Case Report

Short-term outcomes of a comprehensive rehabilitation program with peripheral magnetic stimulation in diabetic polyneuropathy: A case report

Tuangtip Surarangsit*

Department of Rehabilitation, King Chulalongkorn Memorial Hospital, Thai Red Cross Society, Bangkok, Thailand

Abstract

Polyneuropathy is a condition that affects the peripheral nervous system, often resulting in sensory and motor dysfunction in older adults. Treatment options include medications and various physical therapy modalities, such as peripheral magnetic stimulation (PMS). However, evidence supporting the use of PMS for treating nerve dysfunction remains limited. In this case, an 84-year-old man with a history of diabetes mellitus and osteoarthritis presented with bilateral lower extremity sensory and motor polyneuropathy, characterized by weakness, sensory deficits, and gait instability. After limited success with conventional treatments, a comprehensive rehabilitation program was implemented over four weeks, integrating PMS, occupational therapy, and advanced gait training.

Following this intervention, light touch sensitivity improved by up to 55.0%, and proprioception exhibited a 100.0% improvement. Furthermore, balance assessments demonstrated enhanced stability on unstable surfaces. However, nerve conduction studies revealed minimal changes in the sensory and motor functions. The combination of PMS and comprehensive rehabilitation strategies demonstrated promising benefits in improving sensory functions and balance, despite inconclusive nerve conduction study results. This case highlights the potential of a multifaceted rehabilitation approach in the management of polyneuropathy, and future research with larger sample sizes and longer treatment durations is necessary to confirm these findings and evaluate the long-term efficacy.

Keywords: Case report, nerve conduction study, peripheral magnetic stimulation, polyneuropathy, rehabilitation

Polyneuropathy is a disorder of the peripheral nervous system that is characterized by the involvement of sensory, motor, or autonomic nerve fibers. It can manifest in various forms, with distal symmetric polyneuropathy (DSPN) being the most common subtype. This condition is often identified by symmetrical symptoms and abnormal electrodiagnostic findings, which include impaired sensory and motor functions of the distal extremities.(1–4) The etiology of polyneuropathy is diverse, including metabolic disorders, autoimmune conditions, and infections, of which diabetes mellitus is one of the most prevalent causes. Diabetic polyneuropathy (DPN) is a major complication of diabetes, often leading to chronic pain, impaired mobility, and a substantial decrease in the patient's quality of life (QoL).(5, 6) The pathophysiology of DPN is primarily related to prolonged hyperglycemia, which results in microvascular damage, accumulation of advanced glycation end products, and impaired nerve blood supply. These factors contribute to nerve damage, leading to the characteristic sensory and motor deficits associated with the disorder.(7, 8)

DPN primarily presents as a length-dependent, distal symmetric polyneuropathy. Early symptoms include numbness, tingling, and burning sensations in the feet and hands, often progressing to motor

***Correspondence to: Tuangtip Surarangsit,** Department of Rehabilitation, King Chulalongkorn Memorial Hospital, Thai Red Cross Society, Bangkok 10330, Thailand.
E-mail: tstuangtip@gmail.com
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dysfunction and loss of protective sensation. The management of DPN generally involves optimizing glycemic control, pharmacologic interventions for pain management, and lifestyle modifications. Despite these treatments, there is no single, effective cure for DPN, and many patients continue to experience considerable morbidity. The main focus of treatment is to improve QoL by alleviating the symptoms and preventing progression.[9, 10]

Rehabilitation plays a crucial role in the comprehensive management of polyneuropathy. Its objectives include restoring function, preventing abnormal compensation, relieving pain, and improving QoL. A variety of rehabilitation techniques are employed, such as physical therapy, with modalities like peripheral magnetic stimulation (PMS) and transcutaneous electrical nerve stimulation, which are gaining attention for their potential benefits. Although clinical evidence supporting the efficacy of these therapies is still emerging, they have exhibited the potential to enhance nerve conduction and reduce neuropathic symptoms.[11–13]

PMS is a noninvasive therapeutic modality that utilizes rapidly changing magnetic fields to generate electrical currents within the peripheral nerves and muscles. This process induces nerve depolarization and enhances neural excitability, thus potentially facilitating axonal regeneration and improving nerve conduction. Evidence suggests that PMS can improve nerve function in patients with DPN, with improvements observed in nerve conduction velocity (NCV) and sensory nerve action potential (SNAP) amplitude, which are key indicators of nerve health.[14, 15] Despite these promising results, further research is required to better understand the full extent of PMS's therapeutic effects.

