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Study of the Efficacy of Neural Mobilizations to Improve Sensory and Functional Responses of Lower Extremities in Older Adults with Diabetic Peripheral Neuropathy Using Plithogenic n-SuperHyperGraphs

Lisbeth J. Reales-Chacón [1*], María E. Lucena de Ustáriz [2], Francisco J. Ustáriz-Fajardo [3], Andrea C. Peñafiel Luna [4], Gabriela J. Bonilla-Ayala [5], Pablo Djabayan-Djibeyan [6], José L. Erazo-Parra [7], and Mónica A.Valdiviezo-Maygua [8]

[1*] Chimborazo National University, Riobamba. Ecuador; lisbeth.reales@unach.edu.ec
[2] Chimborazo National University, Riobamba. Ecuador; mlucena@unach.edu.ec
[3] Chimborazo National University, Riobamba; francisco.ustariz@unach.edu.ec
[4] Ambato Technical University, Ambato. Ecuador; ac.penafiel@uta.edu.ec
[5] Ambato Technical University, Ambato. Ecuador; bonilla@uta.edu.ec
[6] Chimborazo National University, Riobamba. Ecuador; pdjabayan@unach.edu.ec
[7] Chimborazo National University, Riobamba. Ecuador; jlerazo@unach.edu.ec
[8] Chimborazo National University, Riobamba. Ecuador; mvaldiviezo@unach.edu.ec

Abstract. Diabetic Peripheral Neuropathy (DPN) is an aggravation of diabetes mellitus, which consists of ulcers and loss of sensitivity in the lower limbs. In its most severe stage, the person's limb may be amputated, which causes disability. This is a disease with multiple causes and whose treatment requires several solutions, including drug treatment, physiotherapy, and re-education of the person to change to a healthy lifestyle, if necessary, where the need for adequate nutritional habits appears. It is due to such complexity that we selected the Plithogenic n- SuperHyperGraph as a tool to represent the collected data, which were processed with the help of the multi-way log-linear model for contingency tables. For the first time, these three theories are combined to solve a real-life problem.

Keywords: Diabetes Mellitus, Diabetic Peripheral Neuropathy, Plithogeny, SuperHyperStructures, Plithogenic n- SuperHyperGraph, Multi-way Contingency Tables, Log-Linear Model.

1 Introduction

Diabetes mellitus (DM) is an alteration of blood glucose levels. It has two main subtypes: type 1, considered an autoimmune disease of family inheritance, which mainly affects children and adolescents. Type 2 is the most common because it affects middle-aged and older adults due to their lifestyle and poor diet. Diabetes is considered the most common chronic disease worldwide, affecting 1 in 11 adults between 20 and 79 years of age. 90% of patients suffer from DM 2 [1].

Diabetic Peripheral Neuropathy (DPN) is the most common vascular complication of diabetes mellitus, increasing morbidity and disability due to ulceration and amputation. Peripheral neuropathy is considered a sensory-motor polyneuropathy caused by microvascular and metabolic changes of hyperglycemia. It also produces early segmental demyelination, decreasing nerve conduction velocity.

The prevalence of DPN ranges between 21.3% and 34.5% in type 2 DM worldwide, of which 54% of patients may be asymptomatic. Because DPN affects the peripheral nervous system, distal symmetrical polyneuropathy is the most common, associated with numbness, tingling, pain, or weakness that begins in the feet and ascends proximally [2].

Neuropathy is the leading cause of disability worldwide, affecting the quality of life of diabetic patients because it causes chronic pain, high-risk falls, foot ulcers, and amputations, and is associated with sleep disorders, anxiety, and depression. DPN is considered to be poorly documented in Latin America and the Caribbean due to the lack of studies conducted in each country. However, the prevalence is 46.5% on the continent with an increasing trend over time [3].

For the treatment of DPN, neural mobilization through sliding neurodynamics is considered, i.e. exercises are performed in which the patient is asked to make small movements of a specific joint for 10 seconds, during which they will feel a slight tension in the nerve pathway. These exercises have neurophysiological benefits, manage to minimize the negative effects on peripheral nerve roots, and improve autonomic nervous function.

