Assessment of the preventive management of peripheral diabetic neuropathy by using neutrosophic AHP and neutrosophic uninorm operator

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Abstract

Diabetes mellitus is a disease that plagues all countries in the world. One of the affectations caused by this chronic disease is damage to peripheral nervous tissues. This is the cause of ulcers and amputations in parts of the foot of the diabetic patient. In this paper, we propose a method to evaluate the patient's degree of preventive management of peripheral diabetic neuropathy. For this purpose, the Neutrosophic Analytic Hierarchy Process (AHP) method is used to assess the importance of factors influencing the prevention of peripheral neuropathic complications associated with diabetes mellitus in some patients. For the final evaluation, the aggregator called neutrosophic uninorm is used; especially, the operator based on the combining function utilized in the Prospector expert system.

Keywords: Diabetes mellitus; peripheral diabetic neuropathy; neutrosophic AHP; neutrosophic uninorm

1. Introduction

Diabetes mellitus comprises a series of metabolic disorders that have in common the presence of hyperglycemia or elevated concentration of glucose in the blood persistently or chronically [1]. Its main cause is considered to be the insufficient production of the hormone insulin in the patient suffering from this disease. This is the hormone that influences the process of obtaining the necessary energy in the form of ATP in the body.

The main symptoms to suspect that a person has diabetes mellitus are excessive production of urine (polyuria), excessive increase in the need to eat (polyphagia), increased thirst (polydipsia), and weight loss for no apparent reason. However, these symptoms are not the worst of the disease; they cause different complications and damage to the eyes, kidneys, nerves, and blood vessels. Its acute complications (hypoglycemia, ketoacidosis, nonketotic hyperosmolar coma) are the consequence of the inadequate control of the disease, while its chronic complications (cardiovascular, nephropathies, retinopathies, neuropathies, and microvascular damage) are the consequence of the progress of the disease.

It is also an important health problem worldwide since by 2030 it is estimated that 370 million people will suffer from it. According to the World Health Organization (WHO), it is one of the 10 main causes of death in the world.

As it is a chronic disease, it is not curable, and multiple factors aggravate it. Such patient education and lifestyle changes are necessary to lead a quality life and avoid complications associated with this disease.

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Diabetic neuropathy is the most common symptomatic complication of this disease [1-4]. This consists of the affectation of the motor, sensitive, and autonomic fibers of the peripheral nervous system distally in the lower limbs. This causes loss of sensation in patients, ulcers, and gangrene in the feet, which can lead to the amputation of the person's toes.

This article proposes a method that uses aggregators called neutrosophic uninorms to evaluate the management of the prevention of the risks of having complications in diabetic neuropathy by diabetic patients [5]. The risk of having these complications decreases considerably if the patient strictly follows the measures that are well-known, but which at the same time become complicated to apply in many patients because it means a change in the patient's way of life, some of whom are not willing to face.

The Neutrosophic Uninorms generalize the Uninorms from fuzzy sets to neutrosophic sets. A uninorm within the fuzzy theory allows the definition of aggregation operators from $[0,1]^2$ into $[0,1]$ that have in common with the t-norms and t-conorms that they satisfy the axioms of commutativity and associativity, are non-decreasing, and have a neutral value [6-8]. The neutral value of the t- norms is 1 and that of the t-conorm is 0.

For their part, the Neutrosophic Uninorms contain a triple of uninorms to aggregate neutrosophic sets with a finite cardinality. Interestingly, variations of these operators are used in artificial intelligence, for example, the combining function in the Prospector expert system is a type of uninorm on the interval $[-1,1]$ that can be converted into a uninorm on the interval $[0,1]$ ([6-8]). Additionally, we propose within the methodology the Neutrosophic Analytic Hierarchy Process (AHP) technique for the initial determination of the weight of each of the aspects to be evaluated [9, 10].

The AHP technique is a complex decision-making method based on mathematics and psychology, where pair-wise comparisons of criteria, subcriteria, and alternatives are performed. The AHP is extended to neutrosophic sets, where indeterminacy is evaluated as an explicit value; then this is called Neutrosophic AHP.

This paper consists of the following structure; a section on Materials and Methods is dedicated to explaining the fundamental notions of Neutrosophic AHP and Neutrosophic Uninorm. The next section explains the proposed model. The article ends with the Conclusions.

