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RESEARCH ARTICLE

The Effect of High Frequency Nerve Stimulation on Interoception and Pain in Dialysis Patients with Peripheral Neuropathy

H Swetha[1], **Kalidasan Varathan**[1]*

1 Krupanidhi College of Physiotherapy, Bengaluru, 560035, Karnataka, India

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* **Corresponding author**.

physio.kric@krupanidhi.edu.in

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Abstract

Background and Purpose: Optimal treatment for Uremic Peripheral Neuropathy in dialysis patients is widely agreed to be pharmacological therapy for the underlying cause. Several authors recommend a rehabilitation program or intensive physiotherapy as a vital part of a patient's recovery, but there is little definitive evidence that rehabilitation improves outcome. In part, this is due to the lack of research undertaken into the long-term functional outcomes for patients with Peripheral Neuropathy. **Objectives:** To evaluate High-frequency stimulation on interoception and pain in dialysis subjects with peripheral neuropathy. **Methods:** Based on the inclusion criteria after obtaining informed consent, thirty subjects were included in the study. The participants were administered 20 minutes of Transcutaneous Electrical Nerve Stimulation (TENS) 3 days per week for 6 weeks. The timed Vibration Sense test at the great toe, medial malleolus, tibial tuberosity, Joint Position sense, and Neuropathy Pain scale were used as outcome measures. **Findings:** The result obtained after the analysis of paired t-tests within the group shows significant improvement in mean post-test scores of vibration sense test at great toe, medial malleolus, and tibial tuberosity with p value 0.000. The result also shows significant improvement in mean post-test scores of the joint position sense test and neuropathy pain scale with p-value < 0.05. **Conclusion:** Electrical Nerve stimulation has positively affected interoception and pain for dialysis patients with peripheral neuropathy. TENS may be most beneficial not only for pain reduction but also for subjects with neuropathy symptoms. **Novelty :** This study evaluated the effectiveness of the electrical modalities over the pain and interoception aspects of peripheral neuropathy, as it was not previously assessed.

Keywords: Transcutaneous electrical nerve stimulation; Electrical Stimulation; Peripheral Neuropathy; Uremic Neuropathy; Hemodialysis

1 Introduction

Reduced kidney function that lasts for three months or longer is known as chronic kidney disease (CKD), which includes stages of disease ranging from minor kidney

damage to end-stage disease[1]. Peripheral neuropathy affects 60-100% of people undergoing dialysis for chronic renal disease[2]. The presence of neuropathy in some patients is also treated with the 24-30 hours standard hemodialysis schedule, twice or thrice weekly, and the worsening of peripheral neuropathy after the beginning of chronic hemodialysis[3]. Numerous variables, such as the length of renal insufficiency, the estimated Glomerular Filtration Rate (GFR), the length of dialysis, and others, influence the degree of peripheral neuropathy[4].

It can impact motor, sensory, and cranial nerves and is characterized by axonal degeneration with secondary demyelination that primarily affects the legs instead of the arms[5]. Typically, symptoms of peripheral neuropathy don't start to manifest until the GFR is between 12 and 20 mL/min[6]. The patients frequently have tingling paresthesia, impaired joint position sense (JPS), and impaired vibration sense (VBS)[7]. Electrophysiological data confirm that metabolic polyneuropathies, which are both brought on by chronic kidney disease and diabetes, frequently manifest as a symmetrical, progressive neuropathy beginning in the lower leg nerves[8]. Most illness and death rates are caused by neurological problems[9]. Clinical examination reveals diminished deep tendon reflexes and vibratory sensation[10].

Studies on nerve conduction show axonal generalized neuropathy, including reduced sensory and motor amplitudes and relative preservation of conduction velocities[11]. Small-sized fibers can also be compromised, with changes in temperature perception pain (described as a burning sensation)[12]. The most accurate method for identifying polyneuropathy is an ankle reflex test paired with either vibration or pinprick sensory testing[13]. When there is a decrease in motor function, neuropathy is regarded as a sign that renal replacement therapy should be started[14]. In clinical practice, a battery of tests, including assessing vibratory feeling, is used to diagnose diabetic peripheral neuropathy[15].

