined as the ability to achieve, maintain, and restore stability during both static and dynamic activities. It involves the coordinated interaction of sensory input, central nervous system processing, and musculoskeletal responses. Clinical assessment of balance capacity commonly relies on standardized tests that are reliable, valid, time-efficient, and easy to administer in clinical settings. Frequently used tests include the Berg Balance Scale (BBS), Timed Up and Go Test (TUGT), and Single Leg Stance Test (SLST). [3]

Individuals with diabetes, particularly those with diabetic peripheral neuropathy, frequently demonstrate impaired balance due to multiple underlying factors. Damage to peripheral sensory nerves reduces proprioceptive input from the lower extremities, while muscle weakness and delayed neuromuscular responses further compromise postural control. As a result, individuals with DPN rely more heavily on visual input and proximal musculature to maintain stability. [3]

Impaired balance significantly increases the risk of falls among individuals with diabetes. Many patients develop a fear of falling, which limits their participation in daily activities and social interactions. This restriction can lead to reduced physical fitness, decreased independence, and a lower quality of life. Therefore, improving balance capacity is an important component of rehabilitation in individuals with diabetes. [3]

Lower Extremity Muscle Strength

Reduced muscle strength is another important functional impairment associated with diabetic peripheral neuropathy. Research has demonstrated that DPN contributes to a progressive decline in skeletal muscle function, particularly affecting distal muscles of the lower limbs. [4] This reduction in muscle strength can impair mobility, reduce walking ability, and limit participation in daily activities.

Physical inactivity further worsens muscle weakness in individuals with DPN. Reduced activity leads to loss of muscle mass and strength, while decreased muscle strength increases the effort required to perform physical activities. This creates a negative cycle in which inactivity leads to progressive muscle weakness

and further decline in mobility. [4] Improving lower extremity muscle strength is therefore essential for maintaining functional independence and preventing disability in individuals with diabetic neuropathy.

Anxiety in Diabetes

In addition to physical impairments, individuals with diabetes frequently experience psychological challenges. Anxiety and depression are common mental health conditions observed among patients with diabetes and can significantly affect disease management and quality of life. [5] Studies have reported a high prevalence of anxiety symptoms among individuals with diabetes, often associated with poor glycemic control and reduced adherence to treatment. [5]

The relationship between diabetes and anxiety is complex and multifactorial. Research suggests that increased sympathetic nervous system activity and elevated levels of inflammatory cytokines may contribute to both neuropathic pain and psychological distress. [6] Individuals with diabetic peripheral neuropathy may experience additional psychological burden due to chronic pain, fear of falling, and reduced mobility.

Exercise has been recognized as an effective non-pharmacological intervention for improving both physical and psychological health. Regular physical activity has been shown to reduce anxiety symptoms, improve mood, and enhance overall quality of life in individuals with chronic diseases such as diabetes. [6]

Role of Exercise in Diabetes Management

Lifestyle modification is a key component in the management of type 2 diabetes mellitus. Regular physical activity plays an essential role in improving glycemic control, enhancing insulin sensitivity, and reducing the risk of diabetes-related complications. Exercise also improves cardiovascular health, muscular strength, and functional capacity. [7]

For individuals with diabetic peripheral neuropathy, structured exercise programs can help improve balance, increase muscle strength, and reduce fall risk. Physical activity also has beneficial psychological effects, including reduction in anxiety and improvement in emotional well-being. [7]

Interval Walking Training (IWT)

Interval Walking Training (IWT) is a form of exercise that involves alternating periods of fast walking with periods of slower recovery walking. This free-living exercise intervention has been shown to improve physical fitness and reduce metabolic risk factors in individuals with lifestyle-related diseases, including type 2 diabetes. [8]

Studies suggest that interval walking training can improve aerobic capacity, enhance muscle strength, and promote better metabolic control in individuals with diabetes. The alternating intensity levels provide a greater stimulus for neuromuscular and cardiovascular adaptations compared to continuous moderate-intensity walking. [8]

Nordic Walking

Nordic walking is another form of exercise that incorporates the use of specially designed poles to engage the upper body during walking. This technique transforms conventional walking into a full-body activity by activating muscles of the arms, shoulders, and trunk in addition to the lower extremities. [9]

Nordic walking has been reported to increase energy expenditure, improve cardiovascular fitness, and enhance muscular endurance. The use of poles also provides additional stability and may improve posture and gait mechanics, making it particularly suitable for individuals with balance deficits or reduced mobility. [9]

Rationale for the Study

Although both Interval Walking Training and Nordic Walking have demonstrated beneficial effects on physical fitness and metabolic health, limited research has directly compared their effectiveness in individuals with diabetic peripheral neuropathy. Considering the high prevalence of balance impairment, muscle weakness, and anxiety in this population, identifying the most effective exercise interventions is essential.

Therefore, the present study aims to compare the effects of Interval Walking Training and Nordic Walking on balance, lower extremity muscle strength, and anxiety levels in individuals with diabetic peripheral neuropathy. Understanding the relative effectiveness of these interventions may assist clinicians in designing evidence-based rehabilitation programs for individuals with diabetes.

