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Study of the effectiveness of a home-based pulmonary therapy program in Ecuadorian older adults with prolonged exposure to biomass smoke based on Plithogenic Similarity Measure

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Abstract. Biomass is a form of energy used primarily by people living in rural areas of developing countries. This type of energy is based on the combustion of elements such as wood. Exposure to biomass is linked to diseases such as Chronic Obstructive Pulmonary Disease (COPD), which is a major cause of global mortality. In this paper, we study a group of patients of 65 and over years of age exposed to biomass smoke for long periods in the Ecuadorian province of Cotopaxi. Specifically, we study the effectiveness of a home-based pulmonary rehabilitation program. Since there are different variables to measure, we use plithogenic sets. These also allow us to deal with the uncertainty and indeterminacy inherent in measuring subjective variables. We design a procedure that allows us to classify cases where improvement or lack of progress is evaluated after treatment.

Keywords: Pulmonary therapy, biomass, Plithogenic Set, Plithogenic Measure, Plithogenic Distance Measure, Pythagorean Similarity Measure.

1 Introduction

Biomass, mainly in the form of wood, has played a fundamental role as a primary fuel source in homes, being used both for cooking and heating. This practice has been essential in various cultures, especially in rural areas and developing countries where modern energy is scarce and expensive. However, it is important to highlight that the continued use of biomass as an energy source has had a significant impact on respiratory and general health.

Constant exposure to smoke generated by biomass burning has been linked to various chronic respiratory diseases, including chronic obstructive pulmonary disease, asthma, bronchitis, and pneumonia. Furthermore, the fine particles and gases produced during combustion can penetrate deep into the lungs and sometimes enter the bloodstream, which can lead to or worsen heart problems and other health conditions.

Biomass smoke affects the lungs, primarily through the inhalation of fine particles and toxic gases. These particles can penetrate deep into the lungs, causing inflammation, damage to lung tissue, and reduced lung function. This increases the risk of respiratory diseases. It should be noted that, although there are similarities between wood smoke-induced COPD and tobacco smoke-induced COPD, there are key differences in demographic characteristics, lung function, and some aspects of clinical presentation. Patients with COPD-B (wood smoke) tend to have less severe airflow obstruction and lower sputum production compared to patients with COPD-S (tobacco smoke).

Spirometry is a key diagnostic tool in identifying lung diseases. This test evaluates aspects such as volume and airflow in the lungs, allowing physicians to better understand a patient's respiratory capacity and detect any breathing dysfunction or abnormalities. It also provides data such as respiratory volumes and flows, providing critical information for identifying patterns of respiratory disease. It includes parameters such as Forced Vital Capacity (FVC), Forced Expiratory Volume in One Second (FEV1), and the FEV1/FVC ratio. These values help differentiate between obstructive and restrictive lung disorders, which are essential in diagnosing conditions such as COPD and asthma. Additionally, spirometry can indicate the severity of lung disease and monitor response to treatment.

COPD is characterized by persistent airflow obstruction and is associated with an abnormal inflammatory response of the lungs to harmful particles or gases. The most common symptoms include dyspnea (shortness of breath), chronic cough, and sputum production. COPD is a progressive disease that can lead to a significant decline in a patient's quality of life. It is characterized by airflow limitation that is not fully reversible and progresses over time. This leads to a decline in lung function and breathing difficulties.

Pulmonary rehabilitation for the treatment of chronic obstructive pulmonary disease is critical because of its ability to improve dyspnea and fatigue, increase exercise tolerance and health-related quality of life, and reduce hospitalizations and mortality in patients with COPD.

Exercise is a key component of pulmonary rehabilitation, including exercise assessment and training therapy. It is important to tailor exercise programs to individual patients' needs and abilities. Various training modalities, such as resistance training, aerobic training, and neuromuscular electrical stimulation, are available to accommodate the limitations of patients with COPD. Respiratory physiotherapy is a crucial tool in the comprehensive management of patients with respiratory pathologies, both in the acute phase and in long-term rehabilitation.