The present research on the application of neural mobilization exercises [4] in the elderly with diabetic peripheral neuropathy is carried out because there is no major scientific evidence in Ecuador about the physiotherapeutic intervention in DPN for which a strength evaluation is carried out, Michigan Neuropathy test Screening Instrument (MNSI) that evaluates whether or not the patient has neuropathy, superficial and deep sensitivity evaluation. These evaluations help determine an appropriate intervention for older adults through neurodynamic exercises that help us improve or reduce the signs and symptoms of DPN.

The problem we address in this article could be analyzed using classical statistics. However, one of our objectives is to study in the greatest possible depth the aspects that influence the symptoms that patients suffer from. Among the characteristics that are pointed out is the presence of several factors of a different nature. In addition to the medical problem that comes with suffering from a disease such as diabetes, this takes on other dimensions, such as the family and state economic expense that the presence of the disease means in each country. There is also a social impact due to the presence of people who suffer from a health problem and who are not only unable to work but may also need a caregiver. There is psychological damage to the person who may feel useless and to the caregiver who must dedicate his or her life to supporting this person.

The educational aspect is very important among the solutions to this problem. The patient must change his lifestyle and diet, and this requires relearning. He or she must eliminate toxic habits, such as cigarettes and alcohol, that can worsen his or her health situation.

That is why the mathematical tool that could be used must contain all these aspects. We have taken Plithogeny as a model [5, 6, 7] to study the feasibility of applying neural mobilization to improve the functional and sensory response ofolder adults with diabetic peripheral neuropathy.

Plithogeny is the theory introduced by Smarandache to model the dynamic interaction between concepts. "Plithogeny is the genesis or origin, creation, formation, development, and evolution of new entities from dynamics and organic mergers of multiple contradictory and/or neutral and/or non-contradictory old entities. Plithogeny advocates connections and unification of theories and ideas in any field. We can take "knowledge" as "entities" in various fields, such as the soft sciences, the hard sciences, and the theories of the arts and letters, among others." [8-12].

"Therefore, Plithogeny is the dynamics of many types of opposites, and/or their neutrals, and/or non-opposites and their organic fusion. Plithogeny is a generalization of dialectics (dynamics of a kind of opposites: <*A*> and <*antiA*>), the neutrosophy (dynamics of a kind of opposites and their neutral: <*A*> and <*antiA*>, and <*neutA*>), because plithogeny studies the dynamics of many types of opposites and their neutral and not opposites (<*A*> and <*antiA*>, and <*neutA*>, <*B*> and <*antiB*> and <*neutB*>, etc.), and many that are not opposites (<*C*>, <*D*>, etc.) altogether. A particular application and concept derived from Plithogeny is the plithogenic set, as it is an extension of the classical set, fuzzy set, intuitionist fuzzy set, and neutrosophic set, and has many scientific applications." [13, 14, 15].

We use the n-Super HyperGraphs combined with Plithogeny theory to model this problem. HyperStructures were introduced by Marty [16], which are structures where a HyperOperation is defined from an Operation on the power set of the non-empty set H without taking into account the empty subset, where the HyperAxioms are also added. The SuperHyperStructure was introduced by Smarandache, where the domain is replaced by the power set of H not only the image. Here SuperHyperAxioms is defined in it as well [17-23].

A SuperHyperGraph or n-SuperHyperGraph is the structure defined by Smarandache, where there is a set of vertices (finite or infinite) such that a subset is made up of the Single Vertices (the classic ones), another by the Indeterminate Vertices (unclear, vague, partially know) and a third set is made up of the Null Vertices (totally unknown, empty). In them, the edges are defined on the n-power set of vertices, which are defined recursively as the power of the (n-1)-power set and so on [24-26].

The data collected and represented in the form of plithogenic n-SuperHyperGraphs are statistically processed using the log-linear model for multi-way contingency tables [27, 28]. These data were obtained from a group of older adults in two locations; the facilities in the Ambato canton, in the province of Tungurahua, Ecuador. It is the first time, to the authors' knowledge, that the two theories of plithogenic n-SuperHyperGraphs are combined with classical statistics of contingency tables [29, 30].

The paper consists of a Materials and Methods section, where the main concepts of Plithogeny n-SuperHyperGraphs and log-linear models are explained for multi-way contingency tables. In the following section, we present the results obtained. The last section is dedicated to giving conclusions.

2 Materials and Methods

This section contains two sub-sections, the first one is dedicated to explaining the basic notions of Plithogenic n-SuperHyperGraphs defined in [15]. Then, subsection 2.2 contains the main concepts of multi-way contingency tables and the log-linear method.