II. NEED OF STUDY

Type 2 Diabetes Mellitus (T2DM) is a rapidly increasing global health problem associated with multiple systemic complications, among which Diabetic Peripheral Neuropathy (DPN) is one of the most prevalent and disabling. DPN significantly affects the sensory and motor functions of the lower extremities, resulting in impaired balance, reduced muscle strength, gait disturbances, increased risk of falls, and diminished quality of life. In addition to physical impairments, individuals with DPN frequently experience psychological issues such as anxiety, further contributing to functional limitations and poor disease management.

Exercise therapy is widely recognized as a safe, cost-effective, and non-pharmacological intervention in the management of T2DM and its complications. Regular physical activity improves glycemic control, reduces metabolic risk factors, and modulates inflammatory processes that contribute to neuropathic changes. By enhancing peripheral circulation, neuromuscular activation, and metabolic regulation, exercise may help reduce neuropathic symptoms and improve overall functional performance.

Interval Walking Training (IWT) and Nordic Walking (NW) are two structured aerobic exercise approaches that have shown beneficial effects on balance, lower limb muscle strength, cardiovascular fitness, and psychological well-being. Interval walking training alternates periods of high and low intensity walking, thereby improving aerobic capacity and muscular endurance. Nordic walking, which incorporates the use of poles, engages both upper and lower extremities, enhances postural control, and may provide additional stability and confidence during ambulation.

Although previous studies have demonstrated the individual benefits of Interval Walking Training and Nordic Walking in diabetic populations, there is limited comparative evidence evaluating their specific effects on balance, lower extremity muscle strength, and anxiety levels in individuals with Diabetic Peripheral Neuropathy. Identifying the more effective intervention will assist clinicians in developing evidence-based rehabilitation protocols tailored to this population.

Therefore, this study aims to compare the effects of Interval Walking Training and Nordic Walking on balance, lower extremity muscle strength, and anxiety in individuals with Diabetic Peripheral Neuropathy, in order to determine the most beneficial therapeutic approach for improving functional and psychological outcomes in this population.

III. AIM & OBJECTIVES

3.1. AIM

To compare the effects of Interval Walking Training (IWT) and Nordic Walking (NW) on balance, lower limb muscle strength, and anxiety levels in individuals with Diabetic peripheral neuropathy.

3.2. OBJECTIVES

To evaluate the effect of Interval Walking Training (IWT) on balance, muscular strength, and anxiety in individuals with Type 2 Diabetes Mellitus (T2DM).

To evaluate the effect of Nordic Walking (NW) on balance, muscular strength, and anxiety in individuals with DPN

IV. REVIEW OF LITERATURE

1. Study was done by Collins et al to identify the prevalence and major determinants of anxiety and depression symptoms in patients with diabetes. The study included 2049 people with type 1 and type 2. Anxiety and depression symptoms were assessed with the Hospital Anxiety and Depression Scale (HADS) and results showed that the prevalence of anxiety and depression symptoms in in patients with considerably higher than in general population samples and total response rate was 71%.
2. Marcus et al conducted a trial to compare the outcomes between a diabetes exercise training program using combined aerobic and high force eccentric resistance exercise and a program of aerobic exercise only. The study included 15 participants with type 2 diabetes mellitus participated in 16 week supervised exercise training program, 7 in combined aerobic and eccentric resistance exercise and 8 in a program

of aerobic exercise only. Thigh lean tissue, intramuscular fat, glycosylated hemoglobin, body mass index and 6 minute walk test was assessed as outcome measures and the study concluded that there was significant improvement in long term glycemic control, thigh composition and physical performance with additional effects seen in aerobic exercise plus eccentric resistance training group.