The 6-minute walk test is a method used to assess exercise capacity and the response of body systems during physical exertion. It is primarily used in cases of chronic respiratory diseases. The test involves walking as far as possible in six minutes and follows a standardized protocol. An alternative test called the one-minute sit-to-stand test, is used to determine functional exercise capacity in individuals with COPD, varying the change in shortness of breath.

Currently, there is an increasing number of people who, after repeated exposure to biomass smoke, have not sought treatment, let alone adequate rehabilitation. In Ecuador, there are no in-depth studies on rehabilitation for patients exposed to biomass smoke. This led us to implement this respiratory rehabilitation program for patients who have been voluntarily or involuntarily exposed to biomass smoke throughout their lives, given the lack of this treatment in hospitals and the significant increase in cases currently occurring. In addition to offering a comprehensive view of patient recovery, the importance of applying respiratory techniques aims to reduce the consequences of this exposure on the population at the local and national levels. This implementation will contribute to significant improvements in patients' functional capacity, mortality, quality of life, and risk factor control.

This is a new and highly beneficial proposal for older adults living in the Alaquez parish of Cotopaxi province. This will allow for significant recovery at home, enabling them to perform better in their daily lives.

A high incidence of people with after-effects is frequently observed in the province of Cotopaxi, who in turn have been limited in their daily activities, with respiratory problems occurring in patients of 65 and over years of age. There is an urgent need to establish the beneficial effect of home-based respiratory rehabilitation because complications diminish respiratory function, thereby affecting the patient's quality of life and early recovery and return to work.

In this paper, we propose to study the effectiveness of pulmonary rehabilitation treatment in patients from the province of Cotopaxi who suffer from lung damage caused by prolonged exposure to biomass smoke. To do so, we use the theory of plithogeny, specifically plithogenic sets [1-4]. These sets generalize the previous theories of neutrosophic sets and, therefore, fuzzy sets, and intuitionistic fuzzy sets, among others. The fundamental purpose of plithogenic sets is to represent multidimensional and multiattribute models, which are useful when considering different, interacting variables [5]. To date, there are a large number of papers that apply this theory, especially in decision-making, [6-13].

In this paper, we use plithogeny theory because in the treatment several variables are measured with degrees of dependence on one another. We use the Plithogenic Distance Measure theory and Plithogenic Similarity Measure because they allow us to classify elements based on the possible evaluation of each variable [14, 15]. To do this, we designed an algorithm that will allow us to calculate similarity to determine the most representative combination of classifications in the study conducted and thus determine whether the treatment was successful or failed.

The article is divided into a Materials and Methods section where the concepts of Plithogenic Sets, Plithogenic Distance Measures, and Plithogenic Similarity Measure are recalled. The Results section contains the elements used to conduct the study, the procedure followed, and the final results. The last section is the Conclusion.

2 Materials and Methods

In this section, we review the basic concepts of Plithogenic Sets, Plithogenic Distance Measures, and Plithogenic Similarity Measures.

2.1 Plithogenic Sets

Let U be the universe of discourse, P is a non-empty set of elements, where P is a subset of U [1-4, 16-18]. Given A is defined as $A = \{\alpha_1, \alpha_2, \dots, \alpha_m\}$, $m \geq 1$, a non-empty set of *one-dimensional* attributes. $\alpha \in A$ is an attribute in A whose spectrum of all possible values (or states) is the nonempty set S, such that S might be a discrete finite set $S = \{s_1, s_2, \dots, s_l\}$, $1 \leq l < \infty$, or an infinitely countable set $S = \{s_1, s_2, \dots, s_\infty\}$, or an infinitely uncountable (continuous) set $S =]a, b[$, $a < b$.] ... [denotes any open, half-open, or closed interval of the set of real numbers or another general set.