This retrospective case report evaluates the effectiveness of PMS treatment in combination with a structured rehabilitation program on light touch sensation, proprioception, balance, and nerve conduction studies in a patient with polyneuropathy. The patient underwent eight treatment sessions at the Physical Therapy Unit, Department of Rehabilitation, King Chulalongkorn Memorial Hospital, Thai Red Cross Society. This report aims to contribute to the growing body of evidence regarding the role of noninvasive therapies, such as PMS, in the rehabilitation of patients with DPN and other forms of peripheral neuropathy.

Materials and methods

The patient, an 84-year-old male, had a medical history of diabetes mellitus, dyslipidemia, hypertension, benign prostatic hyperplasia, ankylosing spondylitis, and hip osteoarthritis. His primary concerns were bilateral weakness and numbness in the lower limbs, leading to instability during standing and gait. Although he lives independently, his mobility issues and related symptoms have significantly impacted his QoL. No specific genetic tests were conducted, but his medical history and symptoms suggest a complex interplay of age-related changes and chronic conditions affecting nerve function. The patient had previously been prescribed various medications, including pregabalin, diacerein, methylphenidate, losartan potassium, and amlodipine, to manage his symptoms and underlying conditions. Despite these treatments, pharmacologic and conservative interventions, failed to adequately address his sensory and motor deficits, highlighting the need for an integrated rehabilitation approach. The rehabilitation program was designed to enhance sensory reeducation while improving balance and gait, potentially offering a more comprehensive solution to the challenges associated with his polyneuropathy.

During the physical examination, the patient's muscle strength in both lower extremities was normal, except for the hip flexors, which were graded IV+ on the right and V on the left. Sensory deficits included impaired pinprick and light touch sensations following a glove-and-stocking pattern, accompanied by diminished temperature sensation and proprioception in both lower extremities. Systematic testing of light touch and proprioception was conducted to establish objective and comparable measurements. Static light touch sensation was assessed at various sites, including the medial and lateral aspects of the legs, ankles, and the first to fifth toes. Proprioception testing was performed in the ankle joint and the first to fifth toes, with each area, assessed ten times, and the results were reported as a percentage of the correct responses. For the balance assessment, the modified clinical test of sensory integration and balance (CTSIB) was utilized, which revealed distinct variations in stability under different conditions **(Table 1).** The patient demonstrated excellent balance on a firm surface with eyes open, as indicated by a mean center of gravity sway velocity of 0.3°/s. However, when the visual input was removed, the sway velocity

Table 1. Modified clinical test of sensory integration and balance (CTSIB).

	Firm eyes opened (degree/sec)	Firm eyes closed (degree/sec)	Foam eyes opened (degree/sec)	Foam eyes closed (degree/sec)
Before treatment	0.3	0.8	0.6	1.1
After treatment	0.3	0.9	0.3	0.9

Table 2. Sensory and motor nerve conduction study.

Sites	Latency (ms)	Amplitude (µV)	SNCV/MNCV (m/s)
Sensory nerve			
Before treatment			
Right – ulnar wrist	3.0	20.6	64.0
Right – sural calf	NR	NR	NR
Left – sural calf	2.6	6.2	38.4
After treatment			
Right – ulnar wrist	2.8	26.4	53.9
Right – sural calf	NR	NR	NR
Left – sural calf	1.9	10.8	53.3
Motor nerve			
Before treatment			
Right – ulnar wrist	3.2	8.5	58.1
Right – common peroneal extensor digitorum bravis	NR	NR	NR
Left – tibial abductor hallucis	4.1	3.8	-
After treatment			
Right – ulnar wrist	3.2	10.4	53.3
Right – common peroneal extensor digitorum bravis	NR	NR	NR
Left – tibial abductor hallucis	5.5	2.5	-

*NR, non-response; MNCV, motor nerve conduction study; SNCV, sensory nerve conduction study.

increased to 0.8°/s, suggesting a noticeable decline in stability likely due to reliance on visual cues. When the patient's balance was assessed on an unstable foam surface with eyes open, the patient's sway velocity decreased to 0.6°/s, indicating diminished balance compared to the firm surface, yet he remained relatively stable with visual support. The most pronounced instability occurred on the foam surface with eyes closed, where the sway velocity reached 1.1°/s. These findings highlight the considerable impact of the absence of visual information and surface instability on the patient's balance, thus suggesting areas for further evaluation and targeted intervention. In addition, the patient exhibited an ataxic gait, which contributed to instability during static and dynamic standing.