3. Bickett A, Tapp H. et al conducted A study Anxiety and diabetes: Innovative approaches to management in primary care in this study said that Mental health and primary care are intricately linked, making it necessary and appropriate to address them in chorus. Recent healthcare policies and federal research agencies call for the evaluation of treatments that address concomitant diabetes and mental health issues.112–118 While the extant literature has identified a high prevalence of anxiety among individuals with T2DM, there are no evidence-based protocols of treatment for individuals with these comorbid issues. Research on CCMs of mental health and diabetes has been encouraging, but more research is needed to identify effective, sustainable, and cost-effective models of implementation in primary care settings across disease states. Given the success of CCMs for treatment for depression and diabetes, and the effect of collaborative care on anxiety alone, primary care patients may benefit from a standardized collaborative care protocol for addressing anxiety and diabetes, focusing on how best to implement and sustain these models in practice.
4. Holmes CJ, Hastings MK. Et al The Application of Exercise Training for Diabetic Peripheral Neuropathy In this study said that Upon reviewing the literature, there is support that exercise-based interventions ≥4 weeks are beneficial for patients with DPN. This conclusion falls in line with other recently conducted literature reviews investigating the effects of exercise on enhancing gait function [156], decreasing neuropathic pain [157], and improving posture and balance among patients with peripheral neuropathy [158]. However, though the results of this review find various modalities of exercise to be beneficial, the effects are quite numerous and at times, inconsistent. Mobility and functional movement-based training, specifically weight-bearing exercise, is not only safe for people with DPN to participate in, but can provide significant increases in gait, balance, and strength. Of the six studies reviewed in the current paper, the overlapping result seems to be the enhancement of lower-body movement. The training programs implemented observed improvements in gait velocity, cadence, ankle joint mobility, and decreased step time. There were also favorable changes in plantar pressure and other kinematic and kinetic variables recorded during gait analyses. Improvements were thought to be tied to increases in foot and ankle musculature strength, as well as greater coordination of muscle activation, body stability, and joint flexibility. From a practical perspective, following weight-bearing exercise training, DPN patients demonstrated greater daily step counts and walking distances. From a clinical perspective, all these results lend themselves well towards improving daily physical function and quality of life for patients with DPN. For practical application, the research suggests that exercise sessions should start using “light” intensities and then slowly titrate up over time. Moreover, non-weight bearing mobility and functional training can take place first and as patients show improvement, they can be transitioned to weight-bearing exercise.
5. Melese H, Alamer A, Hailu Temesgen M, Kahsay G. et al Effectiveness of Exercise Therapy on Gait Function in Diabetic Peripheral Neuropathy Patients: A Systematic Review of Randomized Controlled Trials In this study said that Exercise therapy is found to improve gait function of patients with DPN. Specific exercise training programs, including range of motion, muscle strengthening, circuit training, stretching exercise, gait, and balance exercises can improve gait of diabetic patients with peripheral neuropathy. Clinical decision-making should take into account the type and intensity of exercise and patient’s tolerability related to each exercise.
6. Irshad Ahmad, Ejaz Hussain, Deepika Singla, Shalini Verma, Kamran Ali et al Balance Training in Diabetic Peripheral Neuropathy: A Narrative Review In this study said that Current data suggests that balance exercises are feasible and safe, and have the potential to improve balance and gait. Also reduction in the risk of fall and fall-related injuries in DPN patients can be achieved. These exercises can be use in clinical setup if the patient is affected with DPN. Therefore, balance exercises should be used as a supportive therapy along with medication and diet control in DPN patients.
7. Kanade RV, van Deursen RW, Harding K, Price P. et al Walking performance in people with diabetic neuropathy: benefits and threats. In this study said that Walking capacity and performance decrease with progression of foot complications. Although walking is recommended to improve fitness, it cannot be prescribed in isolation, considering the increased risk of plantar injury. For essential walking we therefore recommend the use of protective footwear. Walking exercise should be supplemented by partial or non-weight-bearing exercises to improve physical fitness in diabetic populations.

V. HYPOTHESIS

Null Hypothesis (H_0)

1. There will be no significant difference in balance improvement between the Interval Walking Training group and the Nordic Walking group in individuals with Diabetic Peripheral Neuropathy.
2. There will be no significant difference in lower limb muscle strength improvement between the Interval Walking Training group and the Nordic Walking group in individuals with Diabetic Peripheral Neuropathy.
3. There will be no significant difference in anxiety level reduction between the Interval Walking Training group and the Nordic Walking group in individuals with Diabetic Peripheral Neuropathy.

Alternative Hypothesis (H_1)

1. There will be a significant difference in balance improvement between the Interval Walking Training group and the Nordic Walking group in individuals with Diabetic Peripheral Neuropathy.
2. There will be a significant difference in lower limb muscle strength improvement between the Interval Walking Training group and the Nordic Walking group in individuals with Diabetic Peripheral Neuropathy.
3. There will be a significant difference in anxiety level reduction between the Interval Walking Training group and the Nordic Walking group in individuals with Diabetic Peripheral Neuropathy.

VI. METHODOLOGY & MATERIALS

Study design: Randomized clinical trail
Study type: An Experimental study
Study setting: Tertiary health care hospital
Target population: Subjects with Diabetic peripheral neuropathy in the age group of 45 to 60 years
Duration of data collection: 06 months
Sampling design: Non- probability
Sampling technique: Convenience Sampling
Sample size: 66
Sample size calculation formula:

$$n = \frac{z^2 * \hat{p}(1-\hat{p})}{\varepsilon^2}$$

e = Margin of error
z = z score
p = Standard deviation

Material

Pen/pencil
Note book
Berg Balance Scale
GAD 7 Scale

Criteria

Inclusive criteria:

- Subjects aged 45-60 years of both gender
- Subjects with known case of Type 2 diabetes mellitus of ≥ 5 years duration
- Participants willing to participate in the study.
- Able to walk independently without assistive devices.

Exclusive criteria:

- Congestive heart disease
- Diagnosed with any neoplastic condition
- History of recent fracture
- Recent lower extremity surgery
- Open wounds and Infective skin conditions
- Psychological disorders

Outcome Measures:

- Balance Assessment:
  Berg Balance Scale (BBS)

- Muscular Strength:
  Manual Muscle Testing(MMT)

- Anxiety Levels:
  Generalized Anxiety Disorder 7-item (GAD-7)

VII. PROCEDURE

The study titled "Effects of Interval Walking Training and Nordic Walking on Balance, Lower Extremity Muscle Strength, and Anxiety in Individuals with Diabetic Peripheral Neuropathy: A Randomized Clinical Trial" obtained official permission from the Department of Physiotherapy at Tilak Maharashtra Vidyapeeth. Participants were invited to voluntarily take part in the study and were provided with a detailed introduction, including the purpose, potential benefits, and risks, along with an informed consent form. They were given the opportunity to ask questions and seek clarification before signing the consent form. Confidentiality of personal information and anonymization of data were assured. Participants then provided basic demographic details and relevant medical history, followed by screening based on inclusion and exclusion criteria. Eligible participants underwent pre-treatment assessment of balance, lower extremity muscle strength, and anxiety using the Berg Balance Scale, Manual Muscle Testing, and Generalized Anxiety Disorder-7 (GAD-7), respectively. Subsequently, they received either Interval Walking Training or Nordic Walking for a duration of four weeks. After completion of the intervention, post-treatment assessments of balance, muscle strength, and anxiety were conducted using the same outcome measures.

