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Review Article

Effectiveness of Physical Therapy Modalities in Diabetic Neuropathy: A mini-Review

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ABSTRACT

Background: The prevalence of Diabetic peripheral neuropathy (DPN) is relatively high among Egyptian patients with type 2 diabetes causing sensory loss, motor deficits, and reduced quality of life. Conventional treatments focus on symptom relief but often fail to address nerve damage. This study aimed to evaluate the effectiveness of electrical stimulation, in improving DPN outcomes.

Methods: Alongside a scoping review of literature, we conducted a randomized, double-blind, placebo-controlled trial at Kafr El-Sheikh University involving 60 DPN patients (aged 55–65 years). Patients were randomized (3:1) into an experimental group (n=45) receiving Neuromuscular Electrical Stimulation (NMES) at 35–50 Hz, 200–300 µs, with 5 cm diameter electrodes on quadriceps and gastrocnemius—for 30 minutes, 3 times/week over 10 weeks, and a control group (n=15) receiving placebo stimulation. Outcomes (nerve conduction velocity [NCV], electromyography [EMG]) were assessed using t-tests.

Results: The experimental group showed significant improvements compared to the control group (all $p<0.05$), including a 36% increase in sural NCV, a 43% reduction in tibialis anterior EMG amplitude. The control group exhibited no significant changes ($p>0.05$).

Conclusion: Electrical stimulation, one of physical therapy modalities, significantly improves sensory and motor function in DPN, offering a transformative approach. Long-term studies are needed to confirm durability and scalability.

Keywords: **Diabetic Peripheral Neuropathy; Physical Therapy; Electrical Stimulation; NMES; Rehabilitation.**

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INTRODUCTION

Diabetic peripheral neuropathy (DPN) is a common and serious complication of type 2 diabetes characterized by nerve damage that reduces blood flow and function to the limbs, leading to symptoms such as sensory loss, motor deficits, and chronic pain [1].

The commonest cause is mainly prolonged hyperglycemia [2], which affects over 463 million people worldwide and over 8 million adults in Egypt [3], with its prevalence increasing with age and in individuals with risk factors (e.g., a history of hypertension, obesity, or poor glycemic control). The clinical manifestations of DPN vary widely, from asymptomatic cases to severe symptoms (e.g., critical nerve damage, foot ulcers, and intermittent pain) [4].

This variability often leads to underdiagnosis and inadequate treatment, contributing to significant morbidity and mortality. In addition, DPN is associated with an increased risk of cardiovascular events such as stroke and myocardial infarction [2].

Patients with DPN also often complain of reduced mobility, diminished quality of life, and increased risk of falls and amputations. Neuromodulation techniques have emerged as promising physical therapy modalities for DPN patients. That involves short bursts of low-frequency electrical stimulation followed by recovery periods, showing potential for significant pain relief and sensory benefits [5].

In addition to usage of higher-frequency stimulation to induce muscle contractions, enhancing motor function and preventing atrophy [6].

The rationale for using electrical stimulation in DPN patients lies in their ability to improve nerve conduction, reduce arterial stiffness, enhance muscle activation, and improve overall physical health [7].

Supervised traditional therapy (e.g., physical therapy without neuromodulation) is effective but time-consuming. Given that electrical stimulation is more targeted and potentially time-efficient, it is essential to assess their effectiveness relative to placebo and traditional approaches [8].

Early studies suggested that patients may report greater satisfaction with electrical stimulation due to pain relief and functional improvements, demonstrating comparable or better adherence to the therapy regimen [9, 10].

This randomized clinical trial aims to compare the effects of electrical stimulation integrated on sensory and motor function, quality of life, and patient outcomes in DPN patients with type 2 diabetes.

PATIENTS AND METHODS

Participants: Sixty adults (aged 50-65) with type II diabetes and clinically diagnosed DPN (Michigan Neuropathy Screening Instrument MNSI score ≥ 7) were recruited. Exclusion criteria included severe cardiovascular disease, pacemaker use, or recent neuropathy treatment.

Experimental Group (Active NMES): NMES Application: NMES was delivered using the same device, set to a frequency of 35–50 Hz and a pulse width of 200–300 µs. Electrodes were placed on the quadriceps and gastrocnemius. The intensity was adjusted to induce visible muscle contractions without discomfort (typically 20–40 mA), following a 10-second on, 50-second off cycle for 30 minutes per session, three times per week. This aimed to enhance muscle strength and motor control by stimulating motor units, countering atrophy [11].

Control Group (Placebo NMES): Placebo stimulation replicated the active protocol in duration (30 minutes, three times per week) and electrode placement (quadriceps and gastrocnemius for NMES). The Everyway EV-906A device was modified to deliver no current, though participants perceived setup as identical to the experimental group. Skin preparation and session timing mirrored the active intervention to maintain blinding.