Diagnostic assessments included electrodiagnostic studies, which revealed specific abnormalities in sensory and motor nerve function **(Table 2).** Notably, action potentials for the right sural and common peroneal nerves were unobtainable, and the left tibial nerve compound muscle action potential exhibited low amplitude. Moreover, a borderline distal sensory latency was also observed in the right ulnar nerve. Based on these findings, a diagnosis of sensorimotor axonal polyneuropathy was established. The prognosis for DPN remains uncertain, as maintaining well-controlled glycemic levels has shown potential to halt disease progression, although its long-term effects are not fully understood.

Historical information indicated that the patient had symmetrical bilateral lower extremity impairments, including deficits in light touch, pinprick, temperature

Figure 1. The area of PMS applied at **(A)** medial-lateral leg with three TESLA coil; and **(B)** foot with one TESLA coil.

sensation, and proprioception, accompanied by balance instability. These symptoms did not improve with pharmacological management or behavioral modification. Therefore, the current episode of care began with the initiation of a combined rehabilitation program that included PMS, occupational therapy, and advanced gait and balance training. This treatment lasted for 4 weeks, comprising twice-weekly PMS sessions, weekly occupational therapy, and weekly gait and balance training.

The therapeutic interventions included pharmacological treatments and physical therapy. The patient continued his daily medication regimen, which included pregabalin, diacerein, methylphenidate, losartan potassium, and amlodipine. Physical therapy consisted of the PMS model REMED Salus Talent (Metta Medtech Co., Ltd., Korea), which was applied twice a week using a three TESLA electromagnetic field with burst frequencies ranging from 5 to 40 Hz and one TESLA electromagnetic field at a frequency of 10 Hz, with treatment lasting ten min for each leg and foot. The PMS stimulation intensity was adjusted based on the patient's tolerance, with average intensities recorded at 56.0% for the right leg, 100.0% for the ventral of the right foot, 59.6% for the left leg, and 100.0% for the ventral of the left foot. Advanced gait and balance training occurred during weekly 45-min sessions using a gait trainer and balance master, incorporating visual biofeedback to enhance weight shifting and stepping efficiency, which was more effective than conventional methods. Occupational therapy involved sensory reeducation using various textured equipment and alternating warm- and cold-water applications to areas of sensory deficit, along with a daily home exercise program **(Figure 1)**.

Upon follow-up, clinician-assessed outcomes indicated an improvement in sensory function, with notable increases in the percentage of perceived light touch sensation and proprioception at the toe level **(Figure 2)**. However, nerve conduction studies reflected improvements and deteriorations in nerve function. The results of the light touch and proprioception tests indicated significant enhancements. Specifically, light touch sensitivity