2.1 Plithogenic n-SuperHyperGraphs

Plithogenic n-SuperHyperGraphs were defined by Smarandache in the field of decision-making in [15].

First, an n-SuperHyperGraph is defined as follows [24-26]:

Given $V = \{V_1, V_2, \cdots, V_m\}$, where $1 \leq m \leq \infty$ is a set of vertices, containing *Single Vertices* which are classical, *Indeterminate Vertices* which are unclear, vague, partially known, and the *Null Vertices* that are empty or completely unknown.

$P(V)$ is the power set of V including $\emptyset$. $P^n(V)$ is the n-power set of V, which is defined recursively as follows:

$P^1(V) = P(V)$, $P^2(V) = P\big(P(V)\big)$, $P^3(V) = P\big(P^2(V)\big)$, … , $P^n(V) = P\big(P^{n-1}(V)\big)$, for $1 \leq n \leq \infty$.
Where it is also defined as $P^0(V) = V$.

An n-SuperHyperGraph (*n-SHG*) is an ordered pair $n - SHG = (G_n, E_n)$, where $G_n \subseteq P^n(V)$ and $E_n \subseteq P^n(V)$, for $1 \leq n \leq \infty$. Such that, G_n is the set of vertices and E_n is the set of edges.

G_n contains all possible types of vertices as in the real world:

- *Single Vertices* (the classics),
- *Indeterminate Vertices* (unclear, vague, partially known),
- *Null Vertices* (empty, totally unknown),
- *SuperVertex* (or *SubsetVertex*) contains two or more vertices of the above types put together as a group (organization).
- *n- SuperVertex* which is a collection of vertices, where at least one of them is a *(n-1)- SuperVertex,* and the others can be *r- SuperVertex* for $r \leq n$.

E_n contains the following types of edges :

- *Single Edges* (the classics),
- *Indeterminate Edges* (unclear, vague, partially known),
- *Null Edges* (totally unknown, empty),
- *HyperEdge* (connecting three or more single vertices),
- *SuperEdge* (connecting two vertices, at least one of them is a SuperVertex),
- *n- SuperEdge* (connecting two vertices, at least one of them is an n- SuperVertex and may contain another that is an r-SuperVertex with $r \leq$ n).
- *SuperHyperEdge* (connects three or more vertices, where at least one of them is a SuperVertex),
- *n-SuperHyperEdge* (contains three or more vertices, at least one of which is an n-SuperVertex and may contain an r-SuperVertex with $r \leq$ n),
- *MultiEdge* (two or more edges connecting the same two vertices),
- *Loop* (an edge that connects an element to itself),

Graphs are classified as follows:

- Directed Graph (the classic one),
- Undirected Graph (the classic one),
- Neutrosophic Directed Graph (partially directed, partially undirected, partially indeterminate directed).

Within the framework of the theory of Plithogenic n-SuperHyperGraphs, we have the following concepts [4]:

Enveloping vertex: A vertex representing an object comprising attributes and sub-attributes in the graphical representation of a multi-attribute decision-making environment.

SuperEnveloping vertex: An enveloping vertex comprises of SuperHyperEdges.

Dominant Enveloping Vertex: An enveloping vertex that is with dominant attribute values.

Dominant Super Enveloping Vertex: A super enveloping vertex with dominant attribute values.

Dominant Enveloping Vertex is classified into *input*, *intervene,* and *output* based on the nature of the object's representation.

Plithogenic Connectors: The connectors associate the input enveloping vertex with the output enveloping vertex. These connectors associate the effects of input attributes with output attributes and these connectors are weighted by plithogenic weights.

2.2 Multi-Way Contingency Tables

A multi-way contingency table is a contingency table defined for two or more cross-ratio classification variables. Two-dimensional tables are generally called contingency tables, while the term multi- is applied when the number of variables is at least three [26, 28].

A *Generic Multi-Way Table* is defined using $I = I_1 \times I_2 \cdots \times I_q$ as the set of indices for each variable to be studied $X_1, X_2, \cdots, X_q$, such that I_{j} is the set of indices corresponding to the possible classifications of the jth variable. Thus, $n_{\mathrm{i}_1\mathrm{i}_2\cdots\mathrm{i}_q}$ is the frequency of occurrence of the classifications $\mathrm{i}_1, \mathrm{i}_2, \cdots, \mathrm{i}_\mathrm{q}$ for each of the corresponding variables.

