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Effect of sensory retraining program on latency, amplitude and conduction velocity of sensory nerves of lower limb in type 2 diabetic peripheral neuropathy

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ABSTRACT

Introduction and aim. India is known as the world's diabetes capital. Diabetic neuropathy is the most common complication of diabetes, and if not managed properly, leads to diabetic foot complications like ulcers and amputations. Physiotherapy interventions addressing these complications are very limited. Hence, this study was performed to access to what extent a sensory retraining program affects the latency, amplitude, and conduction velocity of the sural nerve in lower limbs. The study aims to improve the nerve conduction velocity of the sural nerve in diabetic neuropathy with a sensory retraining program.

Material and methods. One-hundred individuals who met the inclusion criteria were randomly allocated into 2 groups. The control group had received routine medical care. The experimental group individuals were managed with a sensory retraining program 5 days a week for 16 weeks. Latency, amplitude, and conduction velocity values were recorded before and after the study.

Results. Results conclude that the sensory retraining program is effective in decreasing the latency and improving conduction velocity. It did not have any effect on the amplitude.

Conclusion. Hence, we conclude that a sensory retraining program can be incorporated into routine physical therapy intervention in subjects with diabetic peripheral neuropathy.

Keywords. amplitude, conduction velocity, diabetic neuropathy, latency, sensory retraining, sural nerve

Introduction

The increasing prevalence of diabetes mellitus (DM) is particularly alarming, and the World Health Organization predicts it will become the sixth leading cause of death by 2030. With 6.7 million deaths attributed to diabetes in 2021, it underscores the urgent need for comprehensive strategies to address this chronic condition.[1] Individuals living with type 2 diabetes mellitus (T2DM) are indeed at risk of experiencing both short-term and long-term complications if the condition is not effectively managed. These complications can significantly impact quality of life and increase the risk of premature death if not managed effectively.[2]

In diabetic individuals, anomalous changes in blood glucose levels can damage nerves.[3] Sixty to seventy percent of DM individuals have nervous system involvement.[4] Peripheral neuropathy is the most common type of neuropathy in DM.[5] Even the state of "Impaired Glucose Tolerance" has a negative influence on the conduction velocity of nerves.[6] Every 20 seconds, a lower limb is lost due to diabetic neuropathy complications. Eighty-five percent of lower limb amputations are preceded by diabetic foot ulcers.[7] Diabetic peripheral neuropathy (DPN) increases the amputation risk 1.7 times.[8] The sural nerve innervates the major weight accepting areas of the sole of the foot. Due to this length dependent relation, it is commonly involved in DPN. The electro-physiological evaluation of the sural nerve has a high diagnostic value in detecting DPN. Gurinder Mohan et al. in their study on type 2 diabetic neuropathy patients have concluded that in 80% of the patients, the sural nerve is involved followed by 62% tibial and 50% deep peroneal nerves.[9]

The treatment protocols for DPN present a challenge as reported in the current literature given the multifaceted nature of the condition and its associated complications, which require careful consideration during physiotherapy interventions. The ongoing debate regarding the potential reversibility of nerve damage highlights the intricate nature of addressing DPN and necessitating a diverse array of treatment strategies. While some research studies have suggested improvements in nerve conduction velocity through pharmacological interventions like aldose reductase inhibitors, others have demonstrated the efficacy of physical exercise modalities such as Tai Chi and aerobic exercises in enhancing nerve function. Nevertheless, there remains a scarcity of empirical evidence regarding the effectiveness of sensory retraining programs in improving key neurophysiological parameters such as latency, amplitude, and conduction velocity of sensory nerves in the lower limb. Given the pivotal role of the sural nerve which is a significant nerve in the lower limb responsible for supplying essential regions of the sole and is closely associated with DPN, this research aims to investigate the potential efficacy of sensory retraining programs in enhancing these parameters.

Aim

The aim of this study is to improve nerve conduction velocity of the sural nerve in diabetic neuropathy by implementation of a sensory retraining program.

Material and methods

Ethical clearance

Approval was obtained from the Ethics Committee (Reg.No.No.ECR/477/Inst/AP/2013.). Patients were informed about the procedure of the study. A written informed consent was obtained from all the patients before their participation in the study.

Inclusion criteria

Type 2 diabetic neuropathy, both genders, Age: 45–60 years, TCSS – moderate neuropathy score 9–11, non-obese individuals.