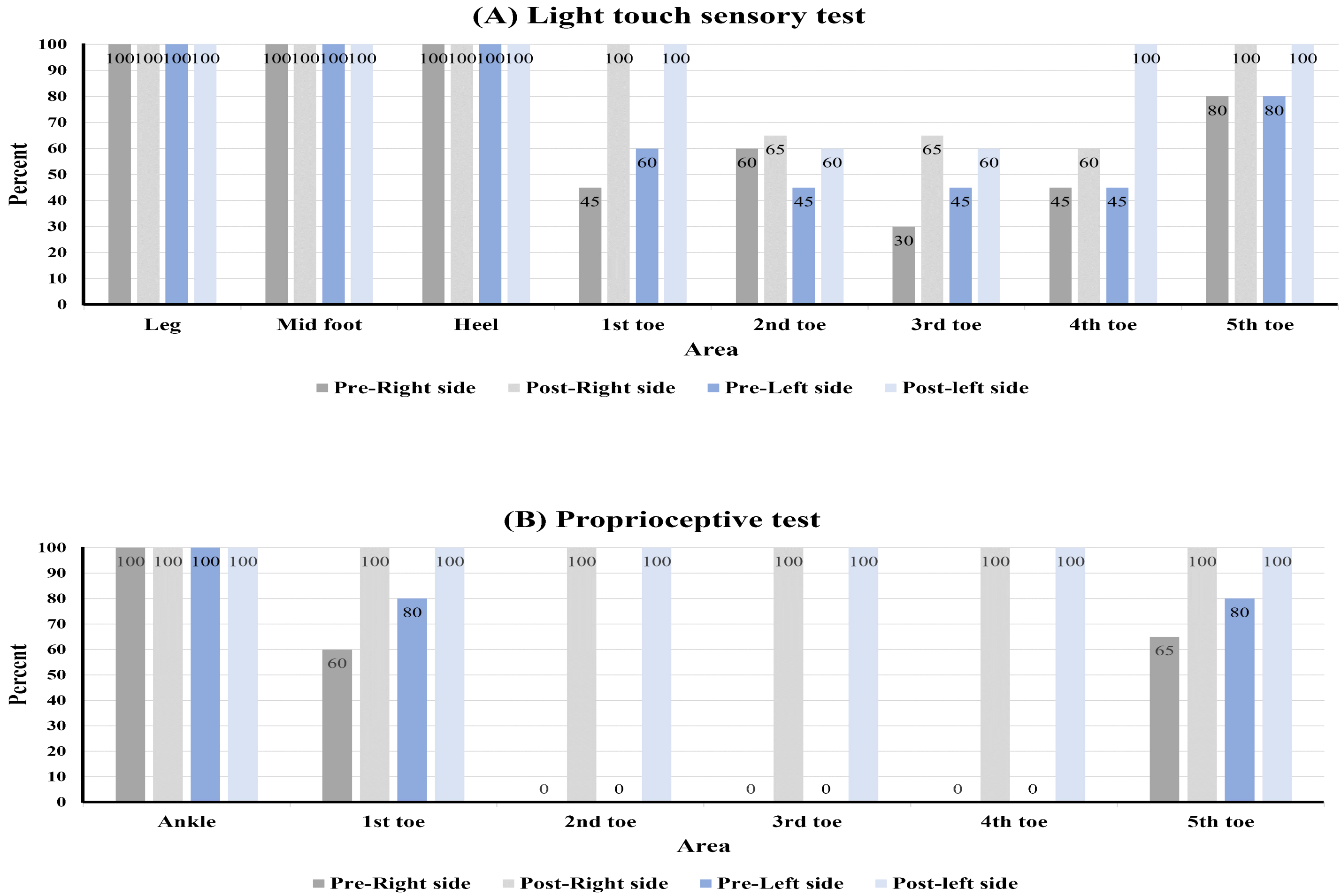

Figure 2. (A) The light touch sensory test; **(B)** The proprioception test.

increased by 55.0%, 5.0%, 35.0%, 15.0%, and 20.0% for the right first to fifth toes and by 40.0%, 15.0%, 55.0%, and 20.0% for the left first to fifth toes, respectively. Proprioception showed enhancements of 40.0%, 100.0%, 100.0%, 100.0%, and 35.0% for the right first to fifth toes and by 20.0%, 100.0%, 100.0%, 100.0%, and 20.0% for the left first to fifth toes, respectively. Balance was assessed using the modified CTSIB, revealing a decrease in sway velocity on an unstable surface with both eyes open and closed. No significant changes were observed on a firm surface. Electrodiagnostic studies showed some improvements, including decreased distal sensory latency and increased amplitude and velocity of the left sural nerve. However, motor nerve conduction studies revealed prolonged distal motor latency and a slight decrease in amplitude of the left tibial nerve. Adherence to the therapy regimen was closely monitored, and patient tolerance to PMS was adjusted according to the individual's comfort levels. Throughout the treatment period, there were no significant adverse or unanticipated events reported.