V is a nonempty subset of S, such that V is the range of all attribute values needed by experts for their application. Each $x \in P$ is considered as the values of all attributes in $V = \{v_1, v_2, \dots, v_n\}$, and $n \geq 1$.

In general, there exists in V a *dominant attribute value*, which is selected by experts according to the context. This is interpreted as the most important attribute value that experts consider as the main of all to fulfill the goal.

Each element $v \in V$ has a corresponding *degree of approval* $d(x, v)$ of the element x, to the set P, for some given criteria.

The degree of appurtenance could be a *fuzzy degree of appurtenance*, an *intuitionistic fuzzy degree of appurtenance*, or a *neutrosophic degree of appurtenance* to the plithogenic set [1-4].

Thus, the *attribute value appurtenance degree function* is:

$$\forall x \in P, d: P \times V \rightarrow P([0,1]^z) \quad (1)$$

Thus, $d(x, v)$ is a subset of $[0,1]^z$, where $\mathcal{P}([0,1]^z)$ is the power set of $[0,1]^z$, where z = 1 (*fuzzy degree of appurtenance*), z = 2 (for the *intuitionistic fuzzy degree of appurtenance*), or z = 3 (for the *neutrosophic degree of appurtenance*).

For $|V| \geq 1$ be the cardinal. Function $c: V \times V \rightarrow [0,1]$ is the *attribute value contradiction degree function* between any two attribute values v_1 and v_2, let us denote it by $c(v_1, v_2)$, which satisfies the following conditions:

1. $c(v_1, v_1) = 0$, that is, the degree of contradiction between the same attribute values is zero;
2. $c(v_1, v_2) = c(v_2, v_1)$, commutativity.

Let us define the *fuzzy attribute value contradiction degree function* (c as above, which we denote by c_F to distinguish it from the following two), an *intuitionistic fuzzy attribute value contradiction function* $c_{IF}(\cdot)$, or more generally, a $c_{IF}: V \times V \rightarrow [0,1]^2$. *Neutrosophic attribute value contradiction degree function* ($c_N: V \times V \rightarrow [0,1]^3$) can be used. It is more complex to calculate, but it is more accurate as well.

Generally, one-dimensional attributes values are defined and the degree of disagreement between them. When we have multi-dimensional attribute values, they are decomposed into one-dimensional attribute values.

The attribute value contradiction degree function contributes to greater accuracy in calculations in certain grouping methods and ordering systems.

The degree fixed to measure the existing disagreement among different values with each other is selected for each area where a special type of group is used, depending on the type of problem to solve. Even when these details are not taken into account, we will obtain results, which will nevertheless lose accuracy.

Thus, (P, a, V, d, c) is called a *plithogenic set*, [1-4]:

1. Such that "P" is a set, "a" is an attribute (multidimensional in general), "V" is the rank of the attribute values, "d" is the degree of appurtenance of the attribute value of each element x to the set P regarding some given criteria ($x \in P$), and "d" is "d_F" or "d_{IF}" or "d_N", in case that it is a fuzzy degree of appurtenance, an intuitionistic fuzzy degree of appurtenance, or a neutrosophic degree of appurtenance respectively of an element x to the plithogenic set P;
2. "c" is defined for "c_F" or "c_{IF}" or "c_N", when it refers to the fuzzy degree of contradiction, fuzzy intuitionistic degree of contradiction, or neutrosophic degree of contradiction between attribute values, respectively.

$d(\cdot,\cdot)$ and $c(\cdot,\cdot)$ are defined in line with the application that experts consider to do.
The notation is the following:

$x(d(x, V))$, where $d(x, V) = \{d(x, v), \text{ for all } v \in V\}, \forall x \in P$.

The degree of attribute value contradiction is calculated between each attribute value concerning the dominant attribute value (that is denoted by v_D) in particular and also to other attribute values.

The attribute value contradiction degree function c between the attribute values is used in the definition of *plithogenic aggregation operators* (intersection (AND), union (OR), implication (⟹), equivalence (⟺), inclusion relation (partial order), and other plithogenic aggregation operators combining two or more attribute value degrees acting on the t-norm and t-conorm.