2. Materials and Methods

A. Neutrosophic AHP

The neutrosophic AHP technique, just like the crisp AHP and fuzzy AHP, is based on psychology and mathematics. Where it starts from a hierarchical tree, such that the main leaf is the goal to be met, and for each level in descending order of hierarchy, the criteria and subcriteria appear to evaluate a group of alternatives that form the bottom of the tree. The original technique was created by Thomas L. Saaty in the 1970s ([11]). Items at the same level are compared in pairs in a matrix according to an evaluative scale proposed by T.L. Saaty.

In the Neutrosophic AHP method, numerical values are replaced by neutrosophic trapezoidal membership functions to account for uncertainty and indeterminacy [9, 12-15]. The notions of this technique are given below:

Definition 1: ([9]) The *Neutrosophic set N* is characterized by three membership functions, which are the truth-membership function T_A, indeterminacy-membership function I_A, and falsity-membership function F_A, where U is the Universe of Discourse and $\forall x\in U$, $T_A(x), I_A(x), F_A(x) \subseteq]^-0, 1^+[$, and $^-0 \leq inf\ T_A(x) + inf\ I_A(x) + inf\ F_A(x) \leq sup\ T_A(x) + sup\ I_A(x) + sup\ F_A(x) \leq 3^+$.

See that according to the definition, $T_A(x), I_A(x), F_A(x)$ are real standard or non-standard subsets of $]^-0, 1^+[$ and hence, $T_A(x), I_A(x), F_A(x)$ can be subintervals of $[0,1]$.

Definition 2: ([9]) The *Single-Valued Neutrosophic Set* (SVNS) N over U is $A = \{< x; T_A(x), I_A(x), F_A(x) > : x\in U\}$, where $T_A: U \to [0,1]$, $I_A: U \to [0,1]$, and $F_A: U \to [0,1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

The *Single-Valued Neutrosophic number* (SVNN) is symbolized by $N = (t, i, f)$, such that $0 \leq t, i, f \leq 1$ and $0 \leq t + i + f \leq 3$.

Definition 3: ([16]) The *single-valued trapezoidal neutrosophic number:*

$\tilde{a} = \langle (a_1, a_2, a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a neutrosophic set on $\mathbb{R}$, whose truth, indeterminacy, and falsity membership functions are defined as follows:

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$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), & a_1 \le x \le a_2 \\ \alpha_{\tilde{a}}, & a_2 \le x \le a_3 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), & a_3 \le x \le a_4 \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{(a_2-x+\beta_{\tilde{a}}(x-a_1))}{a_2-a_1}, & a_1 \le x \le a_2 \\ \beta_{\tilde{a}}, & a_2 \le x \le a_3 \\ \frac{(x-a_2+\beta_{\tilde{a}}(a_3-x))}{a_3-a_2}, & a_3 \le x \le a_4 \\ 1, & \text{otherwise} \end{cases} \quad (2)$$

$$F_{\tilde{a}}(x) = \begin{cases} \frac{(a_2-x+\gamma_{\tilde{a}}(x-a_1))}{a_2-a_1}, & a_1 \le x \le a_2 \\ \gamma_{\tilde{a}}, & a_2 \le x \le a_3 \\ \frac{(x-a_2+\gamma_{\tilde{a}}(a_3-x))}{a_3-a_2}, & a_3 \le x \le a_4 \\ 1, & \text{otherwise} \end{cases} \quad (3)$$

Where $\alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \in [0,1]$, $a_1, a_2, a_3, a_4 \in \mathbb{R}$ and $a_1 \le a_2 \le a_3 \le a_4$.

Definition 4: ([16]) Given $\tilde{a} = \langle (a_1, a_2, a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ and $\tilde{b} = \langle (b_1, b_2, b_3, b_4); \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}} \rangle$ two single-valued trapezoidal neutrosophic numbers and λ any non-null number in the real line. Then, the following operations are defined:

1. Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
2. Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
3. Inversion: $\tilde{a}^{-1} = \langle (a_4^{-1}, a_3^{-1}, a_2^{-1}, a_1^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, where $a_1, a_2, a_3, a_4 \neq 0$.
4. Multiplication by a scalar number:

$$\lambda\tilde{a} = \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3, \lambda a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda > 0 \\ \langle (\lambda a_4, \lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda < 0 \end{cases}$$