Discussion

This case report investigated the effects of a rehabilitation program, including PMS, advanced gait training, and occupational therapy, on NCV, light touch sensitivity, proprioception, and balance in a patient with symmetrical distal polyneuropathy. The primary hypothesis was that PMS could enhance sensory and motor nerve function by generating a magnetic field that helps preserve nerve fiber function. This magnetic stimulation is believed to improve proprioceptive input via the lemniscal-thalamic pathways to the sensory-motor cortex, which may lead to improved motor performance and cortical excitability.[16]

This case is unique because of its comprehensive approach in combining PMS with an advanced rehabilitation program for polyneuropathy. While PMS alone has shown promise in improving nerve function, integrating it with a structured rehabilitation program is relatively novel. This combined approach was expected to offer a more holistic approach to managing polyneuropathy, addressing the sensory and motor deficits more effectively than conventional treatments alone. In addition, the patient's age and the multifaceted nature of his polyneuropathy, combined with a detailed assessment of sensory and motor functions, added to the uniqueness of this case.[17, 18]

PMS parameters can vary, with research indicating that frequencies such as 10 and 25 Hz, or even higher, can influence muscle contraction and proprioceptive stimulation.[19] In this case report, frequencies ranging from 10 to 40 Hz were used to enhance light touch sensitivity and proprioception, which could potentially improve postural stability. Our findings after the intervention showed a decrease in the mean center of gravity sway velocity, as measured by the modified CTSIB test when standing on an unstable surface. This test evaluates the sensory component of postural stability. These results support our hypothesis that PMS can enhance proprioceptive sensation and sensory integration, thereby improving the patient's balance. When combined with other rehabilitation treatments focused on improving strength, flexibility, and correcting biomechanical abnormalities, these outcomes may be further enhanced via this comprehensive treatment approach.

In this case, the nerve conduction study (NCS) showed improvement in the left sural nerve after the 4-week rehabilitation period, while the motor nerve conduction study of the left tibial nerve revealed an increase in distal motor latency.

Previous research suggests that substantial changes in neurophysiological markers, such as SNAP amplitude, may require longer treatment durations.[20] The absence of observed changes in the NCS might be attributed to the short duration of the intervention. As noted by Panathoop A, *et al.* [21], improvements in SNAP amplitude can indicate the onset of neurophysiological changes, though these changes may become more apparent over a longer treatment period.[21]

The primary limitation of this case report is the brief intervention period, which may not have been sufficient to detect meaningful changes in the nerve conduction metrics. In addition, the single-patient design restricts the generalizability of the findings. However, this report emphasizes the potential benefits of a comprehensive rehabilitation approach combining PMS, physical therapy with biofeedback, and occupational therapy. By integrating multiple therapeutic modalities, this approach may offer a more holistic treatment strategy, addressing various aspects of polyneuropathy, thereby potentially providing benefits beyond what is achievable with medication alone. The combined therapies aim to enhance the sensory and motor functions in a complementary manner, which may lead to improved patient outcomes. Future studies with larger sample sizes, extended treatment durations, and control groups are necessary to further evaluate the effectiveness of such comprehensive rehabilitation programs and their role in managing polyneuropathy. The patient expressed a positive outlook on the received treatment, noting improvements in his ability to perform daily activities and better overall stability. He expressed increased confidence and security when walking and standing, which has significantly improved his QoL. The combined approach of PMS, occupational therapy, and advanced gait training was appreciated for comprehensively addressing various aspects of his condition **(Figure 3)**. The patient also acknowledged the need for continued therapy and is hopeful that ongoing treatment will further enhance his functional abilities and nerve health.

Conclusion

This case report assessed the short-term effects of a comprehensive rehabilitation program, including PMS, advanced gait training, and occupational therapy, on the sensory and motor functions in a patient with symmetrical distal polyneuropathy. After a 4-week intervention, significant improvements were observed in light touch sensitivity, proprioception, and stability during gait and balance tasks. Despite these functional gains, the NCS did not reveal significant changes in the neurophysiological parameters. The lack of substantial NCS improvements may be related to the limited duration of the treatment, which suggests that a longer-term intervention may be necessary to achieve measurable changes in nerve conduction metrics. Further research with extended treatment durations and larger sample sizes is needed to confirm these findings and to better understand the long-term efficacy of PMS in combination with rehabilitation therapies for managing polyneuropathy.