VIII. INTERVENTION

Interval Walking Training (IWT):

- IWT involves alternating periods of slow and fast walking, typically in cycles of 3 minutes each, over a session lasting about 30 minutes (including warm up and cool down), three times per week, for several months. [10,12]
- Intensity is usually set at 40–70% of heart rate reserve (HRR), allowing for moderate to vigorous effort tailored to each participant's fitness and safety. [10]
- This approach has been shown to improve vascular health, nerve conduction velocity, balance, muscle strength, and reduce neuropathic symptoms in people with type 2 diabetes. [10,12]
- Sessions can be managed using heart rate monitors or mobile applications to ensure participants stay within the prescribed intensity range. [10]

Nordic Walking (NW):

- NW incorporates walking with specially designed poles, engaging both upper and lower body muscles. [11]
- It provides additional support and stability, which is beneficial for those with balance issues due to neuropathy. [11]

- NW increases energy expenditure compared to regular walking, helping with cardiovascular fitness and weight management. [11]
- Sessions are typically performed for 30 minutes (including warm up and cool down), 2–3 times per week, at a moderate intensity. [11]

General Recommendations for Both Modalities:

- Proper footwear and, for NW, appropriate poles are essential to prevent injury and maximize benefits. [11]
- 5 min Warm-up and 5 min cool-down periods should be included in each session.
- Supervision by trained professionals, especially during initial sessions, ensures correct technique and safety.
- Regular monitoring of blood glucose and symptoms is advised to promptly address any adverse effects. [11,12]

Applying these protocols can help participants improve balance, lower extremity strength, glycemic control, and quality of life, while reducing neuropathic symptoms and anxiety. [10,12]

WARM-UP (5 MINUTES)

1. Marching in Place:
March on the spot for 2–3 minutes, gradually increasing the height of your knees and swinging your arms gently.

2. Ankle Circles:
While standing or seated, lift one foot off the ground and rotate the ankle in circles (10 times each direction per foot).

3. Heel and Toe Raises:
Stand and slowly rise onto your toes, then rock back onto your heels. Repeat 10–15 times to activate the calf and shin muscles.

4. Gentle Arm Swings:
With arms relaxed at your sides, swing them forward and backward gently for 1–2 minutes to warm up the upper body (especially important for Nordic walking).

5. Side Steps:
Step side-to-side in a controlled manner for 1–2 minutes to loosen the hips and legs.

COOL-DOWN (5 MINUTES)

1. Slow Walking:
Reduce your walking pace gradually for 2–3 minutes to bring your heart rate down.

2. Calf Stretch:
Stand facing a wall, place your hands on the wall, and step one foot back, keeping the heel on the ground. Hold for 15–30 seconds per leg.

3. Hamstring Stretch:
Sit on a chair, extend one leg forward with the heel on the ground, and gently lean forward from the hips until you feel a stretch in the back of your thigh. Hold for 15–30 seconds per leg.

4. Quadriceps Stretch:
Standing and holding onto a support, bend one knee and bring your heel toward your buttocks, holding your ankle with your hand. Hold for 15–30 seconds per leg.

5. Shoulder and Arm Stretch:

Gently stretch each arm across your chest and hold for 15–20 seconds per arm to relax the upper body.

IX. DATA ANALYSIS

Table 1. Gender-wise Distribution of Participants

Gender	Number of Participants (n)	Percentage (%)
Male	40	60.6
Female	26	39.4
Total	66	100

Table 2. Age-wise Distribution of Participants

Age Group (years)	Number of Participants (n)	Percentage (%)
45–49	24	36.4
50–54	17	25.8
55–60	25	37.8
Total	66	100

Table 3. Distribution of Participants According to Duration of Diabetes

Duration of Diabetes (Years)	Interval Walking (n)	Interval Walking %	Nordic Walking (n)	Nordic Walking %
≤ 5 years	9	27.3	10	30.3
6–10 years	12	36.4	11	33.3
11–15 years	7	21.2	8	24.2
> 15 years	5	15.1	4	12.1
Total	33	100	33	100

Table 4. Within-Group Comparison of Balance (Berg Balance Scale)

Group	Pre-Intervention Mean ± SD	Post-Intervention Mean ± SD	p-value
Interval Walking (n = 33)	37.88 ± 4.77	44.18 ± 5.62	< 0.001
Nordic Walking (n = 33)	36.94 ± 4.30	44.09 ± 5.04	< 0.001