5. Division of two trapezoidal neutrosophic numbers:

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \left\langle \left(\frac{a_1}{b_4}, \frac{a_2}{b_3}, \frac{a_3}{b_2}, \frac{a_4}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \right\rangle, a_4 > 0 \text{ and } b_4 > 0 \\ \left\langle \left(\frac{a_4}{b_4}, \frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \right\rangle, a_4 < 0 \text{ and } b_4 > 0 \\ \left\langle \left(\frac{a_4}{b_1}, \frac{a_3}{b_2}, \frac{a_2}{b_3}, \frac{a_1}{b_4}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \right\rangle, a_4 < 0 \text{ and } b_4 < 0 \end{cases}$$

6. Multiplication of two trapezoidal neutrosophic numbers:

$$\tilde{a}\tilde{b} = \begin{cases} \langle (a_1b_1, a_2b_2, a_3b_3, a_4b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 > 0 \text{ and } b_4 > 0 \\ \langle (a_1b_4, a_2b_3, a_3b_2, a_4b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 < 0 \text{ and } b_4 > 0 \\ \langle (a_4b_4, a_3b_3, a_2b_2, a_1b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 < 0 \text{ and } b_4 < 0 \end{cases}$$

Where, $\wedge$ is a t-norm and $\vee$ is a t-conorm.

The hybridization of AHP with neutrosophic set theory was used in [12]. This is a more flexible approach to modeling uncertainty in decision-making. Indeterminacy is an essential component to be assumed in real-world organizational decisions.

Table 1 summarizes the scale for measuring the pair-wise comparison of criteria and sub-criteria, and so on.

Table 1: Saaty's scale translated to a neutrosophic trapezoidal scale.

Saaty's scale	Definition	Neutrosophic Trapezoidal Scale
1	Equally influential	$\tilde{1} = \langle (1,1,1,1); 0.50, 0.50, 0.50 \rangle$
3	Slightly influential	$\tilde{3} = \langle (2,3,4,5); 0.30, 0.75, 0.70 \rangle$

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5	Strongly influential	$\tilde{5} = \langle(4,5,6,7); 0.80, 0.15, 0.20\rangle$
7	Very strongly influential	$\tilde{7} = \langle(6,7,8,9); 0.90, 0.10, 0.10\rangle$
9	Absolutely influential	$\tilde{9} = \langle(9,9,9,9); 1.00, 1.00, 1.00\rangle$
2, 4, 6, 8	Sporadic values between two close scales	$\tilde{2} = \langle(1,2,3,4); 0.40, 0.65, 0.60\rangle$
		$\tilde{4} = \langle(3,4,5,6); 0.60, 0.35, 0.40\rangle$
		$\tilde{6} = \langle(5,6,7,8); 0.70, 0.25, 0.30\rangle$
		$\tilde{8} = \langle(7,8,9,9); 0.85, 0.10, 0.15\rangle$

The neutrosophic pair-wise comparison matrix is defined in Equation 4.

$$\tilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} \quad (4)$$

$\tilde{A}$ satisfies the condition $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$, according to the inversion operator defined in Definition 4.

Authors in [15] defined two indices to convert a neutrosophic triangular number into a crisp number. They are the equations of *score* and *accuracy* in Equations 5 and 6, respectively:

$$S(\tilde{a}) = \frac{1}{16}[a_1 + a_2 + a_3 + a_4](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \quad (5)$$

$$A(\tilde{a}) = \frac{1}{16}[a_1 + a_2 + a_3 + a_4](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (6)$$

In the proposed method, it is only necessary to obtain the weights or the importance of each of the criteria.

B. On Neutrosophic uninorms

Definition 5 ([5]). A *neutrosophic uninorm* U_N, is a commutative, increasing, and associative mapping, $U_N: (]^-0,1^+[\times]^-0,1^+[\times]^-0,1^+[)^2 \to]^-0,1^+[\times]^-0,1^+[\times]^-0,1^+[$, such that: $U_N\left(x(T_x,I_x,F_x), y(T_y,I_y,F_y)\right) = (U_NT(x,y), U_NI(x,y), U_NF(x,y))$, where U_NT means the degree of membership, U_NI the degree of indeterminacy and U_NF the degree of non-membership of the aggregation of both x and y. Additionally, there exists a neutral element $e \in]^-0,1^+[\times]^-0,1^+[\times]^-0,1^+[$, where $\forall x \in]^-0,1^+[\times]^-0,1^+[\times]^-0,1^+[$, $U_N(e,x) = x$.