Exclusion criteria

Individuals having following conditions were excluded: plantar ulcers, spinal deformities, amputations, arthritis of lower limb joints, radiculopathy, severe visual and vestibular disorders, history of angina and CABG, neurological disorders like stroke, cerebellar ataxia, myelopathy, postural hypotension, other causes of neuropathy like severe B12 deficiency, liver and kidney diseases, thyroid disorders, connective tissue diseases and other metabolic or hereditary neuropathies, skin lesions that interfere with the procedure, alcoholics, smokers, patients using medicines that interfere with nerve function like isoniazid, and furaxone.

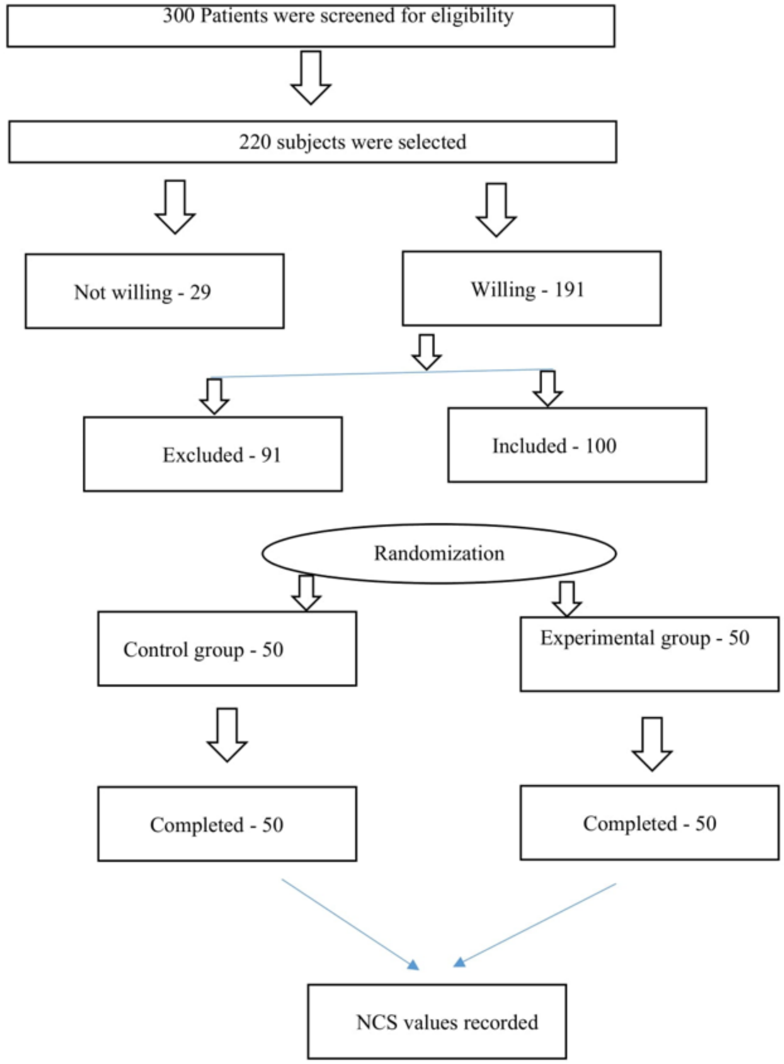

Fig. 1. CONSORT flow diagram

Methodology

In this study, we enrolled 100 subjects. They were randomly split into 2 groups: a control group and an experimental group of 50 each. Once the informed consent was signed, base line recordings were taken and a procedure for sural NCS recording.[10,11] The procedure was carried out by using an Octopus clarity EMG-NCV machine. Based on our previous work, we have recorded and measured unilateral values as there are no right left differences in the NCS parameters in DPN patients.[12] An anti-dromic method of sensory nerve conduction of the sural nerve was followed.

Machine Settings: Frequency – 20 Hz to 3 kHz, Sweep speed- 2 ms/division, Gain – 20 µV/division.

The Microsoft Excel and GraphPad prism software (Graphstats Technologies, Karnataka, India) were used for analysis of the data. The p values less than 0.05 were regarded as statistically significant.

Treatment protocol

Treatment protocol for control group

Continuing their regular medical care, participants in the control group benefit from ongoing foot examinations, ensuring their health is carefully monitored throughout the study. Upon completion of the study period, they receive exercises tailored to support their well-being further.

Treatment protocol for experimental group

Embarking on a transformative journey spanning 16 weeks, participants in the experimental group engage in a meticulously crafted exercise regimen, designed to enhance sensory perception.[13,14] With dedicated sessions five days a week. The exercises were done sequentially starting with warm-up and ending with cool-down, with frequent rest periods in between.

