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Utility of neurodynamic techniques in Diabetes Mellitus from the plitogenic statistical approach

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Abstract: Diabetes mellitus type 2 is an illness condition in which the glucose level is abnormal and causes harm to the peripheral nervous fibers originating the diabetic neuropathy. The major frequent damage occurs in the sensory-motor system, whose symptoms include alteration in tactile perception, temperature, and loss of sensitivity in hands and feet. The evidence for treatments that include neural mobilization is limited, so this study aims to determine if intervention strategies with neural mobilization improve both sensory and functional responses in the neuropathy diabetic peripheral. We selected plithogenic statistics to carry out the statistical study because this disease is dynamically influenced by multiple factors of different natures. Plithogenic statistics studies the random events that occur for the multiple random variables or parameters that determine them. Due to it being based on plithogeny, it is a generalization of dialectics where the neutral is incorporated. The advantage of using this tool is that we yield a more complete result of the study if we compare it to classical statistics.

Keywords: Plithogenic Statistics, T-test, Diabetic Peripheral Neuropathy, Neural Mobilizations, Sensory Responses, Functional Responses.

1 Introduction

Diabetes mellitus is considered a public health problem. International Diabetes Federation estimates that there are 450 million people aged from 18 to 99 with a diagnosis of diabetes worldwide. From 85% to 95% of people have diabetes mellitus type 2, which frequently occurs in adults older than 40 years old, where women are more prone to this condition since in both, developed and underdeveloped countries this index is higher in this sex. According to the World Health Organization (WHO), in Latin America and the Caribbean, there are approximately 62 million people with type 2 diabetes. The prevalence is increasing rapidly in countries of scarce and medium resources in relationship to the developed countries.

According to the National Health and Nutrition Survey of Ecuador (ENSANUT in Spanish), the diabetes percentage in the country corresponds between 7.1% and 7.8% of its population. A very common consequence of diabetes is neuropathy peripheral diabetes, which has a prevalence corresponding between 40% and 50% of this population worldwide. This aggravation affects sensory, motor, and autonomic systems. Symptoms include functional deficits, paresthesia, hyperesthesia, and dysesthesia. The factors of risk are age, smoking, obesity, arterial hypertension, and deficient glycemic control; so it is essential to consider these factors for checking diabetes, and then to prevent the serious consequences of neuropathy peripheral diabetes like ulcerations, amputation, social burden, expensive treatments, state of depression, sleeping disorders, and anxiety. Several authors point out that the treatments advised by the physicians include manual therapy, neurodynamics, electrotherapy, strength, and cardiovascular exercises.

Neurodynamic techniques must be considered for treating neuropathies, and peripheral compression is utilized

to improve the symptoms and to enhance the speed of driving of nervous, and then to decrease the rate of appearance of ulcers and amputations, as well as to improve sensitivity and functionality.

The present research is about the neuropathy peripheral diabetic, a condition that is important to treat for the improvement of the symptomatology of the patient who suffers from it. To this end, we apply the instrument called Michigan Neuropathy Screening Instrument (MNSI) consisting of a questionnaire and a physical examination. The sensitivity evaluation corresponds to the tactile and thermal sensitivity in the dermatomes of the superior member (C5, C6, C7, C8, T1) and lower limb (L2, L3, L4, L 5, S1, S2), sensitivity to vibration (paresthesia) in the olecranon, radial styloid, external malleolus and hallux. The maximum isometric strength is assessed with emphasis on finger flexors and muscles of bilateral plantar flexion.

These instruments help us to analyze the damage at a sensitivity level and the muscular strength of the upper and lower limbs of the patients. After the intervention with neural mobilization, a new assessment helps us to determine if there are changes in the affected areas. Hypothetically, the intervention with neural mobilizations in patients with diabetic peripheral neuropathy is effective and improves the symptoms of this condition.