Table 5. Within-Group Comparison of Anxiety Levels (GAD-7)

Group	Pre-Intervention Mean ± SD	Post-Intervention Mean ± SD	p-value
Interval Walking (n = 33)	9.82 ± 2.73	5.58 ± 2.74	< 0.001
Nordic Walking (n = 33)	10.03 ± 2.63	5.09 ± 3.48	< 0.001

Table 6. Within-Group Comparison of Lower Extremity Muscle Strength (Manual Muscle Testing Scores)

Muscle Group	Intervention	Timepoint	Mean	SD
Hip Flexors	Interval Walking	Pre	3.76	0.43
		Post	4.61	0.49
	Nordic Walking	Pre	3.79	0.42
		Post	4.33	0.48
Knee Extensors	Interval Walking	Pre	3.85	0.36
		Post	4.67	0.48
	Nordic Walking	Pre	3.82	0.38
		Post	4.39	0.5
Ankle Dorsiflexors	Interval Walking	Pre	3.48	0.56
		Post	4.42	0.56
	Nordic Walking	Pre	3.45	0.54
		Post	4.15	0.54

Table 7. Between-Group Comparison of Balance (Post-Intervention)

Outcome	Interval Walking Mean ± SD	Nordic Walking Mean ± SD	p-value
Berg Balance Scale	44.18 ± 5.62	44.09 ± 5.04	0.945

Table 8. Between-Group Comparison of Anxiety Levels (Post-Intervention GAD-7)

Outcome	Interval Walking Mean ± SD	Nordic Walking Mean ± SD	p-value
GAD-7 Anxiety Score	5.58 ± 2.74	5.09 ± 3.48	0.531

Table 9. Between-Group Comparison of Lower Extremity Muscle Strength (Post-Intervention Manual Muscle Testing Scores)

Muscle Group	Interval Walking Mean ± SD	Nordic Walking Mean ± SD	p-value
Hip Flexors (MMT)	4.61 ± 0.49	4.33 ± 0.48	< 0.05
Knee Extensors (MMT)	4.67 ± 0.48	4.39 ± 0.50	< 0.05
Ankle Dorsiflexors (MMT)	4.42 ± 0.56	4.15 ± 0.54	< 0.05

X. RESULTS

A total of 66 participants diagnosed with Diabetic Peripheral Neuropathy (DPN) completed the study. Participants were randomly allocated into two groups:

Group A: Interval Walking Training (IWT) (n = 33)

Group B: Nordic Walking (NW) (n = 33)

All participants completed the intervention protocol without dropouts or adverse events.

1. Baseline Comparison

Baseline demographic and outcome variables were analyzed to determine group homogeneity prior to intervention.

Independent samples t-test was used to compare continuous variables (age, baseline BBS, MMT, GAD-7 scores).

Chi-square test was used for categorical variables (gender distribution).

There were no statistically significant differences between the two groups at baseline ($p > 0.05$), confirming homogeneity.

2. Effect on Balance

Outcome Measure: Berg Balance Scale (BBS)

Within-Group Analysis

To assess pre–post changes within each group, a paired t-test was applied.

Group A (IWT):

There was a statistically significant increase in BBS scores following the intervention ($p < 0.05$).

Group B (NW):

A statistically significant improvement in BBS scores was also observed post-intervention ($p < 0.05$).

This indicates that both interventions significantly improved balance in individuals with DPN.

Between-Group Analysis

An independent samples t-test was used to compare post-intervention BBS scores between groups.

The comparison revealed no statistically significant difference between Group A and Group B ($p > 0.05$).

Interpretation

Both Interval Walking Training and Nordic Walking were equally effective in improving balance. The null hypothesis for inter-group difference in balance was accepted.

3. Effect on Lower Extremity Muscle Strength

Outcome Measure: Manual Muscle Testing (MMT) – Hip Flexors, Knee Extensors, Ankle Dorsiflexors

Within-Group Analysis

A paired t-test was used to analyze pre–post changes in muscle strength within each group.

Group A (IWT):

Significant improvement was observed in hip flexors, knee extensors, and ankle dorsiflexors ($p < 0.05$).

Group B (NW):

Significant improvement was also noted in all assessed muscle groups ($p < 0.05$).

Thus, both interventions were effective in improving lower limb muscle strength.

Between-Group Analysis

An independent samples t-test was conducted to compare post-intervention MMT scores between groups.

Group A demonstrated significantly higher post-intervention muscle strength scores compared to Group B ($p < 0.05$).

Interpretation

Although both groups improved significantly, Interval Walking Training was statistically superior to Nordic Walking in enhancing lower extremity muscle strength. Therefore, the null hypothesis for muscle strength was rejected.

4. Effect on Anxiety

Outcome Measure: Generalized Anxiety Disorder Scale (GAD-7)

Within-Group Analysis

A paired t-test was used to evaluate pre–post changes in anxiety levels.

Group A (IWT):

Significant reduction in GAD-7 scores was observed ($p < 0.05$).

Group B (NW):

A statistically significant reduction in anxiety scores was also noted ($p < 0.05$).

Both interventions were effective in reducing anxiety.

Between-Group Analysis

An independent samples t-test was used to compare post-intervention GAD-7 scores between groups.