Warm-up exercises (5 minutes)

Relaxed deep breathing exercises: 2 minutes

Bilateral knee and ankle free range of motion exercises: 2 minutes, stretching: 1 minute and 1 – minute rest.

Static Balance Exercises – the following exercises were done on firm (floor) surface progressed to foam (soft mattress) surface.

On both the surfaces individuals should practice with the following variations – with eyes open, eyes closed, head neutral, head extended (slightly between 10–20 degrees).

Exercises – normal double limb stance, closed stance, tandem stance, single limb stance – on both legs, heel standing, toe standing. 2 mins rest is allowed.

Dynamic activities – the following exercises were done on firm (floor) surface progressed to foam (soft mattress) Surface. On both the surfaces individuals should practice with the following variations -with eyes open, eyes closed, head neutral, head extended (slightly between 10–20 degrees).

Walking forwards – 4 mins, walking backwards – 4mins. One minute rest is allowed after completing the tasks. Walking sideways – 4 mins, tandem gait – 4 mins. Again 1min rest is allowed.

Exercises on stability disc – Participants may use support initially for confidence. Exercises on stability disc are as following: standing stable – 2 mins, squatting – 2 mins, standing on one leg – 1 min, heel rise – 1min. Upon completing the 4 exercise variants. 2 mins rest is incorporated.

Cool-down (5 minutes):

As the session draws to a close, participants gone through a phase of cool-down exercises which are similar to warm-up exercises. With the completion of the study, participants Sural NCS values are once again meticulously recorded.

Results

There is no significant difference between control group and experimental groups, for the parameters age (years), height (cm), weight (kg), BMI- body mass index (kg/m^2), DM (years), Toronto clinical scoring system (TCSS).

Table 1. Baseline values of control group and experimental group

Parameters	Groups	n	Minimum	Maximum	Mean	SD	p
Age (years)	Control group	50	45	59	51.26	4.29	0.653
	Experimental group	50	45	59	50.88	4.12	
Height (cm)	Control group	50	147	173	159.8	5.77	0.615
	Experimental group	50	147	173	159.2	6.49	
Weight (kg)	Control group	50	50	74	60.54	6.04	0.269
	Experimental group	50	50	72	59.22	5.83	
BMI (kg/m^2)	Control group	50	21.1	25	23.65	1.14	0.220
	Experimental group	50	20.2	25	23.34	1.39	
DM (years)	Control group	50	10	15	11.82	1.64	0.635
	Experimental group	50	10	15	11.98	1.72	
TCSS	Control group	50	9	11	9.82	0.80	0.721
	Experimental group	50	9	11	9.88	0.87	

Table 2. Latency, amplitude and conduction velocity values of control group and experimental group – pre and post intervention.

Parameters	Experimental group (n=50) Mean Value		p	Control group (n=50) Mean Value		p
	Pre	Post		Pre	Post	
Latency	2.92	2.65	<0.0001	2.98	3.00	0.132
Amplitude	7.88	7.76	0.858	7.56	7.42	0.524
Conduction velocity	35.11	38.78	<0.0001	35.22	35.02	0.074

After completion of the treatment period latency, amplitude and conduction velocity values of sural nerve were recorded among all individuals in both the groups.

Table 2 shows in experimental group latency was decreased, amplitude is decreased and CV is increased. This infers the given exercise is effective only on latency and CV. On the other hand in control group –

latency was increased, amplitude is decreased and CV also decreased. This infers that the disease is progressing.

Discussion

In diabetes hyperglycemia stimulates the production of neurotrophin like nerve growth factor (NGF) and accelerates the neuropathy by interfering with the normal axonal repair and regeneration.[15] Neuropathy robs the individual's ability to recognize about detrimental pressure and pain. It is also associated with decreased activity levels, sensory impairments and arterial diseases that results in lower limb complications like ulcers, infections etc.[16] In DPN the touch and thermal sensations are decreased in the heels, which are innervated by sural nerve. This is the nerve to be damaged first in the progression of the disease.[17] There is no effective medical management for enhancing the peripheral nerve function.[18] As the peripheral nerves have the ability to regenerate, early diagnosis and early intervention reduces the morbidity, mortality and increases the QOL.[19]

After completion of the study (Table 2) there observed decreased latency and improved conduction velocity which states that sensory retraining program is effective to improve the peripheral nerve function, means peripheral nerve is responsive to our intervention.