Here we use the notations $0_N = (0,1,1)$ and $1_N = (1,0,0)$ and also, given the universe of discourse U and $x(T_x,I_x,F_x)$, $y(T_y,I_y,F_y)$ two SVNS, we say that $x \leq_N y$ if and only if $T_x \leq T_y$, $I_x \geq I_y$ and $F_x \geq F_y$.

3. The new method

First of all, we will specify the factors to be taken into account to avoid diabetic peripheral neuropathy in patients suffering from the disease. These factors are the following [17]:

Step 1:

1. Glycemic control
1.1. Pharmacological
1.1.1. Insulin
1.1.2. Antidiabetic medicines
1.2. Nonpharmacological
1.2.1. Pancreas transplant
1.2.2. Bariatric surgery
2. Lifestyle modifications
2.1. Nonpharmacological
2.1.1. Supervised exercise programs
2.1.2. Diet
2.1.3. Counseling

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3. Foot care
3.1. Pharmacological
3.1.1. Antibiotics
3.2. Nonpharmacological
3.2.1. Referral to multidisciplinary foot care services
3.2.2. Patient education on foot care
3.2.3. Offloading
3.2.4. Debridement
3.2.5. Revascularization

In this scheme, we have as the goal (G) "to determine the preventive management of peripheral diabetic neuropathy", as criteria we have C_1: Glycemic control, C_2: Lifestyle modifications, C_3: Foot care. The subcriteria are SC_{11}: Pharmacological treatment and SC_{12}: Nonpharmacological treatment. As a sub-subcriteria we have SSC_{111}: Insulin, SSC_{112}: Antidiabetic medicines; SSC_{121} Pancreas transplant, SSC_{122}: Bariatric surgery and so on...

Step 2:

Since there are three levels in the hierarchical tree, three matrices are formed like the one that appears in Equation 4 to compare the criteria, sub-criteria, and sub-subcriteria. These comparisons depend on the patient to be treated so that each criterion becomes more important as the desired treatment is more relevant. For example, in patients with severe, life-threatening diabetes, pancreas transplantation will become more important. On the other hand, in a patient with less severe diabetes, this type of medical treatment will not be needed; perhaps the change of lifestyle on the part of the patient is enough.

These matrices are shown in Tables 2, 3, and 4:

Table 2: Criteria importance comparison generic matrix

	Glycemic control	Lifestyle modifications	Foot care
Glycemic control Lifestyle modifications Foot care	**To fill by the physician(s)**		

Table 3: Generic matrix for comparison of the importance of the subcriteria

	Pharmacological	Nonpharmacological
Pharmacological Nonpharmacological	**To fill by the physician(s)**	

Table 4: Generic matrix for comparison of the importance of the sub-subcriteria

	SSC_{111}	SSC_{112}	SSC_{121}	SSC_{122}	SSC_{211}	SSC_{212}	SSC_{213}	SSC_{311}	SSC_{321}	SSC_{322}	SSC_{323}	SSC_{324}	SSC_{325}
SSC_{111} SSC_{112} SSC_{121} SSC_{122} SSC_{211} SSC_{212} SSC_{213} SSC_{311} SSC_{321} SSC_{322} SSC_{323} SSC_{324} SSC_{325}	**To fill by the physician(s)**												

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The elements within the matrices must be the elements of Table 1 and their inverses. The Neutrosophic AHP algorithm is applied, and the weights or importance of each of the 13 sub-subcriteria are obtained, let us denote them by $SSC_{ij_ik_i}$, with $i = 1, 2, 3$; the j and k are indices that depend on the i's. Then, the weights obtained are brought to crisp values with the help of one of the formulas either 5 or 6. These weights are normalized. Let us denote by $\omega_{ij_ik_i}$ these weights.

Step 3:

The weights obtained $\omega_{ij_ik_i}$ are ordered in descending order. Their values are summed up until they reach 0.9.

Those weights that add up to a total value bigger than 0.9 are not taken into account in the evaluation and they are considered unimportant. Let us denote the important weights by ω_l where l is an index less than or equal to 13. These are the aspects that will be evaluated because they are important to measure the patient's situation. This guarantees a personalized evaluation per patient.

Step 4:

The physician or medical team is asked to assess the patient's compliance with the requirements represented by the weights ω_l with index $l = 1, 2, \dots, L$. Let us denote them by v_l, according to Table 5 on the satisfaction of the sub-subcriteria:

Table 5: Linguistic scale related to neutrosophic numbers for evaluation of compliance with the sub-subcriteria.