One characteristic of this disease is its relationship with multiple factors that dynamically interact with each other and have origins of different natures. We can find educational, nutritional, biological, and genetic factors, among others. A quite recent theory that generalizes dynamical system theory is Plithogeny. While dialectics only takes into account the interaction of contrary concepts, plithogeny also incorporates the neutral aspect [1]. Therefore, the dynamics of the phenomena are studied more completely. Some applications of plithogenic theory are read in [2-7]

On the other hand, the Plithogenic Statistic studies the data according to the Plithogenic Probability [8-11]. The Plithogenic Probability is a multidimensional probability that studies random events that occur for all the random variables (parameters) that determine it. Application of plithogenic statistics can be found in [12-14]

In this paper, we study the effectiveness of intervention strategies with neural mobilizations to improve sensory and functional responses in Diabetic Peripheral Neuropathy. For the study, we based on Neutrosophic Plithogenic Statistic tools.

The paper is made up of the following structure: a Materials and Methods section where the main physiological methods used to study sensory and functional responses are explained. Furthermore, this section presents the basic notions of plithogenic statistics. The results section presents what was obtained from this study. The last section is dedicated to giving the conclusions.

2 Materials and Methods

2.1 Physiological methods for studying sensory and functional responses

Michigan Neuropathy Screening Instrument (MNSI) was created by Feldmann and his colleagues in 1994. It is a questionnaire, practical to apply, whose purpose is the detection of peripheral neuropathy diabetic. It consists of two phases. The first one is a questionnaire of 15 items related to the symptoms presented in the previous week, with responses of YES and NO where we assign the values of 0 and 1, respectively. If they sum up a maximum of 13, it is positive for peripheral neuropathy**.**

The second part consists of a physical exam to observe the appearance of the feet of both members with specific features such as hammer toes, fingers overlapping, hallux valgus, subluxation of the joint, prominent head goal tarsal, and medial convexity, dry skin, infections, cracks or presence of ulcerations. This responds to two variables, “Present” with a value of 0 and “Absent” with a value of 1. The Achilles reflex and perception of vibration in the big toe reply to the “Present” parameter with a value of 0, “Present with reinforcement” equal to 0.5, and “Absent” equal to 1. The final score is obtained by adding the bilateral data and we consider there is peripheral neuropathy when the score is greater than 2/8.

According to medical reports, MNSI has a sensitivity of 79% and a specificity of 94% for the detection of Peripheral Neuropathy. The evaluation of the superficial and deep sensitivity is considered as a neurological clinical method evaluation which consists of two parts. The first one is the assessment of the superficial tactile and thermal sensitivity of the dermatomes (C5, C6, C7, C8, T1, L2, L3, L4, L5, S1, S2) with direction distal to proximal and the second one is the sensitivity to the vibration (paresthesia) in the olecranon, styloid of the radius, external malleolus and hallux. So, the following variables correspond to the numerical values of Absent = 0, Altered = 1, Normal = 2, and NE= Not Evaluated.

The evaluation of the maximum isometric force with the dynamometer yields a value with emphasis on the finger flexors and the plantiflexion muscles. Each muscular proof is run 3 times. Between each repetition, we wait for twenty seconds, and finally, we choose the higher and less variational result.

For the evaluation of the muscle flexors of the finger, the patient recumbent supine, the elbow is flexing 90° and the patient has to hold and pressure with maximum force. For the evaluation of the plantiflexion muscles, the patient will be in a recumbent position, supine and the dynamometer will be placed at the height

of the metatarsal region and he/she should do the flexion plant with a maximum force.

2.2 Basic Notions of Neutrosophic Statistics

Plithogenic Statistics (PS) comprises the analysis and observations of the events studied by the Plithogenic Probability [9].

Plithogenic Statistics generalizes classical MultiVariate Statistics, and in turn, allows an analysis of many output variables that are neutrosophic or indeterminate. It is also a multi-indeterminate statistic.