Electrical currents are applied to the skin above the painful location in transcutaneous electrical nerve stimulation (TENS) with frequencies between 10 and 120 Hz[16]. Numerous frequencies, lengths of time, and intensities are adjustable with TENS. Raising the sensory threshold in the area, the 40–120 Hz high-frequency TENS momentarily lowers the cutaneous (skin) perception of touch[17]. TENS uses an electrical current to modify the membrane polarity of peripheral nerves[18]. TENS can produce evoked tactile sensations[19]. The fundamental mechanism of TENS is based on the pain gate control theory, which prevents nociceptive signal transmission[20]. Although this intervention stimulates cutaneous nerves and muscle spindle, it causes a mixed experience of tactile feedback and proprioception[21]. TENS enhances strength, joint position awareness, and balance[22].

It is generally accepted that pharmaceutical therapy is the best way to treat peripheral neuropathy in dialysis patients. There is little concrete proof that rehabilitation programs improve outcomes, despite many authors advising that they are essential to a patient's recovery. Since the beneficial aspect of electrical stimulation to peripheral neuropathy in dialysis patients still needs to be addressed, additional research may be required to determine whether the method's effectiveness is impacted. Although many studies have been done on TENS, there needs to be more studies to analyze the effect of TENS on interoceptive aspects of the disease, which has to be identified as a research gap. Thus, the need for the investigation was created. This novel high-frequency nerve stimulation method is used for these two symptoms in patients who have peripheral neuropathy and are receiving dialysis.

2 Methodology

The study was conducted at nephrology consultation centers and home visits. The sample design was Convenience Sampling Technique, and the sample size was thirty. Ethical clearance was obtained from the institutional ethical committee of Krupanidhi College of Physiotherapy. The subjects were informed regarding the purpose and procedure of the study. Written consent for participation was obtained from each subject individually, and they were selected based on selection criteria. The study included subjects who had met the inclusion criteria. Single-group pre- and post-test experimental study design was used. The Inclusion criteria were patients diagnosed with chronic kidney disease who showed symptoms of peripheral neuropathy excluding any cardiovascular comorbities[16]and all dialysis patients, regardless of specific age and sex, undergoing standard hemodialysis plan 3 times a week[4].

Patients with open wounds, prominent varicose veins, edema or lymphedema, peritoneal dialysis, kidney transplant, Sepsis, and Skin infections were excluded from the study. The exclusion criteria includes the unusual skin allergy to TENS electrodes, and patients with pacemaker implants, metallic implants, and pregnant women[23].

2.1. Outcome measures

2.1.1. Joint position sense testing (JPS) :

The big toe's flexion and extension were used to assess the JPS. The therapist delicately held the big toe at the sides and was randomly rotated in directions by at most 20°. Then, the patient was said to recognize and describe the position. Ten trials were conducted, and the successful trials were noted[7]. The optimal cutoff point for JPS testing at the great toe was 2 or more

incorrect responses. At this cutoff, the sensitivity was 33% and specificity was 87.6%.

2.1.2.Timed Vibration Sense test (VBS)

The vibration perception was given at the medial malleolus, the tibial tuberosity, and the distal IP joint of the big toe on both limbs using a tuning fork of 128 Hz. The therapist strikes it against the palm to produce a clanging sound. Then, the therapist used two fingers to hold the tuning fork's stem while avoiding contacting the tines. A stopwatch is used to record the beginning and ending times of the VBS [23].

2.1.3.10-point Neuropathic Pain Scale of Galer and Jensen (NPS) :

The patients were asked a total of 10 questions that describe the types of pain, like intense, sharp, hot, dull, cold, sensitive, etc., which he experiences. Each item was rated from 0 to 10 [24].

2.2. Procedure

The subjects were given 20 minutes of High Frequency Nerve Stimulation (TENS). Position: Sitting with back support. Electrodes placement Site: Ankle dorsi flexors and plantar flexors. Frequency: 90-100 Hz, up to 200pps. The treatment sessions were 3 alternative days/week for 6 weeks. Pre- and Post-test interoception and pain assessment were done using the Timed Vibration Sense test at three sites: great toe, medial malleolus and tibial tuberosity, Joint position sense testing, and 10-point Neuropathic Pain Scale. Data was collected, after which it was tested statistically to conclude.