The *Partial/Conditional Tables* involve fixing the category of one of the variables. Fixed variables are denoted in parentheses. For example, the XZ and YZ-partial tables are denoted by $n_{\mathrm{i(j)k}}$ and $n_{\mathrm{(i)jk}}$, respectively. Also, the *Partial/Conditional Probabilities* are calculated by $\pi_{\mathrm{ij(k)}} = \pi_{\mathrm{ij/k}} = Prob(X = i, Y = j/Z = k)$. *Partial/Conditional Proportions* are defined by $p_{\mathrm{ij(k)}} = p_{\mathrm{ij/k}} = \frac{\pi_{\mathrm{ijk}}}{\pi_{\mathrm{++k}}}$ for $k = 1, 2, \dots, K$. Where $\pi_{\mathrm{++k}}$ is the frequency for i and j setting k, for more information see [26, 28].

Below, we briefly explain what log-linear models consist of. To simplify the exposition we take the case of the three-way contingency table. If X, Y, and Z are the variables, then the following possible models are obtained [16, 17]:

- Model (X, Y, Z): All variables are considered independent, the model is as follows:

$\ln F_{ij} = \lambda + \lambda_i^X + \lambda_j^Y + \lambda_k^Z$ (1)

- Model (X, YZ): Only the YZ association is considered, while X is independent of the other two variables.
  $\ln F_{ij} = \lambda + \lambda_i^X + \lambda_j^Y + \lambda_k^Z + \lambda_{jk}^{YZ}$ (2)
- Model (XY, YZ): X and Z are independent for each value of Y:
  $\ln F_{ij} = \lambda + \lambda_i^X + \lambda_j^Y + \lambda_k^Z + \lambda_{ij}^{XY} + \lambda_{jk}^{YZ}$ (3)
- Model (XY, YZ, XZ): There is a pair-wise association between all variables, but there is no joint association between the three.
  $\ln F_{ij} = \lambda + \lambda_i^X + \lambda_j^Y + \lambda_k^Z + \lambda_{ij}^{XY} + \lambda_{ik}^{XZ} + \lambda_{jk}^{YZ}$ (4)
- Model (XYZ): If the above model does not fit the data well, then the association between the three variables should be considered:
  $\ln F_{ij} = \lambda + \lambda_i^X + \lambda_j^Y + \lambda_k^Z + \lambda_{ij}^{XY} + \lambda_{ik}^{XZ} + \lambda_{jk}^{YZ} + \lambda_{ijk}^{XYZ}$ (5)

To contrast two different models, the statistic called *likelihood ratio is used*, which is calculated as:

$G^2 = 2\sum f ln(f/F)$ (6)

Where f is the observed frequency and F is the expected frequency according to the model. This statistic is distributed according to a chi-square under the hypothesis that the model is correct, with degrees of freedom depending on the parameters used to fit the model.

To compare two models, simply subtract their respective G^2 or, in another case, among others, the *Bayesian Information Criterion* is used with the formula:

$BIC = G^2 - \mathrm{df}\log\mathrm{N}$ (7)

Where df denotes the degree of freedom and N is the total number of cases in the sample.

3 The Study

In the research, 3 instruments were used to collect data, which were designed and validated by experts in the subject, based on their reliability during their application were the following:

Michigan Neuropathy Screening Instrument (MNSI)

Michigan Neuropathy Screening Instrument, created by Feldman and his colleagues in 1994, was developed to adapt and simplify the evaluation criteria for diabetic peripheral neuropathy. This is considered a rapid and objective detection tool with a qualitative evaluation system, which consists of 2 parts: a questionnaire and a clinical examination. The questionnaire consists of 15 questions and each of them will have a score of one point if positive or zero if negative. It consists of 2 false questions that will not be graded, the maximum score being 13.

The second part of MNSI performs a physical examination of the foot. It carefully evaluates the deformities of the skin, whether it presents dry skin, infection, or cracks. The score is obtained by adding the data of both limbs; if the score is greater than 2 it is considered as DPN.

Manual Dynamometry Test

The manual dynamometer test is performed to assess the muscle strength of different areas of the body. A dynamometer is used and is held by the evaluator over the patient's structure to be assessed. The assessment is performed with reduced gravity. The patient will exert a sustained force on the dynamometer for a period of 5 seconds while the evaluator holds the dynamometer stable. This measurement will be performed three times on each left and right limb. The procedure has been described for different muscle groups, which is why compliance with these procedures is recommended.

