

Investigating the effect of conventional physiotherapy training on muscle activity among diabetic neuropathy patients through wireless EMG: a pilot study

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Abstract: Persons with diabetes often experience muscle weakness and decreased mobility due to diabetic neuropathy. This condition usually arises due to prolonged elevated blood sugar levels, which damage the motor nerves, innervating the muscles and sensory nerves. As the neuropathy progresses, it can cause loss of muscle mass and diminished motor function in the legs and feet. Consequently, individuals with diabetic neuropathy may experience difficulties with balance, walking, and performing daily activities. This weakness increases the risk of falls and injuries and contributes to reduced mobility and a lower quality of life. Hence, early intervention and management are essential to preserve muscle strength and functionality among the diabetic population. Managing muscle function and mobility in affected individuals is a significant challenge. This pilot study aimed to investigate the effect of conventional physiotherapy training on muscle activity in diabetic neuropathy patients using Noroxon wireless sensor electromyography (EMG) technology. The study included 8 patients aged 45-65; after obtaining consent and meeting selection criteria, these patients were enrolled. Wireless sensor EMG monitored muscle activity in the tibialis anterior and soleus. Participants underwent conventional physiotherapy, consisting of 40 minutes daily, 5 days a week, over 3 months. The result showed a significant increase in the maximum voluntary contraction of tibialis anterior and soleus muscles on both right and left side mean values at $p \leq 0.001$. In conclusion, the study demonstrated that diabetic neuropathy causes alterations in muscle dynamics, particularly in distal muscles. These findings offer valuable insights into the progression of neuropathy and highlight the effectiveness of physiotherapy in mitigating its effects by significantly enhancing the maximum voluntary contraction of these muscles.

Keywords: Diabetic neuropathy; Noroxon wireless EMG; Diabetes; Physiotherapy; Voluntary contraction; Muscle activity.

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1.0 INTRODUCTION

Diabetic neuropathy (DN), a prevalent complication of diabetes, affects up to 50% of patients with diabetes, leading to progressive nerve damage and associated musculoskeletal issues ([Pop-Busui et al., 2017](#)). Diabetic neuropathy significantly impacts muscle activity, particularly in the lower limbs, where it can cause weakness, decreased functionality, and impaired mobility ([Parasoglou et al., 2017](#)). DN is a form of nerve damage caused by chronically high blood sugar levels, leading to various neurological impairments. Among these, peripheral neuropathy is the most prevalent, significantly affecting the lower limbs ([Teskaye et al., 2011](#)). The condition is characterized by a progressive loss of nerve fibres, resulting in diminished sensory perception, pain, and, ultimately, muscle weakness and atrophy ([Feldman et al., 2019](#)). Degeneration of muscle tissue in the lower limbs due to DN impairs mobility and contributes to a higher risk of foot ulcers, infections, and amputations, making it a critical area of study.

The pathophysiology of DN involves a complex interplay between the metabolic and vascular factors that lead to nerve damage. Hyperglycaemia triggers a cascade of metabolic pathways, such as the polyol pathway, advanced glycation end-product formation, and oxidative stress, resulting in nerve damage and dysfunction ([Callaghan et al., 2012](#)). Lower limbs are particularly vulnerable because of their length and the increased metabolic demand placed on the nerves supplying these areas ([Edwards et al., 2008](#)). As nerve function deteriorates, muscles in the lower limbs suffer from decreased innervation, leading to muscle weakness, imbalance, and atrophy over time ([Ramji et al., 2007](#)).

Studies have shown that the muscles of individuals with DN undergo significant alterations, including a reduction in muscle fibre size, a shift from type I (slow-twitch) to type II (fast-twitch) fibres, and an increase in intramuscular fat infiltration ([Andersen et al., 2018](#)). These changes further exacerbate the functional decline seen in DN patients, as type I fibres are essential for endurance and posture maintenance. In contrast, type II fibres are more prone to fatigue ([Jensen et al., 2021](#)).

The impact of diabetic neuropathy extends beyond sensory disturbances to include profound effects on the motor system, particularly on muscle activity and strength. As neuropathy progresses, the nerves responsible for muscle control are increasingly damaged, leading to muscle atrophy and weakness. Patients with DN often exhibit slower walking speeds,

shorter stride lengths, and increased time spent in the double-support phase of gait, all of which are indicative of compensatory mechanisms to avoid falls ([Allet et al., 2009](#)). Furthermore, the loss of muscle mass and strength, particularly in the distal muscles such as the tibialis anterior and intrinsic muscles of the feet, impairs the ability to perform activities of daily living, such as standing up from a chair, climbing stairs, or walking long distances ([Resnick et al., 2002](#)). This deterioration in muscle function contributes to a cascade of functional impairments, including difficulty in walking, climbing stairs, and performing other activities of daily living ([Armstrong et al., 2017](#)). Furthermore, muscle weakness and reduced mobility can exacerbate the risk of developing foot ulcers and subsequent amputations, further highlighting the need for effective interventions to preserve muscle function in this population ([Ziegler et al., 2018](#)). Therefore, understanding the impact of DN on the lower limb muscles is crucial for developing targeted interventions that can prevent or mitigate these severe outcomes.