2.3. Statistical analysis

The information data was analyzed utilizing SPSS (version 29.0). A paired t-test was used to determine the significant difference in variables such as VBS, JPS, and NPS. The graphs and tables were generated using Microsoft Excel. A 95% confidence level and 5% error were used to check significant values by t-test.

3 Results

Table 1. Descriptive statistics – Age and BMI

VARIABLE	MEAN	SD
Age (years)	61.50	8.79
BMI (kg/m^2)	27.70	5.42

For the study, 30 dialysis patients were taken irrespective of age group; however, the patients included in the study ranged from 39 to 77 years. The study subjects' mean age (years) was 61.50±8.79, as shown in Table 1. The BMI was calculated based on the height and weight of the subjects who participated. The study subjects' mean BMI (kg/m2) were 27.70±5.42, as shown in Table 1.

Table 2. Outcome measures pre and post-treatment evaluation within the group

TEST	MEAN	SD	DIFFERENCE		t	P	SIGNIFICANT/NON-SIGNIFICANT
			MEAN	SD			
Vibration sense testing for great toe right- pretest (sec)	5.56	0.98	-1.0	0.54	-10.117	.000	SIGNIFICANT
Vibration sense testing for great toe right- post-test (sec)	6.36	0.82					
Vibration sense testing for great toe left- pretest (sec)	5.25	1.07	-0.98	0.67	-7.97	.000	SIGNIFICANT
Vibration sense testing for great toe left- post-test (sec)	6.23	0.80					
Vibration sense testing for medial malleolus right- pretest (sec)	5.38	1.03	-1.00	0.43	-12.577	.000	SIGNIFICANT

Continued on next page

Table 2 continued

Vibration sense testing for medial malleolus right- post-test (sec)	6.38	0.89					
Vibration sense testing for medial malleolus left- pretest (sec)	5.35	1.01	-0.96	0.65	-8.075	.000	SIGNIFICANT
Vibration sense testing for medial malleolus left- post-test (sec)	6.31	0.74					
Vibration sense testing for tibial tuberosity right- pretest (sec)	5.30	1.09	-0.95	0.67	-7.720	.000	SIGNIFICANT
Vibration sense testing for tibial tuberosity right- post-test (sec)	6.25	0.71					
Vibration sense testing for tibial tuberosity left-pretest (sec)	5.36	1.06	-0.98	0.66	-8.125	.000	SIGNIFICANT
Vibration sense testing for tibial tuberosity left- post-test (sec)	6.35	0.82					
Joint position sense test right-pretest	4.60	0.89	-0.86	1.04	-4.557	.000	SIGNIFICANT
Joint position sense testing right- post-test	5.46	0.97					
Joint position sense test left-pretest	3.80	0.84	-1.00	0.83	-6.595	.000	SIGNIFICANT
Joint position sense test left-post-test	4.80	1.03					
Neuropathy pain scale- pretest	7.72	1.03	1.39	0.91	8.36	.000	SIGNIFICANT
Neuropathy pain scale- post-test	6.33	1.06					

SD- Standard Deviation, t- Paired t value, p- Probability

From Table 2, it is inferred that the mean difference between vibration sense testing for great toe right- pre and post score(sec) was -1.0±0.54; great toe left- pre and post score(sec) was -0.98±0.67; medial malleolus right- pre and post score(sec) was -1.0±0.43; medial malleolus left- pre and post score(sec) was -0.96±0.65; tibial tuberosity right- pre and post score(sec) was -0.95±0.67; tibial tuberosity left- pre and post score(sec) was -0.98±0.66; joint position sense testing for right lower extremity - pre and post score was -0.86±1.04; joint position sense testing for left lower extremity - pre, and post score was -1.00±0.83; neuropathy pain scale- pre and post score was 1.39±0.91 after 6 weeks of intervention within group. The student t-distribution table was used to determine the p-value. The determined p-value is less than the 0.000 threshold for statistical significance($p<0.05$). Therefore, there is a statistically significant improvement in interoception and pain reduction after 6 weeks of intervention in dialysis patients with peripheral neuropathy with p-value<0.005.