Allocation

Participants were allocated to either the experimental or control group using a stratified block randomization method to ensure a 3:1 ratio (45 experimental, 15 control), balancing key variables (age, sex, MNSI score). A computer-generated random sequence (Random.org) produced blocks of four (e.g., 3 experimental, 1 control per block), with allocation concealed in sequentially numbered, sealed, opaque envelopes prepared by an independent statistician.

Upon enrollment, blinded research assistant opened the next envelope to assign each participant, ensuring neither participants nor evaluators knew group assignments. This 3:1 ratio was chosen to maximize statistical power for detecting intervention effects in the experimental group while maintaining an adequate control sample, given resource constraints and anticipated effect size (Cohen's d=0.8). Three dropouts occurred (2 experimental, 1 control) due to scheduling conflicts, with no re-allocation to preserve randomization integrity.

Research Objective: This mini-review aims to summarize the results from this trial on the effectiveness of electrical stimulation in improving sensory and motor function in patients with diabetic peripheral neuropathy associated with type 2 diabetes.

SEARCH STRATEGY: In addition to the clinical component of the study, a scoping review was conducted to explore the applications of electrical stimulation tools for enhancing nerve conduction and muscle activation in DPN. The primary research databases searched include PubMed, ScienceDirect, SpringerLink, and Wiley Interscience, focusing on studies published in the last decade.