Superficial and deep sensitivity test

Sensitivity assessment has been standardized thanks to Dr. Jean Ayres. These are responsible for identifying sensory modulation. During the examination, the physiotherapist will explain the procedure to the patient. The patient will be comfortable and blindfolded to avoid bias during the assessment. In this way, the recognition of the stimulus without a visual field provides sensory integrity. The test will be performed on both limbs for comparison. The superficial sensitivity test explores each dermatome (touch, temperature) and is carried out on the dermatomes of the upper and lower limbs.

To evaluate the vibratory sensitivity, a tuning fork is used on a bony surface. The patient will indicate what he or she feels, where he or she feels it, and when the stimulus stops. His or her response will determine:

- Hypopalesthesia: decreased vibratory sensitivity,
- Hyperpalesthesia: increased vibratory sensitivity,
- Apalesthesia: absence of vibratory sensitivity.

The investigation was carried out in two locations: the facilities of the Atahualpa Parish Council in the Ambato canton, and also the facilities of the old train station in the Cevallos canton, in the province of Tungurahua.

Population and Sample

The research population consisted of 34 adults, of which 17 participants completed the 8 weeks of intervention, with a pre- and post-execution evaluation. The 17 participants were eliminated because they did not comply with the 8-week treatment or because they did not attend the final evaluation, for which reason a confidence level of 95% was obtained, with a margin of error of 5% in patients with Diabetic Peripheral Neuropathy.

Inclusion criteria

- Male or female patients aged 65 years or older.
- Patients diagnosed with type 2 diabetes mellitus.
- Patients who have altered sensitivity in the lower limb.
- Patients who have independent mobility.
- Patients who have signs or symptoms of diabetic peripheral neuropathy.

Exclusion criteria

- Patients with high-risk diseases such as heart disease.
- Patients with vascular problems such as varicose veins.
- Adults who do not have mobility in their lower limbs due to amputation or injury.
- People who have had recent surgeries

The input object (V) in this study is *Patients*, where it is understood that they are the patients selected to study the effectiveness of neural mobilizations in improving DPN. The Enveloping Vertex (Super Enveloping Vertex or Dominant Enveloping Vertex or Dominant Super Enveloping Vertex) in this problem is related to the following attributes and sub-attributes:

V_1= Socio-Demographic Data, V_2= Lower Extremity Sensitivity, V_3= Michigan Questionnaire, V_4= Michigan Physical Examination.

Attribute sets = {Socio-Demographic Data, Lower Extremity Sensitivity, Michigan Questionnaire, Michigan Physical Examination}.

Socio-Demographic Data = {Age (V_{11}), Weight (V_{12}), Gender (V_{13})}.

Lower Limb Sensitivity = {Tactile Sensitivity (V_{21}), Thermal Sensitivity (V_{22}), Vibration (V_{23})}.

Age = {Older Adults (V_{111}), Adults (V_{112})}.

Weight = {Normal (V_{121}), Overweight (V_{122}), Obese (V_{123})}.

Gender = {Male (V_{131}), Female (V_{132})}.

Touch Sensitivity = {Initial (V_{211}), Final (V_{212})}.

Thermal Sensitivity = {Initial (V_{221}), Final (V_{222})}.

Vibration = {Initial (V_{231}), Final (V_{232})}.

Initial = {Absent, Altered, Normal}.

Final = {Absent, Altered, Normal}.

Michigan Questionnaire = {Initial (V_{31}), Final (V_{32})}.

Michigan Physical Examination = {Initial (V_{41}), Final (V_{42})}.

In the case of Michigan tests, it is determined:

Initial = {Altered, Normal}.

Final = {Altered, Normal}.

Table 1 summarizes these variables:

Table 1: Vertex, Vertex Attributes, Vertex Sub Attributes, and Vertex Sub Sub Attributes in the study carried out. The variable that represents them appears in parentheses.