Various Subclasses of Plithogenic Statistics are as follows :

- Multivariate Statistics,
- Plithogenic Neutrosophic Statistics,
- Plithogenic Indeterminate Statistics,
- Plithogenic Intuitionistic Fuzzy Statistics,
- Plithogenic Picture Fuzzy Statistics,
- Plithogenic Spherical Fuzzy Statistics,
- and in general: Plithogenic (fuzzy-extension) Statistics,
- and Plithogenic Hybrid Statistics.

On the other hand, Plithogenic Refined Statistics are the most general form of statistics that studies the analysis and observations of events described by Plithogenic Refined Probability.

In classic inference statistics, the population's average of the variable is estimated from the sample's average.

When we have a classic random variable, the exact size of the sample is known and all the elements in the sample belong 100% to the population. However, this does not reflect the dynamics of a population such as the students in a college, where there is the fluctuation of them within the courses; in addition to the fact that the membership of each student varies depending on whether they are studying in a full-time, part-time or over-time course.

In a Neutrosophic Population, each element has a triple probability of membership such that $0 \leq T_j + I_j + F_j \leq 3$.

If we assume that $n \geq 2$ where n is the sample size, then the average probability for all elements in the sample is calculated by Equation 1.

$$\frac{1}{n}\sum_{j=1}^{n}(T_j, I_j, F_j) = \left(\frac{\sum_{j=1}^{n} T_j}{n}, \frac{\sum_{j=1}^{n} I_j}{n}, \frac{\sum_{j=1}^{n} F_j}{n}\right) \quad (1)$$

3 Results

The present investigation was carried out in the Atahualpa parish of the Ambato Canton and the "Aire Libre" neighborhood of the Cevallos Canton. It began with the socialization of the project, where the topic, objectives, and methodology that will be used in this study were made known. Therefore, the informed consent was presented and delivered, which is an important document to carry out the research. Immediately the study was carried out at strategic points in both Cantons. It was divided into 2 phases: the first phase of collecting information to fill out the clinical history and the second phase consisting of executing the Michigan test, evaluation of sensitivity, and the assessment of the muscular force with a duration of 25 minutes by patient.

The population of this study was made up of 34 individuals with diabetic peripheral neuropathy, of which 17 participants completed the 8-week intervention by applying an evaluation before and after it. The remaining participants were excluded from the research work due to their non-attendance. The data were calculated with a 95% confidence interval and 5% margin of error for patients with diabetic peripheral neuropathy.

The inclusion criteria were:

- Signing of the informed consent.
- People with type ll diabetes mellitus.
- Indistinct sex.
- Autonomous and independent patients.

The exclusion criteria were:

- Patients with severe cardiac pathologies.
- Patients with cognitive impairment of any level.
- Patients undergoing major surgery in the last 3 months,
- Patients with recent fractures in both the upper and lower limbs.

- Patients with varicose ulcers.

The following procedure was carried out:

Phase I (Survey)

Personal data sheet

Data collection was carried out for the individual medical history prepared to collect the sociodemographic data considered most important for this study.

Phase II (Evaluation)

The Michigan Test (MNSI)

Before the execution, the patients were explained what this assessment consists of. They were asked to lie down on the stretcher for more comfort and the questions from the questionnaire were asked about the symptoms of the previous week. After this, a physical examination of both lower limbs was carried out to see the appearance of the foot, the presence of ulcerations, Achilles reflex assessed with the hammer for reflexes in both extremities where there were observed the absence, presence or presence with reinforcement. Perception of vibration on the big toe was also observed and valued with the 128 Hz tuning fork.