The majority of the plithogenic aggregation operators are linear combinations of the fuzzy t-norm (which is denoted by $\wedge_F$), and the fuzzy t-conorm (let us denote it by $\vee_F$), but nonlinear combinations can also be built.

When we have the result of applying the t-norm between the dominant attribute value (v_D), and additionally, the contradiction between v_D and v_2 is fixed ($c(v_D, v_2)$), then we have the following:

$$[1 - c(v_D, v_2)] \cdot t_{norm}(v_D, v_2) + c(v_D, v_2) \cdot t_{conorm}(v_D, v_2) \quad (2),$$

Or, equivalently by using symbols:

$$[1 - c(v_D, v_2)] \cdot (v_D \wedge_F v_2) + c(v_D, v_2) \cdot (v_D \vee_F v_2) \quad (3).$$

Also, having the t-conorm between the dominant attribute value v_D, and the contradiction between v_D and v_2 which is $c(v_D, v_2)$, then we have:

$$[1 - c(v_D, v_2)] \cdot t_{conorm}(v_D, v_2) + c(v_D, v_2) \cdot t_{norm}(v_D, v_2) \quad (4).$$

Or equivalently:

$$[1 - c(v_D, v_2)] \cdot (v_D \vee_F v_2) + c(v_D, v_2) \cdot (v_D \wedge_F v_2) \quad (5).$$

The *Plithogenic Neutrosophic Intersection* is defined as follows:

$$(a_1, a_2, a_3) \wedge_P (b_1, b_2, b_3) = \left(a_1 \wedge_F b_1, \frac{1}{2}[(a_2 \wedge_F b_2) + (a_2 \vee_F b_2)], a_3 \vee_F b_3\right) \quad (6),$$

The *Plithogenic Neutrosophic Union* is:

$$(a_1, a_2, a_3) \vee_P (b_1, b_2, b_3) = \left(a_1 \vee_F b_1, \frac{1}{2}[(a_2 \wedge_F b_2) + (a_2 \vee_F b_2)], a_3 \wedge_F b_3\right) \quad (7),$$

Thus, the membership and non-membership in Equations 6 and 7 are interchanged, and the indeterminacy does not change and is the average between the fuzzy conjunction and disjunction.
The *Plithogenic Neutrosophic Inclusion* is defined as follows:

Because of the degrees of contradiction are $c(a_1, a_2) = c(a_2, a_3) = c(b_1, b_2) = c(b_2, b_3) = 0.5$, then: $a_2 \geq [1 - c(a_1, a_2)]b_2$ or $a_2 \geq (1 - 0.5)b_2$ or $a_2 \geq 0.5b_2$ and $c(a_1, a_3) = c(b_1, b_3) = 1$.

Given $a_1 \leq b_1$ the opposite applies for $a_3 \geq b_3$, such that $(a_1, a_2, a_3) \leq_P (b_1, b_2, b_3)$ if and only if $a_1 \leq b_1$ and $a_2 \geq 0.5b_2$, $a_3 \geq b_3$.

2.2 Plithogenic Distance Measures

Definition 1 ([14-19]). The definition of Plithogenic Distance Measure (PDM) contains the Plithogenic Hamming Distance Measure (d_H^R), the Normalized Plithogenic Hamming Distance Measure (d_{NH}^R), the Plithogenic Euclidean Distance Measure (d_E^R), and the Normalized Plithogenic Euclidean Distance Measure (d_{NE}^R). These distances are defined for calculating the distance between two plithogenic sets R_1 and R_2. See the Equations below:

The Plithogenic Hamming Distance (PHD) is,

$$d_H^R(R_1, R_2) = \frac{1}{m}\sum_{i=1}^{m}\sum_{j=1}^{l}\left|d_{R_1}^i(\delta_j) - d_{R_2}^i(\delta_j)\right| max\left(c_F^i(\delta_j, \delta_d)\right) \quad (8)$$