Vertex	**Vertex Attributes**	**Vertex Sub Attributes**	**Vertex Sub Sub Attributes**
Socio-demographic data (V_1)	Age (V_{11})	Older adults (V_{111})	
		Adults (V_{112})	
	Weight (V_{12})	Normal (V_{121})	
		Overweight (V_{122})	
		Obesity (V_{123})	
	Gender (V_{13})	Male (V_{131})	
		Female (V_{132})	
Lower limb sensitivity (V_2)	Tactile Sensitivity (V_{21})	Initial (V_{211})	Absent (V_{2111})
			Altered (V_{2112})
			Normal (V_{2113})
		Final (V_{212})	Absent (V_{2121})
			Altered (V_{2122})
			Normal (V_{2123})
	Thermal Sensitivity (V_{22})	Initial (V_{221})	Absent (V_{2211})

Vertex	Vertex Attributes	Vertex Sub Attributes	Vertex Sub Sub Attributes
			Altered (V_{2212})
			Normal (V_{2213})
		Final (V_{222})	Absent (V_{2221})
			Altered (V_{2222})
			Normal (V_{2223})
	Vibration (V_{31})	Initial (V_{231})	Absent (V_{2311})
			Altered (V_{2312})
			Normal (V_{2313})
		Final (V_{232})	Absent (V_{2321})
			Altered (V_{2322})
			Normal (V_{2323})

Note that the sub-attributes V_{211}, V_{221}, and V_{231} are input enveloping vertex, while V_{212}, V_{222}, and V_{232} are output enveloping vertex. The intervene enveloping vertex are the others.

Table 2 contains the absolute frequency of each of the variables:

Table 2: Absolute frequency obtained for each of the variables. They appear in parentheses.

Vertex	Vertex Attributes	Vertex Sub Attributes	Vertex Sub Sub Attributes
Socio-demographic data (17)	Age (17)	Older Adults (13)	
		Adults (4)	
	Weight (17)	Normal (2)	
		Overweight (8)	
		Obesity (7)	
	Gender (17)	Male (4)	
		Female (13)	
Lower Limb Sensitivity (17)	Tactile Sensitivity (17)	Initial (17)	Absent (0)
			Altered (2)

Vertex	Vertex Attributes	Vertex Sub Attributes	Vertex Sub Sub Attributes
			Normal (15)
		Final (17)	Absent (0)
			Altered (0)
			Normal (17)
	Thermal Sensitivity (17)	Initial (17)	Absent (0)
			Altered (4)
			Normal (13)
		Final (17)	Absent (0)
			Altered (0)
			Normal (17)
	Vibration (17)	Initial (17)	Absent (2)
			Altered (3)
			Normal (12)
		Final (17)	Absent (0)
			Altered (2)
			Normal (15)

Note that each of the absolute frequencies can be converted to relative frequencies by dividing by 17.

Table 3 contains the vertices corresponding to the Michigan examination, which is written separately for space reasons and to make it more understandable; however, it should be understood as a continuation of Table 1:

Table 3: Vertex, Vertex Attributes and Vertex Sub Attributes in the study carried out for the Michigan tests. The variable that represents them appears in parentheses.

Vertex	Vertex Attributes	Vertex Sub Attributes
Michigan Questionnaire (V_3)	Initial (V_{31})	Altered (V_{311})
		Normal (V_{312})

	Final (V_{32})	Altered (V_{321})
		Normal (V_{322})
Michigan Physical Examination (V_4)	Initial (V_{41})	Altered (V_{411})
		Normal (V_{412})
	Final (V_{42})	Altered (V_{421})
		Normal (V_{422})

Note that the sub-attributes V_{31}, V_{41} are input enveloping vertex, while V_{41}, V_{42} are output enveloping vertex.

Table 4 contains the absolute frequencies of the variables in Table 3.

Table 4: Absolute frequency obtained for each of the variables corresponding to the Michigan examination. The variable that represents them appears in parentheses.

Vertex	Vertex Attributes	Vertex Sub Attributes
Michigan Questionnaire (17)	Initial (17)	Altered (3)
		Normal (14)
	Final (17)	Altered (0)
		Normal (17)
Michigan Physical Examination (17)	Initial (17)	Altered (3)
		Normal (14)
	Final (17)	Altered (2)
		Normal (15)

Let us now use Log-Linear models to statistically process the data. To simplify the method we will use 3-way contingency tables. We will calculate the coefficient G^2in each case.

Table 5 contains a summary of these results:

Table 5: G^2 result of the processed models.