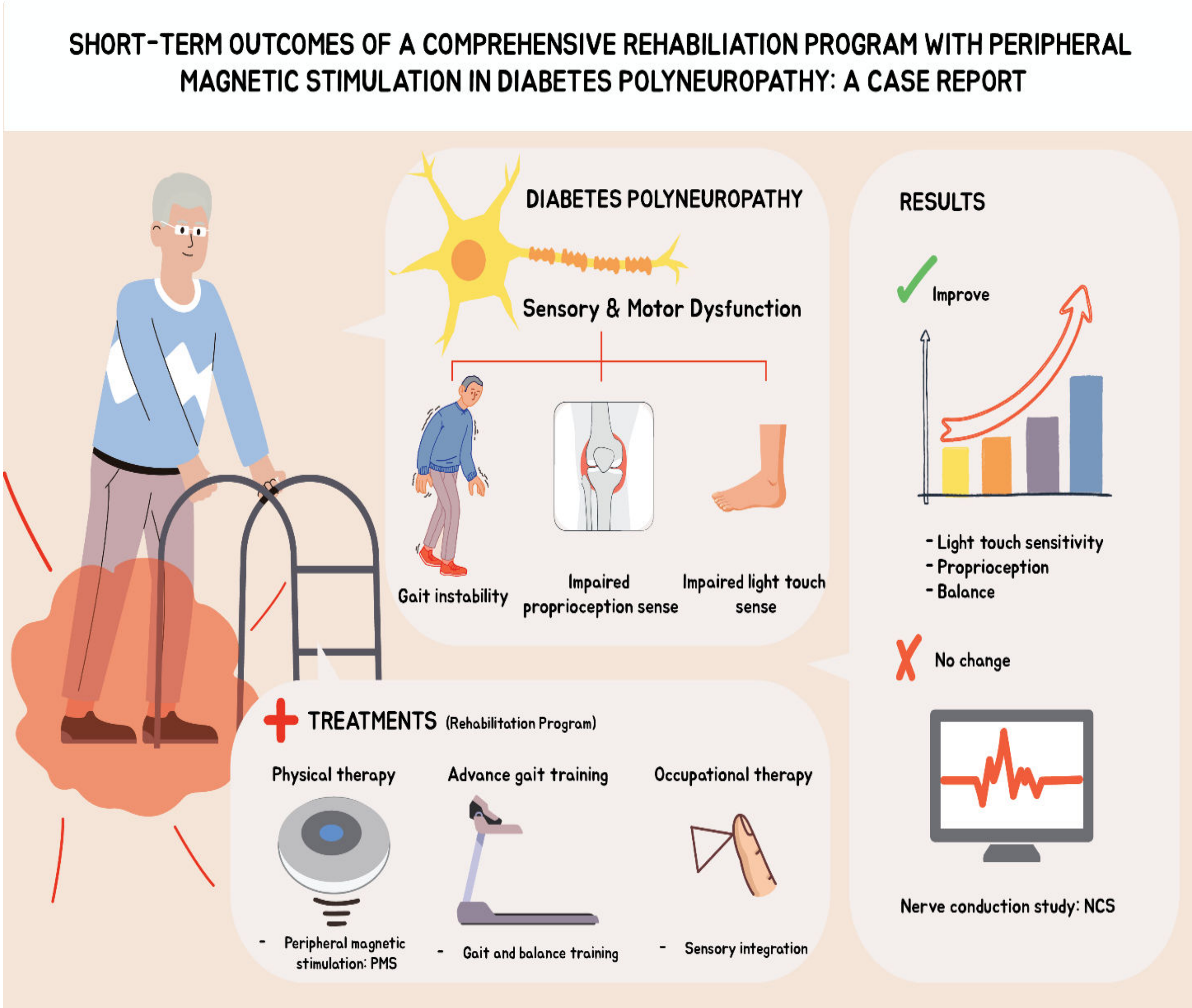

Figure 3. The combined approach of PMS treatment**.**

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Conflict of interest statement

The author has completed an ICMJE disclosure form. The author declares that they do not have any potential or actual relationship, activity, or interest related to the content of this article.

Data sharing statement

Data generated or analyzed for the present report are included in this published article. Further details are available from the corresponding author on reasonable request after deidentification of the patient whose data are included in the report.

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