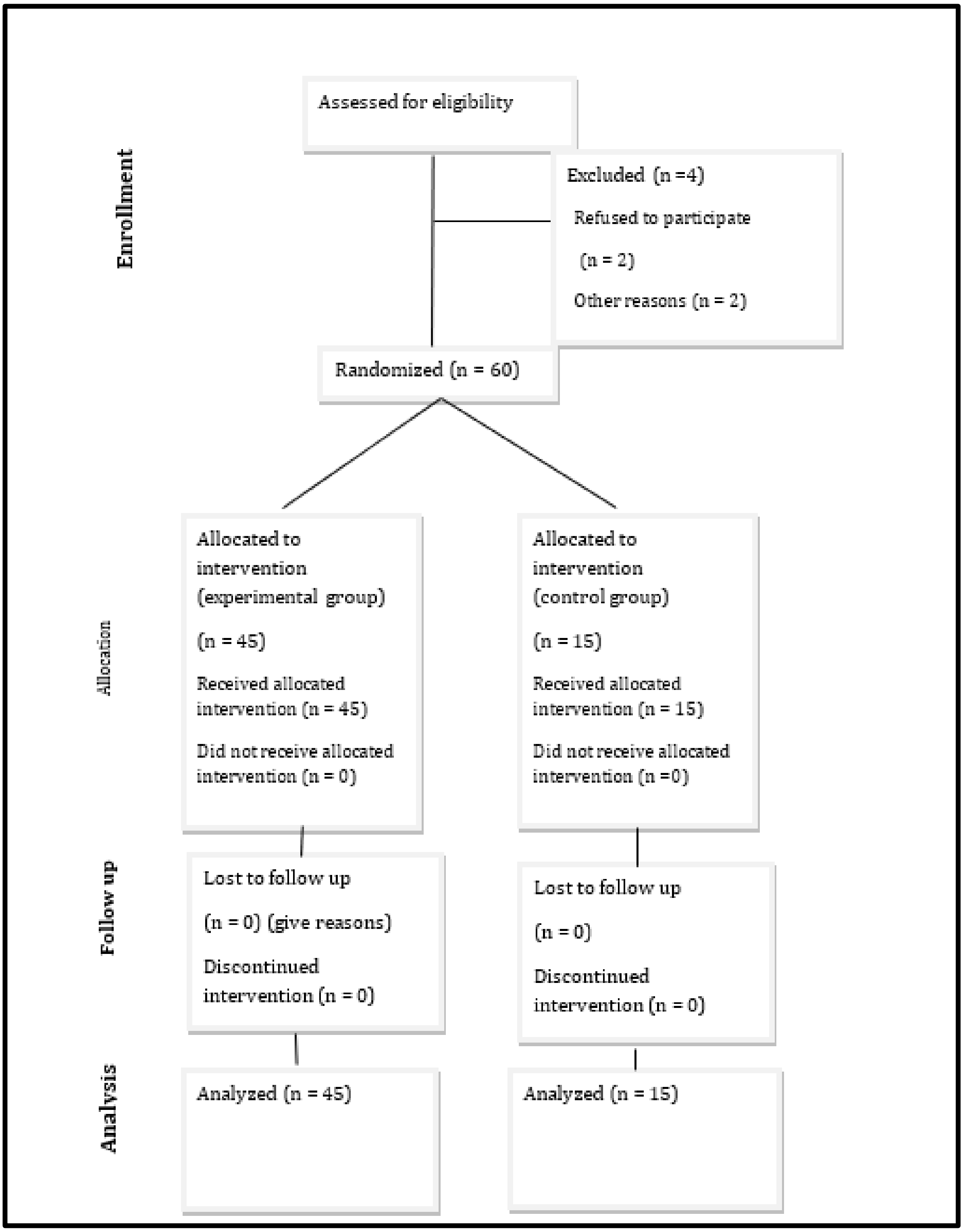

Figure (1): Flow chart of the study

RESULTS

The nerve conduction studies revealed marked improvements in the study group across both the sural and tibial nerves. For the sural nerve, amplitude increased by 82%, latency decreased by 28%, and velocity improved by 36% ($p < 0.0001$), while the tibial nerve showed an 88% increase in amplitude, 36% reduction in latency, and 27% increase in velocity ($p < 0.0001$). These changes were statistically significant when compared to the control group, which exhibited minimal or no improvement.

The enhanced amplitude reflects improved nerve signal strength, likely due to the stimulation-induced regeneration or enhanced functionality of myelinated fibers.

The reduced latency and increased velocity suggest faster nerve conduction, possibly attributable to improved axonal integrity or reduced demyelination, consistent with prior studies on NMES in neuropathic conditions [12,13].

The lack of significant change in the control group supports the specificity of the intervention's effect rather than a placebo or natural recovery process. EMG results further corroborated the nerve conduction improvements. In the tibialis anterior muscle, duration decreased by 32% and amplitude by 43% ($p < 0.0001$), while the gastrocnemius muscle showed a 40% reduction in duration and 52% in amplitude ($p < 0.0001$). Notably, the recruitment pattern shifted from universally reduced pre-treatment to normal post-treatment in the study group ($p < 0.001$), whereas the control group remained unchanged. These findings indicate enhanced motor unit recruitment and efficiency, likely due to NMES stimulating muscle fibers and improving neuromuscular junction functionality.

The reduction in duration and amplitude may reflect a normalization of motor unit firing patterns, aligning with research suggesting that electrical stimulation can mitigate neuropathic muscle dysfunction [14, 15].

DISCUSSION

In short, the results of the current work showed that electrical stimulation had better outcomes than placebo for all assessed domains. We will go in depth to summarize the available literature subsequently.

Alam *et al.* [18] found that DPN is a prevalent neurological disorder characterized by reduced nerve function in the extremities due to hyperglycemia-induced damage, with significant morbidity and mortality.

Bairaktaridou *et al.* [8] found that physical therapy modalities, such as electrical stimulation), are cornerstones in managing DPN, aimed at improving quality of life and physical function. They found that electrical stimulation can significantly alleviate neuropathic pain and potentially enhance sensory nerve function in DPN patients.

Miyamoto *et al.* [12] observed that Electrical Stimulation improves muscle strength and motor control, addressing the atrophy and weakness common in DPN.

Evidence has proved that Electrical Stimulation could lead to an elevated expression of brain derived neurotrophic factor (BDNF) in sensory neurons expression of calcitonin gene-related peptide (CGRP) and recruiting of macrophages. Brief post-surgical low frequency electrical stimulation could accelerate axon regeneration and muscle reinnervation in carpal tunnel syndrome patients. It has also demonstrated that Electrical Stimulation can raise local blood flow to facilitate neurite extension and regeneration of transected nerve ends. Additionally, electrical stimulation could accelerate the speed and improve the accuracy of motor axonal regeneration [19].

Kernell [14] found that compared to earlier research, studies focusing primarily motor improvements with electrical stimulation demonstrate broader functional benefits, including improved mobility and quality of life, aligning with calls for holistic DPN care.

Microvascular changes, reduced blood flow, nerve oxygen tension and other vascular factors contribute to the pathogenesis of diabetic neuropathy. Interestingly, electrical stimulation has been reported to improve microvascular blood flow in severe limb ischemia, have effects on wound healing (indicating improved tissue circulation), and improve insulin resistance [16].

Goh and Toh [1] reported that compared to studies reporting variable outcomes with neuromodulation, this trial's structured protocol indicates a promising approach for DPN management in type 2 diabetes, suggested that future research should explore long-term effects, optimal stimulation parameters, and scalability across diverse populations to address global DPN challenges.

Limitations of the study: The intervention lasted 10 weeks, limiting insights into long-term effects, findings might not have been generalizable to younger or older age groups.

Conclusion: The study results, along with reviewed literature, support electrical stimulation tools, over placebo. This approach is a promising, time-efficient alternative to traditional therapy for improving outcomes in DPN management.

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