Model	G^2
Age*Initial Tactile Sensitivity*Final Tactile Sensitivity	3.376055160243798e-7
Age*Initial Thermal Sensitivity*Final Thermal Sensitivity	3.1509848869970483e-7
Age*Initial Vibration*Final Vibration	2.700844228575832e-7
Age*Initial Michigan Questionnaire*Final Michigan Questionnaire	3.150984931596926e-7
Age*Initial Michigan Physical Examination*Final Michigan Physical Examination	2.700844197327017e-7
Weight*Initial Tactile Sensitivity*Final Tactile Sensitivity	4.95154775293477e-7

Model	G^2
Weight*Initial Thermal Sensitivity*Final Thermal Sensitivity	4.951547730729273e-7
Weight*Initial Vibration*Final Vibration	4.5014069907952255e-7
Weight*Initial Michigan Questionnaire*Final Michigan Questionnaire	4.951547595348044e-7
Weight*Initial Michigan Physical Examination *Final Michigan Physical Examination	4.7264773118348784e-7
Gender*Initial Tactile Sensitivity*Final Tactile Sensitivity	3.3760552898716755e-7
Gender*Initial Thermal Sensitivity*Final Thermal Sensitivity	3.1509849150197596e-7
Gender *Initial Vibration*Final Vibration	2.925914528725019e-7
Gender *Initial Michigan Questionnaire*Final Michigan Questionnaire	3.3760552126440676e-7
Gender *Initial Michigan Physical Examination* Final Michigan Physical Examination	2.925914568035818e-7

Note that, for example, in the first model three vertices were combined to form a SuperVertex, since there is uncertainty and indeterminacy due to the nature of the problem being addressed and that is why statistics are used. See Figure 1, which serves to graphically illustrate this example; for each of the models, there is a similar graphic representation.

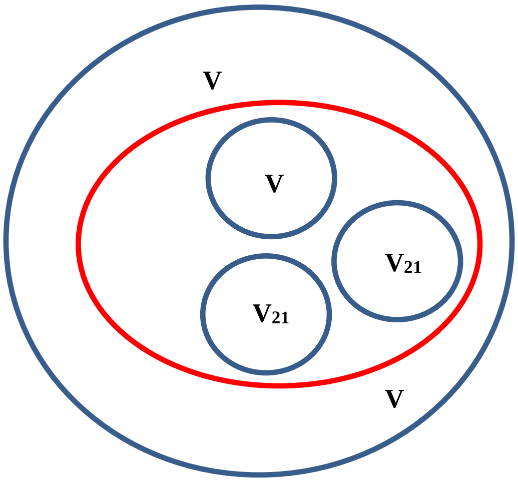

Figure 1: HyperGraph graphically representing the first model in Table 5. The HyperGraph Edge appears in red.

As for dominance, two vertices were always dominant: the initial one (representing the input) and the final one (representing the output). See Figure 2 for representing the plithogenic connector (C_1).

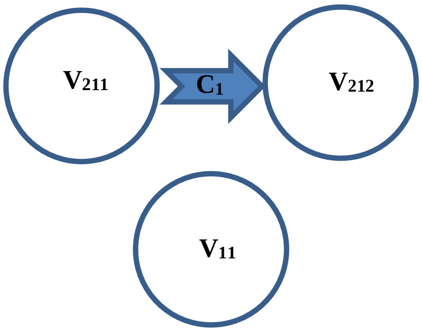

Figure 2: Plithogenic connector (C_1) of the variables represented in the first model in Table 5.

Regarding the statistical interpretation, all values were of a $G^2 < 0.01$ in log-linear nature, so all the obtained log-linear models fit the data well. When the models were analyzed in more detail for all cases, it was concluded that there was significant improvement among the variables analyzed. In other words, the treatment is effective for all patients, regardless of gender, weight, and age.

5. Conclusion

This paper had as its main objective the study of the feasibility of applying the treatment of neural mobilizations in adult patients of the city of Ambato in Ecuador. These patients suffer from Diabetic Peripheral Neuropathy, which is a sequel of diabetes. The results were statistically processed using the log-linear model for multi-way contingency tables. For the representation of the data, plithogenic n-SuperHyperGraphs were used, which allowed to representation of the different combinations of possible variables and the uncertainty and indeterminacy arising from the statistical component of the problem. We use these new tools that emerged within Neutrosophy because they allow us to model complex interactions between variables of different natures, as is the case in which we find ourselves. For the first time, to the knowledge of the authors, the plithogenic tools are combined with SuperHyperGraphs and some traditional statistical methods.

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