The inter-group comparison revealed no statistically significant difference ($p > 0.05$).

Interpretation

Both Interval Walking Training and Nordic Walking were equally effective in reducing anxiety levels in individuals with DPN. The null hypothesis for anxiety reduction was accepted.

Overall Statistical Conclusion

Paired t-test analysis demonstrated significant improvements within both groups for balance, muscle strength, and anxiety ($p < 0.05$).

Independent t-test analysis revealed:

No significant difference between groups for balance and anxiety ($p > 0.05$).

A significant difference favoring Interval Walking Training for lower limb muscle strength ($p < 0.05$).

Thus, while both interventions are effective in managing impairments associated with Diabetic Peripheral Neuropathy, Interval Walking Training provides superior improvement in lower extremity muscle strength.

XI. Discussion

The present randomized clinical trial was conducted to compare the effects of Interval Walking Training (IWT) and Nordic Walking (NW) on balance, lower extremity muscle strength, and anxiety in individuals with Diabetic Peripheral Neuropathy (DPN). DPN is one of the most common microvascular complications of Type 2 Diabetes Mellitus and is characterized by progressive sensory loss, impaired proprioception, distal muscle weakness, and psychological distress, all of which contribute to increased fall risk and reduced quality of life.[2]

Exercise therapy is widely recommended as a non-pharmacological intervention for individuals with DPN because it improves neuromuscular function, glycemic control, and psychological well-being.[11] The present study therefore aimed to compare two structured walking interventions to determine their effectiveness in addressing functional and psychological impairments in individuals with DPN.

Demographic Characteristics

Gender Distribution

Table 1 presents the gender distribution of participants in the study. Out of the total 66 participants, 40 (60.6%) were males and 26 (39.4%) were females.

This distribution reflects the commonly reported epidemiological pattern where Type 2 diabetes and its complications are slightly more prevalent among males in middle-aged populations.[1] Previous prevalence

studies conducted in India have also reported a higher representation of male participants in diabetes-related clinical research.[1]

Despite this variation in gender distribution, both intervention groups contained participants of both sexes, ensuring that the outcomes of the study were not restricted to a single gender group.

Age Distribution

Table 2 shows the age distribution of participants. The majority of participants were within the 45–60 year age range, with the highest representation in the 55–60 years group (37.8%), followed by 45–49 years (36.4%), and 50–54 years (25.8%).

This age range corresponds with the period during which Type 2 Diabetes Mellitus and its long-term complications such as DPN are most frequently diagnosed.[2] Chronic hyperglycemia over several years contributes to microvascular damage, resulting in progressive nerve degeneration and sensory impairment.[2]

The presence of participants predominantly in middle adulthood highlights the importance of early rehabilitation strategies aimed at preserving mobility and preventing functional decline in individuals with diabetes.

Duration of Diabetes

Table 3 presents the duration of diabetes among participants in both intervention groups. In the Interval Walking Training group, the majority of participants had diabetes for 6–10 years (36.4%), followed by ≤5 years (27.3%), 11–15 years (21.2%), and >15 years (15.1%). A similar distribution was observed in the Nordic Walking group, where 33.3% had diabetes for 6–10 years, followed by 30.3% with ≤5 years, 24.2% with 11–15 years, and 12.1% with >15 years.

The comparable distribution between the two groups indicates baseline homogeneity, ensuring that the outcomes observed in the study were primarily influenced by the intervention rather than differences in disease duration.

Longer duration of diabetes has been strongly associated with the development of diabetic neuropathy due to chronic metabolic and vascular disturbances affecting peripheral nerve function.[2]

Effect on Balance

Balance performance was assessed using the Berg Balance Scale (BBS). Table 4 demonstrates the within-group comparison of BBS scores.

Participants in the Interval Walking Training group showed a significant improvement in BBS scores from 37.88 ± 4.77 (pre-intervention) to 44.18 ± 5.62 (post-intervention) with $p < 0.001$. Similarly, participants in the Nordic Walking group improved from 36.94 ± 4.30 to 44.09 ± 5.04, also with $p < 0.001$.

These findings indicate that both interventions significantly improved balance in individuals with DPN.

Balance impairment in DPN occurs due to loss of plantar sensation, impaired proprioception, delayed neuromuscular responses, and distal muscle weakness.[4] Reduced sensory feedback from the lower extremities forces individuals to rely more heavily on visual and vestibular inputs for postural control, which increases instability during gait and standing tasks.[2]

Regular walking activity may improve balance through several mechanisms:

- stimulation of plantar mechanoreceptors,
- enhancement of proprioceptive feedback,
- strengthening of ankle and knee musculature,
- improvement in neuromuscular coordination.

Previous systematic reviews have also reported that structured exercise programs significantly improve balance capacity in individuals with Type 2 diabetes.[3]

Table 7 presents the between-group comparison of post-intervention BBS scores. The results show no statistically significant difference between groups ($p = 0.945$), indicating that both walking interventions were equally effective in improving balance.

Nordic Walking incorporates the use of poles, which provides additional external support and increases base of support during gait. This may help improve trunk stability and promote symmetrical arm swing, thereby enhancing postural control during walking.[9]

Thus, the findings of this study suggest that both Interval Walking and Nordic Walking are effective strategies for improving balance and reducing fall risk in individuals with DPN.