Sensitivity assessment

To do this, the evaluated patient was asked to keep his eyes closed and completely relaxed. Where tactile sensitivity was assessed with a cotton pad through the dermatomes C5, C6, C7, C8, T1, L2, L3, L4, L5, S1, and S2 in a proximal to distal direction. Thermal sensitivity was evaluated with ice, taking care of the integrity and physical health of the patients from proximal to distal through the bilateral dermatomes already mentioned. Sensitivity to vibration (paresthesia) was evaluated with the 128 Hz tuning fork in the olecranon, radial styloid, external malleolus, and hallux with caution, asking what sensation they perceived.

Evaluation of maximum isometric strength with dynamometer during hand flexion and plantar flexion.

Phase III (treatment)

Neural mobilization exercises for the upper limb (Radial Neurodynamics, Ulnar Neurodynamics, Median Neurodynamics).

Neural mobilization exercises for the lower limb (Sciatic Neurodynamics, Peroneus Neurodynamics).

To gain greater accuracy in the results of the study, the different classic tests were adapted. Instead of adding points for each response, the results of each individual are grouped into triads of the type (P, I, N), which means "Positive", "Indeterminate", and "Negative". The value "Indeterminate" covers cases of indeterminacy due to some reason the patient's status could not be identified as positive or negative.

Below there are the tables that summarize the personal data of the patients. Table 1 corresponds to the sociodemographic data and Table 2 to the personal pathological data:

	Frequency	**Percentage**
SEX		
Male	4	23.5
Female	13	76.5
AGE		
Older adults	13	76.5
Adults	4	23.5
ICM		
Low weight	4	23.5

Overweight	5	29.4
Obesity	8	47.1

Table 1. Sociodemographic data

Background Pathological Personal		
	Frequency	Percentage
None	6	35.3
HTA	2	11.8
Hypothyroidism	6	35.3
Respiratory	3	17.6

Table 2. Personal pathological history

Table 3 shows the results of the original Michigan Test.

Michigan Questionnaire Initial Category		
Results	**Frequency**	**Percentage**
Normal	13	76.5
Altered	4	23.5
Michigan Questionnaire Final Category		
Results	**Frequency**	**Percentage**
Normal	17	100

Table 3. Results of the classical Michigan Test

The results of applying the method proposed in this article to the Michigan Test adapted to (P, I, N), using the average of the sum of points of the respondents before and after the treatment are $(0.35294, 0.29412, 11.58824)$ and $(0.00, 0.00, 13)$.

Table 4 shows the results of the sensitivity test in its classic variant:

Variable	**State**	**Frequency**	**%**
Sensitivity Tactile Member Superior Initial	Normal	17	100
Sensitivity Tactile Member Superior Final	Normal	17	100
Sensitivity Thermal Member Superior Initial	Altered Normal	1 16	5.9 94.1
Sensitivity Thermal Member Superior Final	Normal	17	100
Sensitivity Tactile Member Lower Initial	Altered Normal	2 15	11.8 88.2
Sensitivity Tactile Member Lower Final	Normal	17	100
Sensitivity Thermal Member Lower Initial	Altered	4	23.5

	Normal	13	76.5
Thermal Sensitivity Member Lower Final	Normal	17	100

Table 4. Results of the classic sensitivity test

In the proposed method in this article, the results were those shown in Table 5:

Variable	**State**
Tactile Sensitivity Superior Member Initial	(2,0,0)
Tactile Sensitivity Superior Member Final	(2,0,0)
Thermal Sensitivity Superior Member Initial	(1.88235,0.0,0.11765)
Thermal Sensitivity Superior Member Final	(2,0,0)
Tactile Sensitivity Lower Member Initial	(1.76471, 0.00,0.23529)
Tactile Sensitivity Lower Member Final	(2,0,0)
Thermal Sensitivity Lower Member Initial	(1.52941, 0.00, 0.47059)
Sensitivity Thermal Lower Member Final	(2,0,0)

Table 5. Results of the adapted sensitivity test

We must note that the results in Table 5 are given based on the triple (P, I, N), but in this case, the desirable result is given in reverse order to the previous one. That is, while for the MNSI the desired result is that all of them are negative, in the sensitivity test a desired result is that all of them are positive.