The Normalized Plithogenic Hamming Distance (NPHD) is,

$$d_{NH}^R(R_1, R_2) = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{l}\left|d_{R_1}^i(\delta_j) - d_{R_2}^i(\delta_j)\right| max\left(c_F^i(\delta_j, \delta_d)\right) \quad (9)$$

The Plithogenic Euclidean Distance (PED) is,

$$d_E^R(R_1, R_2) = \left[\frac{1}{m}\sum_{i=1}^{m}\sum_{j=1}^{l}\left(d_{R_1}^i(\delta_j) - d_{R_2}^i(\delta_j)\right)^2 max\left(c_F^i(\delta_j, \delta_d)\right)\right]^{\frac{1}{2}} \quad (10)$$

The Normalized Plithogenic Euclidean Distance (NPED) is,

$$d_{NE}^R(R_1, R_2) = \frac{1}{n}\left[\frac{1}{m}\sum_{i=1}^{m}\sum_{j=1}^{l}\left(d_{R_1}^i(\delta_j) - d_{R_2}^i(\delta_j)\right)^2 max\left(c_F^i(\delta_j, \delta_d)\right)\right]^{\frac{1}{2}} \quad (11)$$

Definition 2 ([14-19]). The Pythagorean Similarity Measure (PSM) is defined as follows:

$$M^R(R_1, R_2) = \frac{1}{1 + d^R(R_1, R_2)} \quad (12)$$

Where, $d^R(R_1,\ R_2)$ is a plithogenic distance, that can be either a PHD, NPHD, PED, or NPED.

3 Results

The population of this study consisted of a total of 432 older adults belonging to the Aláquez parish of the Latacunga canton, Cotopaxi province, Ecuador. Of these, 160 were older adults and presented respiratory problems according to records from the statistics department of the Alaquez Parish Health Center. The sample was chosen by convenience and consisted of 40 older adults from the population who met the inclusion criteria.

Inclusion criteria

- Older adults with decreased respiratory function,
- Not dependent on oxygen,
- Without adjacent metabolic problems,
- No involvement of the locomotor system,
- Acceptance to participate in the research (sign the informed consent).

Exclusion criteria

- Diagnosed with mental disorders,
- Another type of respiratory rehabilitation treatment,
- With poor cognitive ability.

Exit criteria

- Failure to execute the rehabilitation activities included in the program with the established priority,

- Continue burning biomass for household activities.

An open interview was conducted with the older adults who decided to participate in the study, in order to collect key information on socio-demographic variables such as age, gender, marital status, educational level and time of exposure to biomass smoke, see Table 1.

Table 1. Socio-demographic characterization of the study sample

VARIABLES	NUMBER	%
Age (years)		
65–75	8	20
76-85	21	52.5
More than 85	11	27.5
Marital status		
Single	2	5
Married	33	82.5
Divorced	3	7.5
Widower	2	5
Level of education		
Primary	24	60
Secondary	-	-
Third level	-	-
Fourth level	-	-
None	16	40
Smoke exposure time		
From 1 to 10 years	-	-
From 11 to 20	-	-
From 21 to 30	-	-
From 31 to 40	4	10
From 41 to 50	29	72.5
From 51 to 60	4	10
More than 61	3	7.5
Concomitant diseases		
Hypertension	25	62.5
Hypothyroidism	18	45
Diabetes	14	35
Arthritis	34	85

In addition, they were asked about signs and symptoms associated with prolonged exposure to this smoke (such as coughing up phlegm, excessive fatigue, dizziness, and pain in the lower extremities). All data were recorded on a specially designed data collection form.

Additionally, respiratory function was assessed in relation to continuous exposure to biomass smoke using spirometry, with the aim of obtaining accurate and reliable results on the respiratory status of the participants.