Very few studies were done to know the effect of exercise on NCV. Our study results co insides with the work done by Hung et al. who have proved that 12 weeks of Tai Chi Chuan exercise showed increase in MNCV of bilateral median and tibial nerves.[20] Snehil Dixit et al. have given 8 weeks of aerobic training for DPN patients and proved that both sural and peroneal nerves have shown improved conduction.[21] Sukhee Ahn et al. have proved that 1 hour of Tai Chi per session, twice a week for 12 weeks, improved glucose control, balance, neuropathic symptoms, and some dimensions of quality of life in diabetic patients with neuropathy.[22] Zakaria et al., treated DPN patients with LASER and exercises. The results of this study showed significant improvement in sensory and motor nerve conduction velocity due to increase in nerve regeneration which leads to improvement in superficial sensation.[17] Balduccia et al., in their study of 4 years of mild aerobic exercise can arrest the development of DPN. Sural NCV in control group decreased and in experimental group remained the same.[23] Amplitude is not increased after the intervention as exercise can never change the number of nerve fibers. This has been supported by Balduccia et al.[23] Exercise can influence the micro vascular factors by facilitating the blood flow to the peripheral nerves. So the improvement in the NCS measures could be due to vascular adaptations in the nerves.[24] While doing exercise there will be increased temperature. With increase in the skin temperature the sodium channels will undergo hyper polarisation and there will be faster impulse propagation. Sodium influx is increased and the latency is decreased. Per 1 degree Celsius raise in the temperature there is 5% increase in the nerve conduction.[25]

With exercise there will be a decrease in oxidative stress and reduced inflammation is seen. Even the neurotrophin growth factor levels are restored. The demyelination process can be arrested and myelin damage is prevented. Physical activity will decrease Ca^{2+} channel dysfunction and help to improve nerve conduction.[27]

Study limitations

The exploration of sensory retraining-induced conduction increment mechanism was not conducted in this study. A follow-up to ascertain the extent of treatment benefits was not conducted as part of this study. Future research can be done to know the reversibility of nerve function that can be thoroughly analyzed through the utilization of invasive and quantitative techniques such as intraepidermal nerve fiber density (I E2N3 FD) etc. Follow-up trials can provide valuable insights into the duration for which the treatment effects are sustained, offering a comprehensive understanding of the long-term efficacy of the intervention.

Clinical implications

The implementation of a sensory retraining program emerges as a promising avenue within rehabilitation, offering tangible benefits for nerve function enhancement. Clinicians can strongly recommend this treatment protocol for betterment of the patients. The sensory retraining program holds promise not only as a treatment technique but also as a proactive preventive therapy. By incorporating it into preventive care strategies, individuals may proactively fortify their sensory functions, potentially averting the onset or progression of conditions like diabetic peripheral neuropathy.

Conclusion

Routine balance training can be incorporated with sensory specific exercises to get promising benefits to DPN individuals. The findings of this study conclude that there is significant improvement in latency, conduction velocity with sensory specific retraining in DPN individuals. Thus these exercises are recommended for reversing the pathological process of the distal nerves of the lower limbs.

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Declarations

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Author contributions

Conceptualization, S.M., S.A., K.K.B., E.R.K. and S.P.; Methodology, S.M., S.A., K.K.B., E.R.K. and S.P.; Software, S.M., S.A., K.K.B., E.R.K. and S.P.; Validation, S.M., S.A., K.K.B., E.R.K. and S.P.; Formal Analysis, S.M., S.A., K.K.B., E.R.K. and S.P.; Investigation, S.M., S.A., K.K.B., E.R.K. and S.P.; Resources, S.M., S.A., K.K.B., E.R.K. and S.P.; Data Curation, S.M., S.A., K.K.B., E.R.K. and S.P.; Writing – Original Draft Preparation, S.M., S.A., K.K.B., E.R.K. and S.P.; Writing – Review & Editing, S.M., S.A., K.K.B., E.R.K. and S.P.; Visualization, S.M., S.A., K.K.B., E.R.K. and S.P.; Supervision, S.M., S.A., K.K.B., E.R.K. and S.P.; Project Administration, S.M., S.A., K.K.B., E.R.K. and S.P.; Funding Acquisition, S.M., S.A., K.K.B., E.R.K. and S.P.

Conflicts of interest

No potential conflict of interest was reported by the author(s).

Data availability

The data related to the current study is available with the corresponding author.

Ethics approval

Approval was obtained from the Ethics Committee (Reg.No.No.ECR/477/Inst/AP/2013.)

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