Linguistic value	**Neutrosophic number**
Strongly disagree	(0.1,0.1,0.9)
Disagree	(0.3,0.25,0.7)
Neither agree nor disagree	(0.5,0.5,0.5)
Agree	(0.7,0.25,0.3)
Totally agree	(0.9,0.1,0.1)

Step 5:

Let us now use the following uninorm operator that is obtained from the combining function of Prospector:

$$P'(x, y) = \frac{xy}{(1-x)(1-y)+xy} \qquad (7)$$

This is a uninorm in $[0, 1]$ with a neutral value of 0.5, which becomes a neutrosophic operator when given any $\boldsymbol{X} = (x_T, x_I, x_F), \boldsymbol{Y} = (y_T, y_I, y_F) \in [0, 1]^3$, we have:

$$\boldsymbol{U}(\boldsymbol{X}, \boldsymbol{Y}) = \left(P'(x_T, y_T), P'(x_I, y_I), P'(x_F, y_F)\right) \in [0, 1]^3 \qquad (8)$$

The final evaluation is obtained by applying $\boldsymbol{U}(\boldsymbol{X}, \boldsymbol{Y})$ to all the values v_l.

Some properties of $P'(x, y)$ are the following:

- $P'(x, 0.5) = P'(0.5, x) = x$
- $P'(x, y) > x, y$; for $x, y > 0.5$
- $P'(x, y) < x, y$; for $x, y < 0.5$
- $x < P'(x, y) < y$; for $x < 0.5 < y$

Step 6:

The obtained final neutrosophic number is converted into a crisp value using Equation 9.

$$\beta\left((x_1, x_2, x_3)\right) = \frac{2+x_1-x_2-x_3}{3} \qquad (9)$$

If this value is greater than 0.5, then the patient minimally complies with self-management to avoid complications with diabetes.

Below we illustrate the method with an example.

Example 1. Suppose that a medical team determines that patient P has diabetes mellitus and makes an assessment of the factors that affect the patient for risk to suffer peripheral diabetic neuropathy, according to the

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scale that appears in Table 1. The comparison matrices to measure the ratio of the importance of the factors in this patient are the following in Tables 6, 7, and 8:

Table 6: Comparison matrix for measuring criteria importance

	Glycemic control	Lifestyle modifications	Foot care
Glycemic control	$\hat{1}$	$\hat{1}$	$\hat{3}$
Lifestyle modifications	$\hat{1}$	$\hat{1}$	$\hat{3}$
Foot care	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{1}$

Table 7: Matrix for comparison of the importance of the subcriteria

	Pharmacological	Nonpharmacological
Pharmacological	$\hat{1}$	$\hat{3}$
Nonpharmacological	$\hat{3}^{-1}$	$\hat{1}$