The subjects' physical capacity was also assessed using the 6-minute walk test, which collected data such as weight and height, as well as other data obtained in the initial interview, providing a comprehensive view of the participants' physical capacity.

The findings support the need to develop an intervention program aimed at pulmonary rehabilitation in older adults with long-term exposure to biomass smoke. To this end, the normative and strategic phases of program planning were implemented, with the active participation of key stakeholders, namely the research team composed of healthcare professionals specializing in respiratory rehabilitation, along with experts who complemented the activities.

The pulmonary rehabilitation program was designed to provide older adults with respiratory difficulties resulting from exposure to biomass smoke with an appropriate framework for carrying out both preventive and educational activities that promote improved respiratory capacity.

The key actions, objectives, number of sessions, and strategic guidelines for the program were established.

A rehabilitation program was also developed, and evaluation systems and indicators were defined to measure the effectiveness of the proposed program.

The program design included simple, easy-to-learn, and highly reproducible exercises tailored to the specific needs of older adults exposed to biomass smoke, ensuring their adherence to the program.

To implement the pulmonary rehabilitation program, a quasi-experimental study was conducted with a single group of older adults. A pre- and post-intervention evaluation was conducted, with the patients themselves serving as their controls. Monthly meetings were held with the participation of the research team to monitor the program's implementation, allowing for ongoing monitoring.

Data collection throughout the entire process was carried out using the same instruments used in the first stage of the research. These data were used to calculate indicators that allowed us to measure the program's effectiveness.

Throughout the program, standardized tools were used to record each assessment in detail, and each participant was assigned an individual form documenting their immediate progress after each assessment. In addition, portable devices such as a saturator, blood pressure monitor, and spirometer were used to monitor vital signs in real-time, ensuring both data accuracy and participant safety and comfort. This provided reliable, essential information for later analysis of the program's effectiveness.

In summary, the study was divided into two periods, before and after treatment. In addition to the quantitative measurements specific to each physiological test, when possible, a qualitative linguistic scale was used that matched the quantitative measurement obtained. The advantage of this linguistic scale is that specialists can more accurately express each patient's actual condition; while patients' communication is clarified because it helps them better understand their health status. The scale is shown in Table 2.

Table 2: Linguistic values associated with plithogenic numbers for the assessment.

LINGUISTIC EXPRESSION	PLITHOGENIC NUMBER (T, I, F)
Bad (B)	$(0.25, 0.60, 0.80)$
Medium (M)	$(0.60, 0.40, 0.50)$
Fine (F)	$(0.80, 0.10, 0.30)$

Four physiological tests were evaluated, each before and after treatment. These tests are explained below in Table 3.

Table 3: Physiological tests applied, variables to be measured, and their definitions.

PHYSIOLOGICAL TEST	DEFINITION	VARIABLES
v_1: Spirometry	A diagnostic test that measures the amount of air a person can inhale and exhale, as well as how quickly they can empty their lungs.	Forced Vital Capacity (FVC) Maximum Expiratory Volume in One Second (FEV1) FEV1/FVC ratio.
v_2: Saturation	Percentage of oxygen in blood	It is an essential indicator of the efficiency of oxygen transport in the body.
v_3: Respiratory rate	It is the number of breaths a person takes per minute.	It is measured by observing the rise and fall of a person's chest or abdomen.
v_4: Dyspnea	It is a numerical tool that measures a person's perception of effort during physical activity, gauging how much work they feel they are doing.	There are no "normal values" per se; the scale is designed to be subjective and reflect the individual's experience of exertion during an activity.

The procedure to follow is:

We start from a group of variables denoted by $\tilde{v}_{ijk}$ $i = 1, 2, 3, 4$, where it is one of the variables defined above. $j = 0, 1$, where 0 means the result before treatment and 1 the result after treatment, and $k = 1, 2, \ldots, 40$ denotes the kth patient.
Here, $\tilde{v}_{ijk} \in \{B, M, F\}$ from Table 2.