4 Discussion

The most frequent neurological consequence of chronic renal failure is peripheral neuropathy, affecting predominantly men than women [2]. Axonal degeneration and secondary demyelination are its defining features, damaging cranial, motor, and sensory nerves in which the legs are often more affected than the arms [5]. When patients' GFR is less than 12 ml/min, they show clinical symptoms of peripheral nerve damage, usually diagnosed using electrophysiological tests [6]. In mild forms, distal paresthesia, loss of vibration sensitivity in the lower limbs, and impaired ankle reflexes are the main signs [7].

The results indicate that, for dialysis patients with peripheral neuropathy, there is a substantial improvement in the mean post scores of vibration sense tests for the great toe, tibial tuberosity, and medial malleoli with a p-value of 0.05 or below after 6 weeks of intervention. The current study's findings are congruent with those of a prior study by Jie Zhang et al. (2022), which found that all amputees and non-disabled volunteers consistently evoked vibration sensations at 20 Hz as the major sensation categories [19].

It is also inferred that there is a significant improvement in mean post scores of joint position sense testing right and left for dialysis patients with peripheral neuropathy with p-value <0.05 after 6 weeks of intervention. The current study's findings are consistent with those of a prior study conducted by Johnson MI et al. (2022) [17], who found that proprioception sense for those with arthritic changes is positively impacted by conventional TENS with sensory threshold amplitude [17].

It is also inferred that there is a significant improvement in mean post scores of the neuropathy pain scale for dialysis patients with peripheral neuropathy with a p-value <0.05 after 6 weeks of intervention. The new study's result is reliable to those of a prior study by Abdelkader et al. (2019)[16], which found that high-frequency stimulation of the lower limb motor cortex can effectively reduce pain caused by chronic neuropathy[16].

The Transcutaneous electrical stimulation utilized by Rohit Rangwani et al. (2021)[21] consistently modulates joint proprioception with the illusion of joint movements. As a result, after using TENS, this sensation improves, increasing the sensory afferents[21]. According to a study by Akifumi Takahashi et al. (2019)[25], the electrical stimulation method induces proprioception without presenting a cutaneous sensation[24]. The authors of the study by Zeng H et al. (2020)[18] concluded that TENS therapy can change cortical reorganization, which ultimately enhances the inhibitory drive and thus reduces pain-related excessive excitability[18].

This study evaluated the effectiveness of the electrical modalities over the pain and interoception aspects of peripheral neuropathy, as it was not previously assessed. The results imply that TENS may be especially helpful for people with sensory impairments and pain relief.

5 Conclusion

This study focused on evaluating the effectiveness of the electrical modalities over the pain and interoception aspects of peripheral neuropathy as it was not previously assessed, which raised the need for the study. In dialysis patients with peripheral neuropathy, this study assessed the impact of high-frequency nerve stimulation on interoception and pain. This novel high-frequency nerve stimulation method is used for these two symptoms in patients who have peripheral neuropathy and are receiving dialysis. The study's main finding is that TENS helps dialysis patients with peripheral neuropathy with their perception of vibration, their sense of joint position, and their sense of pain. The results indicate that in patients diagnosed with chronic kidney disease who showed symptoms of peripheral neuropathyand all dialysis patients, regardless of specific age and sex, undergoing standard hemodialysis plan 3 times a week, there is a substantial improvement in the mean post scores of vibration sense tests for the great toe, tibial tuberosity, and medial malleoli, joint position sense test and neuropathic pain scale with a p-value 0.001 after 6 weeks of intervention. Therefore, TENS may be most beneficial for pain reduction and subjects with neuropathy symptoms.

Limitations and recommendations

1. The study needs a follow-up to know the interventions' lasting effect
2. The limitation of this study is the small population. Hence, a large population is recommended for future studies.
3. The study's findings cannot be generalized to all dialysis patients with neuropathy deficits
4. Additional research is required to determine how electrical nerve stimulation affects interoception and proprioceptive impairments in peripheral neuropathy patients.

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