Effect on Anxiety

Anxiety levels were evaluated using the Generalized Anxiety Disorder-7 (GAD-7) scale.

Table 5 shows the within-group comparison of anxiety scores. In the Interval Walking group, the mean GAD-7 score decreased significantly from 9.82 ± 2.73 to 5.58 ± 2.74 ($p < 0.001$). Similarly, the Nordic Walking group showed a reduction from 10.03 ± 2.63 to 5.09 ± 3.48 ($p < 0.001$).

These results indicate that both exercise interventions significantly reduced anxiety levels in participants with DPN.

Psychological distress is commonly observed in individuals with diabetes due to factors such as chronic disease burden, neuropathic pain, reduced functional independence, and fear of complications.[5] Anxiety disorders have been reported to affect nearly one-third of individuals with diabetes, often leading to poorer glycemic control and reduced adherence to treatment.[6]

Exercise has been shown to improve psychological health through multiple mechanisms including:

- endorphin release,
- reduction of sympathetic nervous system activity,
- improvement in glycemic regulation,
- enhancement of self-confidence and physical independence.

Table 8 presents the between-group comparison of post-intervention anxiety scores, which revealed no statistically significant difference ($p = 0.531$) between the groups. This suggests that both Interval Walking Training and Nordic Walking are similarly effective in reducing anxiety levels.

Previous studies have also demonstrated that regular physical activity can significantly reduce symptoms of anxiety and depression in individuals with diabetes.[5]

Effect on Lower Extremity Muscle Strength

Lower extremity muscle strength was assessed using Manual Muscle Testing (MMT) for hip flexors, knee extensors, and ankle dorsiflexors.

Table 6 shows that both intervention groups demonstrated improvements in muscle strength following training.

For example:

- Hip flexor strength improved from 3.76 ± 0.43 to 4.61 ± 0.49 in the Interval Walking group, compared to 3.79 ± 0.42 to 4.33 ± 0.48 in the Nordic Walking group.
- Knee extensor strength increased from 3.85 ± 0.36 to 4.67 ± 0.48 in the Interval Walking group and from 3.82 ± 0.38 to 4.39 ± 0.50 in the Nordic Walking group.
- Ankle dorsiflexor strength improved from 3.48 ± 0.56 to 4.42 ± 0.56 in the Interval Walking group and from 3.45 ± 0.54 to 4.15 ± 0.54 in the Nordic Walking group.

However, Table 9 demonstrates that post-intervention muscle strength was significantly higher in the Interval Walking group compared to the Nordic Walking group ($p < 0.05$).

Muscle weakness in DPN results from motor nerve degeneration, reduced motor unit recruitment, and muscle fiber atrophy.[4] This weakness is particularly pronounced in the distal muscles such as the ankle dorsiflexors, which play a crucial role in maintaining gait stability.

The greater improvement observed in the Interval Walking Training group may be explained by the principle of overload in exercise physiology. Interval training alternates periods of higher intensity walking with recovery phases, which may lead to:

- increased motor unit recruitment,
- enhanced type II muscle fiber activation,
- improved neuromuscular efficiency,
- greater metabolic stimulus for muscle adaptation.

Previous research has also demonstrated that interval-based walking programs can significantly improve physical fitness and metabolic health in individuals with Type 2 diabetes.[8]

Improved muscle strength is clinically important because stronger lower limb muscles enhance gait stability, shock absorption, and joint support, thereby reducing the risk of falls and improving functional mobility.

Overall Interpretation

The findings of the present study indicate that both Interval Walking Training and Nordic Walking are effective interventions for individuals with Diabetic Peripheral Neuropathy.

Key findings include:

- Significant improvement in balance in both groups.
- Significant reduction in anxiety levels following both interventions.
- Significant improvement in lower limb muscle strength, with greater gains observed in the Interval Walking Training group.

These results highlight the importance of structured exercise programs in the rehabilitation of individuals with diabetic neuropathy, as physical activity not only improves neuromuscular function but also enhances psychological well-being.[11]

Clinical Implications

The findings of this study have several important implications for physiotherapy practice:

- Walking-based exercise programs are safe and effective for individuals with DPN.
- Interval Walking Training may be preferable when muscle strengthening is the primary rehabilitation goal.
- Nordic Walking may provide additional stability and confidence during ambulation due to pole support.
- Incorporating regular physical activity into diabetes management programs may help reduce fall risk and improve overall quality of life.

Conclusion

In conclusion, both Interval Walking Training and Nordic Walking significantly improved balance, lower limb muscle strength, and anxiety levels in individuals with Diabetic Peripheral Neuropathy. While both modalities were equally effective in improving balance and reducing anxiety, Interval Walking Training demonstrated superior effects on lower extremity muscle strength. These findings support the integration of structured walking programs, particularly interval-based protocols, into comprehensive rehabilitation strategies for individuals with DPN.

XII. CONCLUSION

The present randomized clinical trial compared the effects of Interval Walking Training (IWT) and Nordic Walking (NW) on balance, lower extremity muscle strength, and anxiety levels in individuals with Diabetic Peripheral Neuropathy (DPN).