The data are processed using equivalent values in plithogenic form of neutrosophic numbers as shown in Table 2. Let us call them $v_{ijk} \in \{(0.25, 0.60, 0.80), (0.50, 0.40, 0.60), (0.80, 0.10, 0.30)\}$.

Average values are calculated for all patients:

$$\bar{v}_{ij} = \frac{\sum_{k=1}^{40} v_{ijk}}{40} \qquad (13)$$

8-tuples of possible values for the variables are formed according to the scale shown in Table 2. For example, (F, F, F, F, F, F, F, F) is the case in which the 8-tuple of variables $(\bar{v}_{10}, \bar{v}_{20}, \bar{v}_{30}, \bar{v}_{40}, \bar{v}_{11}, \bar{v}_{21}, \bar{v}_{31}, \bar{v}_{41})$ all are fine.

There is a possible number of cases equal to $3^8 = 6{,}561$. However, because the actual number of variables to be classified is $2 \times 4 = 8$, then 6,560 of the cases will be unclassified into any of the possible 8-tuples, and the calculations will therefore be simplified.

The 8-tuples (F, F, F, F, F, F, F, F), (F, F, F, F, F, F, F, M),…, (B, B, B, B, B, B, B, B) are compared to select such which has greater similarity with $(\bar{v}_{10}, \bar{v}_{20}, \bar{v}_{30}, \bar{v}_{40}, \bar{v}_{11}, \bar{v}_{21}, \bar{v}_{31}, \bar{v}_{41})$. For this purpose, the PSM of Equation 12 is used in combination with the NPED of Equation 11. Here we choose the attribute value contradiction degree function $c_F^i(\delta_j, \delta_d) = 0.5$, since none of the attributes is dominant. This is because we consider all physiological tests to be equally important in determining whether or not there is improvement.
It is checked that the 8-tuple satisfies that $\forall i\ \bar{v}_{i0} < \bar{v}_{i1}$ or that $\bar{v}_{i0} = \bar{v}_{i1} = F$. In this case, the treatment produces an expected improvement.

After following this procedure we achieved the following results:

$\bar{v}_{10} = (0.48375, 0.4525, 0.5975)$, $\bar{v}_{20} = (0.57375, 0.415, 0.5225)$, $\bar{v}_{30} = (0.70, 0.242, 0.395)$, $\bar{v}_{40} = (0.6, 0.4, 0.5)$, $\bar{v}_{11} = (0.545, 0.4175, 0.545)$, $\bar{v}_{21} = (0.6, 0.4, 0.5)$, $\bar{v}_{31} = (0.795, 0.1075, 0.305)$, and $\bar{v}_{41} = (0.74, 0.19, 0.36)$.

The best-fitting 8-tuple was (M, M, F, M, M, M, F, F) with PSM equal to 0.9592.

It is noted that the last variable is the only one with a qualitative improvement, although all the variables comply $\bar{v}_{i0} < \bar{v}_{i1}$ quantitatively, using the criterion between neutrosophic numbers such that $(T_1, I_1, F_1) \leq (T_2, I_2, F_2)$, if and only if, $T_1 \leq T_2$, $I_2 \leq I_1$, and $F_2 \leq F_1$.

4 Conclusion

This study demonstrates that a home-based pulmonary rehabilitation program designed for older adults chronically exposed to biomass smoke in rural areas can generate benefits in terms of lung function, exercise tolerance, perception of dyspnea, and associated musculoskeletal symptoms. The results obtained are consistent with recent international and regional evidence, strengthening the validity of the applied model. We reached this conclusion after conducting a study of 40 patients of 65 and over years of age from the province of Cotopaxi. Specifically, a significant qualitative change was observed in dyspnea. Improvements also occurred in spirometry, saturation, and respiratory rate. The use of plithogenic similarly allowed us to deal with uncertainty and indeterminacy when it comes to subjective assessments, which can hardly be adequately expressed on a numerical scale.

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