Conventional physiotherapy has long been considered a cornerstone in managing the musculoskeletal complications associated with diabetic neuropathy. It typically involves a combination of exercises designed to improve muscle strength, flexibility, and balance alongside education and other supportive therapies ([Kluding et al., 2016](#)). The goals of physiotherapy in this context are multifaceted: to enhance functional mobility, reduce pain, prevent the progression of muscle weakness, and ultimately improve the overall quality of life for patients with diabetic neuropathy ([Geraldes & King, 2010](#)). Despite its widespread use, there is a need for more robust evidence regarding the specific impacts of physiotherapy on muscle activity in diabetic neuropathy patients, particularly in light of the recent technological advancements in monitoring muscle function.

Wireless electromyography (EMG) has opened new avenues for assessing and monitoring muscle activity during physiotherapy interventions. Unlike traditional EMG systems, which are often cumbersome and limited to clinical settings, wireless EMG offers a more flexible and patient-friendly approach for muscle activity assessment. Noraxon EMG technology in managing diabetic neuropathy offers a significant advantage in monitoring and evaluating muscle activity, thereby enhancing the understanding of neuromuscular impairments in this condition. Noraxon EMG systems are known for their accuracy, reliability, and flexibility in clinical and research settings, allowing for detailed

assessments of muscle function and motor unit behaviour in patients with diabetic neuropathy (Vieira et al., 2012). This technology enables clinicians and researchers to measure muscle activation patterns during various physical activities and therapeutic interventions, facilitating the development of tailored physiotherapy protocols to improve muscle strength and reduce the risk of complications associated with neuropathy (Jahantigh Akbari et al., 2020).

Understanding the efficacy of conventional physiotherapy in improving muscle activity among patients with diabetic neuropathy is critical for several reasons. First, it can inform the development of targeted intervention strategies to address the specific needs of this population. Second, it can help healthcare providers optimise physiotherapy protocols, ensuring patients receive the most beneficial and cost-effective treatments. Finally, it can contribute to a broader knowledge of diabetic neuropathy management, potentially leading to care delivery innovations and patient outcomes.

Thus, this study is anticipated to provide valuable evidence regarding the efficacy of conventional physiotherapy in improving muscle activity among diabetic neuropathy patients. Specifically, improvements in tibialis anterior and soleus muscle strength and lower limb function, as evidenced by changes in EMG readings.

2.0 MATERIALS AND METHODS

This pilot study was conducted in the Physiotherapy Department (OPD) at Dr. M.G.R. Educational and Research Institute, with ethical approval granted by the institution's review board-reference number ANRU06/PHYSIO/IRB/2022-2023. The study adhered to the guidelines of the revised Helsinki Declaration of 2008. Eight participants, aged 40-60 years, with diabetic neuropathy, were selected, including both men and women with an HbA1C level of 6.5% or higher. Eligible subjects had either type 1 or type 2 diabetes mellitus and scored above 2.5 on the Michigan Neuropathy Screening Instrument (MNSI). Individuals with conditions related to the cervical or lumbar spine, those with partial or complete foot amputation, visual impairments, or any other systemic illnesses were excluded from the study. After acquiring their written informed consent, subjects who fulfilled the inclusion criteria were evaluated for the study. All the subjects underwent conventional physiotherapy exercises for 40 minutes per day, five days a week, over three months.

Muscle activity was measured using Noraxon wireless EMG before and 12 weeks after the intervention.

2.1 Physiotherapy intervention

The physiotherapy intervention aimed to improve muscle function, balance, and mobility in diabetic neuropathy patients. It began with 5 minutes of relaxed breathing exercises and 5 minutes of range-of-motion exercises for the ankle, knee, and hip to enhance flexibility. The core session included 15 minutes of balance training with sit-to-stand, weight shifts, functional reach, bipedal heel rises, and unipedal standing exercises to strengthen lower limbs and stability. All exercises were performed for 10 repetitions, with a 1-minute rest between each set. The session concluded with 15 minutes of brisk walking to boost cardiovascular health and circulation. This structured regimen targeted multiple aspects of physical health to mitigate the effects of diabetic neuropathy.