The findings of the study indicate that both IWT and NW significantly improved balance, muscle strength, and anxiety levels following the intervention period. Both groups demonstrated comparable improvements in balance (Berg Balance Scale) and anxiety (GAD-7), with no statistically significant difference between the two interventions.

However, Interval Walking Training showed significantly greater improvements in lower extremity muscle strength, including hip flexors, knee extensors, and ankle dorsiflexors, compared to Nordic Walking.

Therefore, while both walking modalities are effective and safe for individuals with DPN, Interval Walking Training may be considered more beneficial when the primary goal is enhancing lower limb muscle strength. Nordic Walking remains a suitable alternative, particularly for individuals requiring additional support and stability.

In conclusion, structured walking-based exercise programs should be incorporated into comprehensive rehabilitation protocols for individuals with Diabetic Peripheral Neuropathy to improve physical function, reduce anxiety, and enhance overall quality of life.

XIII. LIMITATIONS

Despite demonstrating significant findings, the present study has certain limitations that should be considered while interpreting the results:

1. **Sampling Method**

The study used convenience sampling, which may limit the generalizability of the findings to the broader population of individuals with Diabetic Peripheral Neuropathy (DPN).

2. **Short-Term Intervention Duration**

The intervention period was limited, and long-term follow-up was not conducted. Therefore, the sustainability of improvements in balance, muscle strength, and anxiety could not be determined.

3. **Lack of Blinding**

Blinding of participants and assessors was not performed, which may introduce performance or assessment bias.

4. **Subjective Strength Assessment**

Muscle strength was assessed using Manual Muscle Testing (MMT), which is examiner-dependent and less sensitive compared to objective tools such as handheld dynamometry.

5. **Limited Age Group**

The study included participants aged 45–60 years only. Hence, the results cannot be generalized to younger or older individuals with DPN.

6. **No Objective Neuropathy Severity Measurement**

The severity of neuropathy was not quantified using nerve conduction studies or standardized neuropathy scales, which could have provided more detailed clinical correlation.

7. **Psychological Assessment Limited to Anxiety**

Only anxiety was assessed using GAD-7. Other psychological variables such as depression, quality of life, or fear of falling were not evaluated.

8. **Single-Center Study**

The study was conducted in a tertiary healthcare hospital, which may limit external validity to community-based settings.

XIV. FUTURE SCOPE

The findings of the present study open several avenues for future research in the management of Diabetic Peripheral Neuropathy (DPN):

1. Long-Term Follow-Up Studies

Future studies should include long-term follow-up to evaluate the sustainability of improvements in balance, muscle strength, and anxiety levels after cessation of the intervention.

2. Larger and Multicenter Trials

Conducting multicenter randomized controlled trials with larger sample sizes would enhance the generalizability and external validity of the findings.

3. Objective Measurement Tools

Future research may incorporate objective assessment tools such as handheld dynamometry for muscle strength, computerized posturography for balance, and nerve conduction studies to assess neuropathy severity.

4. Comparison with Other Exercise Modalities

Further studies could compare Interval Walking Training and Nordic Walking with other structured exercise programs such as resistance training, balance-specific training, aquatic therapy, or combined exercise protocols.

5. Assessment of Additional Outcomes

Future research may evaluate additional parameters such as:

- o Glycemic control (HbA1c levels)
- o Fear of falling
- o Quality of life
- o Depression levels
- o Functional mobility tests (e.g., TUG, 6MWT)

6. Home-Based and Tele-Rehabilitation Models

Investigating the effectiveness of home-based or digitally monitored walking programs could increase accessibility and adherence, especially in rural or underserved populations.

7. Different Age Groups and Severity Levels

Studies involving older adults (>60 years) or individuals with varying severities of neuropathy may provide deeper clinical insights.

8. Biomechanical and Neuromuscular Mechanism Studies

Future research may explore the underlying mechanisms responsible for strength and balance improvements, including muscle activation patterns, proprioceptive enhancement, and inflammatory markers.

XV. Clinical Implication

The findings of the present study highlight the importance of structured walking interventions in the rehabilitation of individuals with Diabetic Peripheral Neuropathy (DPN).

Both Interval Walking Training (IWT) and Nordic Walking (NW) can be safely incorporated into physiotherapy management programs to improve balance, lower limb muscle strength, and reduce anxiety levels. These interventions are simple, cost-effective, and require minimal equipment, making them feasible in hospital, outpatient, and community settings.

Interval Walking Training may be particularly beneficial when the primary goal is to improve lower extremity muscle strength, as it demonstrated superior improvements in hip flexors, knee extensors, and ankle dorsiflexors. Nordic Walking may be preferred for individuals who require additional stability and upper limb involvement during ambulation.

Improved balance and ankle dorsiflexor strength are clinically significant, as they may contribute to fall prevention and improved gait safety in individuals with DPN. Additionally, the reduction in anxiety levels supports the integration of exercise therapy as part of holistic diabetes management, addressing both physical and psychological components.

Therefore, structured walking programs should be recommended as a routine non-pharmacological intervention in individuals with Type 2 Diabetes Mellitus and Diabetic Peripheral Neuropathy.

XVI. References

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