Table 8: Matrix for comparison of the importance of the sub-subcriteria

	SSC_{111}	SSC_{112}	SSC_{121}	SSC_{122}	SSC_{211}	SSC_{212}	SSC_{213}	SSC_{311}	SSC_{321}	SSC_{322}	SSC_{323}	SSC_{324}	SSC_{325}
SSC_{111}	$\hat{1}$	$\hat{5}^{-1}$	$\hat{9}$	$\hat{9}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{5}$	$\hat{5}$	$\hat{3}^{-1}$	$\hat{5}$	$\hat{5}$	$\hat{5}$
SSC_{112}	$\hat{5}$	$\hat{1}$	$\hat{9}$	$\hat{9}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{5}$	$\hat{5}$	$\hat{3}$	$\hat{5}$	$\hat{5}$	$\hat{5}$
SSC_{121}	$\hat{9}^{-1}$	$\hat{9}^{-1}$	$\hat{1}$	$\hat{1}$	$\hat{9}^{-1}$	$\hat{9}^{-1}$	$\hat{9}^{-1}$	$\hat{9}^{-1}$	$\hat{9}^{-1}$	$\hat{9}^{-1}$	$\hat{9}^{-1}$	$\hat{7}^{-1}$	$\hat{7}^{-1}$
SSC_{122}	$\hat{9}^{-1}$	$\hat{9}^{-1}$	$\hat{1}$	$\hat{1}$	$\hat{9}^{-1}$	$\hat{9}^{-1}$	$\hat{9}^{-1}$	$\hat{9}^{-1}$	$\hat{9}^{-1}$	$\hat{9}^{-1}$	$\hat{9}^{-1}$	$\hat{7}^{-1}$	$\hat{7}^{-1}$
SSC_{211}	$\hat{3}$	$\hat{3}$	$\hat{9}$	$\hat{9}$	$\hat{1}$	$\hat{1}$	$\hat{1}$	$\hat{3}$	$\hat{3}$	$\hat{3}$	$\hat{3}$	$\hat{3}$	$\hat{3}$
SSC_{212}	$\hat{3}$	$\hat{3}$	$\hat{9}$	$\hat{9}$	$\hat{1}$	$\hat{1}$	$\hat{1}$	$\hat{3}$	$\hat{3}$	$\hat{3}$	$\hat{3}$	$\hat{3}$	$\hat{3}$
SSC_{213}	$\hat{3}$	$\hat{3}$	$\hat{9}$	$\hat{9}$	$\hat{1}$	$\hat{1}$	$\hat{1}$	$\hat{3}$	$\hat{3}$	$\hat{3}$	$\hat{3}$	$\hat{3}$	$\hat{3}$
SSC_{311}	$\hat{5}$	$\hat{5}^{-1}$	$\hat{9}$	$\hat{9}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{1}$	$\hat{1}$	$\hat{5}^{-1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$
SSC_{321}	$\hat{5}$	$\hat{5}^{-1}$	$\hat{9}$	$\hat{9}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{1}$	$\hat{1}$	$\hat{5}^{-1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$
SSC_{322}	$\hat{3}$	$\hat{3}^{-1}$	$\hat{9}$	$\hat{9}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{5}$	$\hat{5}$	$\hat{1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$
SSC_{323}	$\hat{5}^{-1}$	$\hat{5}^{-1}$	$\hat{9}$	$\hat{9}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$
SSC_{324}	$\hat{5}^{-1}$	$\hat{5}^{-1}$	$\hat{7}$	$\hat{7}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$
SSC_{325}	$\hat{5}^{-1}$	$\hat{5}^{-1}$	$\hat{7}$	$\hat{7}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{3}^{-1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$	$\hat{1}$

Table 9 contains the weights of each of the sub-subcriteria, according to the Neutrosophic AHP.

Table 9:: Weights of the sub-subcriteria according to the Neutrosophic AHP and the result of whether or not it is important

Sub-subcriteria	Weight	Is it important?
SSC_{111}	0.1354574	Yes
SSC_{112}	0.2015472	Yes
SSC_{121}	0.0031280	No
SSC_{122}	0.0031280	No
SSC_{211}	0.1973122	Yes
SSC_{212}	0.1973122	Yes
SSC_{213}	0.1973122	Yes
SSC_{311}	0.0259301	No

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SSC_{321}	0.0078549	No
SSC_{322}	0.0110565	No
SSC_{323}	0.0110565	No
SSC_{324}	0.0044525	No
SSC_{325}	0.0044525	No

The most important sub-subcriteria are SSC_{111}, SSC_{112}, SSC_{211}, SSC_{212}, and SSC_{213}, with weights $w_1 = 0.1354574$, $w_2 = 0.2015472$, $w_3 = w_4 = w_5 = 0.1973122$, respectively, whose sum is equal to 0.92894.

Suppose that physicians rate patient satisfaction with the sub-subcriteria “Insulin” and “Antidiabetic medicines” as “agree”, while they rate “Neither agree nor disagree” to the aspects “Supervised exercise programs”, “Diet”, and “Counseling”, then these 5 values are aggregated using formula 8, the result is:

$(0.84483, 0.1, 0.15517)$, whose crisp value applying Equation 9 is equal to 0.86322. As $0.86322 > 0.5$, it can be affirmed that patient P meets the requirements to avoid the complications associated with peripheral neuropathies.

6. Conclusion

This article was dedicated to developing a method for the medical evaluation of the preventive management of diabetic peripheral neuropathy by a diabetic patient. To this end, a set of 13 measures was proposed, of which the diabetic patient must comply with some of them depending on the severity of their disease to avoid complications and avoid acquiring neuropathy. So, the method allows us to select the criteria that are most important for the severity of the disease of each patient, therefore the proposed method is personalized. This selection is carried out with the help of the Neutrosophic AHP technique. Then, the Neutrosophic Uninorms are used to carry out the final evaluation, specifically the one related to the combining function of Prospector, which is used in evaluations of expert systems. In future works, we intend to incorporate more preventive measures and carry out statistical studies of the effectiveness of the proposed method.

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