2.2 Procedure for muscle activity EMG

Ensure the subject is lying down in a relaxed position. To record tibialis anterior and soleus muscle activity using Noraxon wireless EMG, prepare the subject by cleaning the skin and identifying the muscles first. Place electrodes over the tibialis anterior, one-third down the leg from the knee, and over the soleus, 2-3 cm below the gastrocnemius on both sides. Attach sensors to each electrode and fix it over the skin. Power on the Noraxon system, sync it with the software and calibrate. Record baseline maximal voluntary contraction during dorsiflexion for tibialis anterior and plantarflexion for soleus.

3.0 RESULTS

3.1 Data collection

Data was meticulously collected using surface EMG to measure muscle activity during the pre-test and post-test phases. The collected data were then analysed using SPSS 28 software, ensuring rigorous statistical analysis and accuracy. Further, a paired *t*-test was adopted to find the statistical difference within the group.

3.2 Statistical analysis

On the right side, the mean maximal voluntary contraction score for the tibialis anterior increased from 1069.38 in the pre-test to 1158.75 in the post-test. The right soleus also showed a notable increase, with mean maximal voluntary contraction scores rising from 289.86 in the pre-test to 439.87 in the post-test. These changes reflect a significant enhancement in maximum

voluntary contraction (MVC), with the statistical analysis showing a highly significant difference at $p \leq 0.001$. The marked increase in EMG activity indicates that the intervention was particularly effective in improving muscle performance on the right side, as seen in **Table 1**.

Similarly, on the left side, the tibialis anterior exhibited an increase in mean maximal voluntary contraction

score from 1078.75 in the pre-test to 1166.36 in the post-test. The left soleus muscle also significantly rose, with maximal voluntary contraction increasing from 325.5 in the pre-test to 433.86 in the post-test. These results mirror those observed on the right side, showing a significant difference between pre-test and post-test values at $p \leq 0.001$. The consistent improvement in EMG activity on the left side, as seen in **Table 2**, further supports the effectiveness of the intervention.

Table 1. Comparison of maximal voluntary contraction of tibialis anterior and soleus on the right-side.

EMG Right	Pre-Test		Post-Test		t-Test	df	Significance
	Mean	SD	Mean	SD			
Tibialis Anterior	1069.38	21.05	1158.75	25.98	-9.45	7	.000**
Soleus	289.86	23.84	439.87	33.45	-11.86	7	.000**

** $p \leq 0.001$

Table 2. Comparison of maximal voluntary contraction of tibialis anterior and soleus on the left side.

EMG Left	Pre-Test		Post-Test		t-Test	df	Significance
	Mean	SD	Mean	SD			
Tibialis Anterior	1078.75	13.07	1166.36	35.1	-7.65	7	.000**
Soleus	325.5	32.38	433.86	41.17	-14.12	7	.000**

** $p \leq 0.001$

4.0 DISCUSSION

The results of this study demonstrated a statistically significant improvement in muscle activity among diabetic neuropathy patients following conventional physiotherapy training, as assessed through wireless EMG. Specifically, the findings revealed substantial increases in the MVC of the tibialis anterior and soleus muscles on both the right and left sides, indicating the efficacy of the intervention.

The significant improvement in EMG scores for both the tibialis anterior and soleus muscles post-intervention is consistent with previous studies highlighting physiotherapy's benefits in managing diabetic neuropathy. Physiotherapy enhances muscle strength, improves balance, and increases overall functional mobility in patients with diabetic neuropathy ([Allet et al., 2009](#)). The increase in MVC observed in this study suggests that conventional physiotherapy effectively enhances neuromuscular function, likely by improving the recruitment and activation of motor units within the affected muscles ([Kluding et al., 2016](#)).

The tibialis anterior and soleus muscles play crucial roles in maintaining posture, balance, and gait. The tibialis anterior is primarily responsible for the dorsiflexion of the foot, while the soleus contributes to plantar flexion and provides stability during standing and walking ([Jensen et al., 2021](#)). In diabetic neuropathy, these

muscles often exhibit reduced strength and activation owing to nerve damage and associated muscle atrophy ([Ijzerman et al., 2012](#)). The improvement in EMG scores post-physiotherapy suggests reversing some deleterious effects, potentially leading to better patient functional outcomes.

The increased muscle activity, as evidenced by higher post-test EMG scores, can be attributed to several physiological mechanisms. First, physiotherapy likely enhances neuromuscular coordination, improving the efficiency of motor unit recruitment. This is particularly important in diabetic neuropathy, where nerve damage can impair the communication between the nervous system and muscles, leading to suboptimal muscle activation ([Callaghan et al., 2015](#)). By engaging patients in targeted exercises that stimulate both the nervous system and musculature, physiotherapy can help restore some of this lost function.