Below, Table 6 shows the results of vibration according to the classical method.

Vibration Superior Member Initial		
	Frequency	Percentage
Absent	2	11.8
Altered	5	29.4
Normal	10	58.8
Vibration Superior Member Final		
	Frequency	Percentage
Normal	17	100.0
Vibration Lower Member Initial		
	Frequency	Percentage
Absent	2	11.8
Altered	3	17.6
Normal	12	70.6

Vibration Lower Member Final		
	Frequency	Percentage
Altered	2	11.8
Normal	15	88.2

Table 6. Vibration evaluation according to the classical method

Finally, Table 7 contains the results applied to the method proposed in this article, based on the percentages in Table 6.

Variable	State
Vibration Superior Member Initial	(0.588,0.294,0.118)
Vibration Superior Member Final	(1,0,0)
Vibration Lower Member Initial	(0.706,0.176,0.118)
Vibration Lower Member Final	(0.882,0.118,0)

Table 7. Vibration evaluation according to the proposed method

Although we could apply statistics according to traditional methods, we prefer to use them based on the data summarized in Tables 5 and 7 in addition to what was obtained for the MNSI before and after. It is evident that each applied physiological test showed an improvement in patients. To prove that this improvement was statistically significant, the t-test was used for each triple before and after [15, 16].

The results are shown below:

Physiological test	Triple of p-values in t-test
MNSI	$(4.6610 \times 10^{-29}, 4.4833 \times 10^{-25}, 1.8120 \times 10^{-45})$
Tactile Sensitivity Superior Member	(NN, NN, NN)
Thermal Sensitivity Superior Member	$(5.8069 \times 10^{-12}, NN, 1.5987 \times 10^{-14})$
Tactile Sensitivity Lower Member	$(2.6017 \times 10^{-22}, NN, 0.00)$
Thermal Sensitivity Lower Member	$(7.3437 \times 10^{-31}, NN, 0.00)$
Vibration Superior Member	$(1.9620 \times 10^{-30}, 0.00, 6.7526 \times 10^{-12})$
Vibration Lower Member	$(2.2287 \times 10^{-30}, 2.5083 \times 10^{-7}, 2.1578 \times 10^{-12})$

Table 8. Results of the tests with the Plithogenic Statistic. NN means this is not a number.

From Table 7 it is evident that all the numerical values of the triads of p values are less than 0.05 and therefore the null hypothesis is rejected, which means that the improvement is statistically significant. *NN* values are obtained in cases where all patients had the desired outcome at the maximum level before the treatments and remained the same afterward.

Conclusion

Any progress that is achieved in terms of knowledge about Diabetic Peripheral Neuropathy is important since this is a scourge that affects an increasingly growing number of people in the world, including Ecuador. In this study, we worked with a group of 17 patients who suffer from this disease and to whom a treatment was applied to improve the effects caused by the disease. The effectiveness of the treatment was evaluated with the help of the t-test in the field of neutrosophic plithogenic statistics. The advantage of using this tool is that we obtain greater accuracy in the results because we are working with triples of values instead of only one. The medical values obtained from this work were the following:

- This research presented several results with a pre and post-evaluation after the intervention, where the sliding neural mobilization strategies for the upper limb (median nerve, ulnar radial) and lower limb (sciatic and peroneal nerve) are optimal to reduce symptoms, such as cramps, numbness, loss of sensitivity to touch,

temperature, and vibration. Especially in the hands and feet of the studied population with diabetic peripheral neuropathy.

- The tactile and thermal perception and vibratory sensitivity of an altered and absent state reached a state of normality in those who complied with the 8-week treatment plan, thus obtaining encouraging sensory responses that are directly related to neurodynamics.
- These strategies do not infer on foot morphology, or skin condition such as dryness and cracks, they also involve personal care and the progression of the disease.

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