Second, the increased muscle activity may also reflect muscle hypertrophy in response to the physiotherapy intervention. Although diabetic neuropathy is associated with muscle atrophy, regular physical activity can stimulate muscle growth and counteract the effects of atrophy ([Resnick et al., 2002](#)). Exercises involved in conventional physiotherapy, such as resistance training and functional movements, are known to promote muscle hypertrophy by increasing the muscle load,

leading to an adaptive response characterized by increased muscle fibre size and strength ([Andersen et al., 2018](#)).

Additionally, physiotherapy may improve muscle blood flow, enhancing oxygenation and nutrient delivery. Diabetic neuropathy often involves microvascular complications that compromise blood flow to the lower limbs ([Edwards et al., 2008](#)). Improved circulation by physiotherapy could help alleviate some of these issues, contributing to better muscle function and increased MVC, as observed in the present study.

The results of the present investigation are consistent with a larger array of studies highlighting the advantages of physical exercise and rehabilitation in treating diabetic neuropathy. According to previous research ([Kluding et al., 2016](#); [Tesfaye et al., 2011](#)), exercise in patients with diabetic neuropathy can improve muscle strength, reduce discomfort, and improve overall quality of life. These interventions included resistance training, balancing exercises, and aerobic conditioning. Physiotherapy benefits this population, as demonstrated by the noteworthy increase in muscle activation noted in this study.

Furthermore, wireless EMG in this study represents an important advancement in assessing muscle function in diabetic neuropathy. Traditional EMG methods are often limited by the need for cumbersome equipment and restricted patient movement, which can affect the accuracy and reliability of data ([Ullah & Iqbal, 2020](#)). On the other hand, Wireless EMG allows for more natural movement during assessment, leading to potentially more accurate reflections of muscle function during everyday activities ([Rampichini et al., 2020](#)). The significant differences in the pre- and post-test EMG scores observed in this study highlight the potential of wireless EMG as a valuable tool for clinical assessment and research.

4.1 Clinical implications

The results of this study have important clinical implications for managing diabetic neuropathy. The significant improvements in muscle activity following conventional physiotherapy suggest that such interventions should be considered a cornerstone of treatment for patients with diabetic neuropathy, particularly those experiencing muscle weakness and reduced mobility. By improving muscle function, physiotherapy can help prevent the progression of complications associated with diabetic neuropathy, such as foot ulcers, falls, and amputations ([Harris-Hayes](#)

[et al., 2020](#)).

Moreover, these findings support the integration of wireless EMG into clinical practice as a means of monitoring muscle function in patients with diabetic neuropathy. Wireless EMG provides clinicians with a non-invasive and reliable method for assessing the effectiveness of physiotherapy interventions, allowing for more personalized and adaptive treatment plans ([Merletti et al., 2023](#)). By regularly monitoring changes in muscle activity, clinicians can adjust exercise prescriptions to maximize therapeutic outcomes and prevent further decline in muscle function.

4.2 Limitations and future recommendations

Although the study's results are beneficial, several limitations must be noted. The small sample size may limit the generalizability of the findings. Future research should focus on more extensive and diverse populations to better assess the effectiveness of conventional physiotherapy across different subgroups of individuals with diabetic neuropathy.

Furthermore, the effects of traditional physiotherapy constituted the only subject matter of this investigation. The best way to increase muscular activity in individuals with diabetic neuropathy would be to compare these findings with those of other rehabilitation methods such as electrotherapy, balancing training, or combination therapies. Future research may also examine how physiotherapy affects muscular function over the long run and whether persistent improvements continue to be seen even when the intervention is continued without supervision.

Finally, although the Noraxon wireless EMG has several benefits in terms of portability and user-friendliness, it is still a relatively new technology. More studies must confirm its accuracy and dependability in various clinical contexts. Future research should investigate wireless EMG in conjunction with other diagnostic methods, such as gait analysis or imaging, to offer a more thorough picture of muscle function in patients with diabetic neuropathy.

5.0 CONCLUSIONS

The study's findings, supported by higher EMG maximal voluntary contraction scores in the tibialis anterior and soleus muscles, indicate that conventional physical therapy considerably increases muscle activity in diabetic neuropathy patients. These results emphasize the role of physiotherapy in treating diabetic neuropathy and highlight wireless EMG as a useful tool

for evaluating and tracking muscle function in this population. These findings add to the excessive research demonstrating the value of physical therapy in reducing the impairing symptoms of diabetic neuropathy and enhancing patient outcomes.

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