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Study of the relationship between moderate intermittent exercise and blood pressure in institutionalized older adult patients, using the neutrosophic correlation coefficient

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Abstract. This paper aims to analyze the effects of moderate intermittent exercise in institutionalized older adults and its relationship with blood pressure. It is an investigation where the impact of sporadic exercises on blood pressure values over time was evaluated. A total of 29 older adults were analyzed to whom moderate intermittent exercises were applied for 4 weeks, 3 times a week for 30 minutes each session, with 12 interventions. Because blood pressure is an indicator that changes over time during the course of the day and its measurement is not precise, we use single-valued neutrosophic sets as data instead of numerical values. Neutrosophic Statistics techniques were applied to these data. This is a branch of statistics and neutrosophy where the methods of classical statistics are extended to data or parameters in interval form, or in the case of samples or populations whose exact size is not known. Specifically, we use neutrosophic correlation methods applied to neutrosophic data. Although this is not interval data, it could also be considered part of the Neutrosophic Statistics because it is not crisp data.

Keywords: Neutrosophic statistics**,** neutrosophic correlation, blood pressure, older adults, preventive medicine, moderate physical exercises.

1 Introduction

High blood pressure is a condition seen in approximately 20-40% of the adult population in the Americas region, which means around 250 million people experience elevated blood pressure levels. Non-pharmacological treatment, such as physical exercise, has been undervalued by medical personnel, but it can contribute to the control of blood pressure levels in hypertensive patients, reduce their need for medications, improve their quality of life, and reduce cardiovascular mortality, among others [1].

On the other hand, conventional treatment of hypertension, which involves the use of medications, is not only expensive from a financial perspective, but can also lead to various problematic side effects in the case of older adults. Thiazide diuretics, long-acting calcium channel blockers, and angiotensin-converting enzyme inhibitors are some of the drugs considered first-line for the treatment of hypertension in older adults. For this reason, complementary and combined therapeutic approaches are considered, which do not involve the use of medications. These approaches include modifying diet, reducing caloric intake, as well as incorporating regular physical activity, with a minimum of thirty minutes per day [2].

Likewise, physical activity is an effective way to control high blood pressure in older adults. Moderate or intense exercise is especially beneficial for reducing blood pressure; it is one of the most recommended preventive and therapeutic measures to control blood pressure, but some different modalities and protocols can have different effects on this variable.

Therefore, this research aims to contribute to current scientific knowledge by examining the relationship between moderate intermittent exercise and blood pressure in institutionalized older adults. Given the context and data presented above, the need to implement a research project oriented towards the prevention and improvement of conditions such as high blood pressure in institutionalized older adults at the “Hogar Sagrado Corazón de Jesús”, in Ambato, Ecuador, becomes evident.

There were 29 older adults undergoing the treatment by performing moderate physical exercises for a period of four weeks. The results of the blood pressure measurements were processed in the form of single-valued neutrosophic numbers instead of precise numerical values. This is because blood pressure is a value subject to inaccuracies due to the nature of the measuring equipment, the differences in blood pressure that occur during the course of the day and that is natural, the difference in blood pressure due to factors external to the person such as stress or performing some physical activity such as walking.

For this study, we carry out an evaluation where the neutrosophic correlation coefficient is used [3-9]. This test generalizes a method from classical statistics to neutrosophic statistics [10-16]. In neutrosophic statistics, results are obtained where the data or parameters are values in the form of an interval. Populations or samples where their exact size is not known are also taken into account. The objective is to gain accuracy by incorporating indeterminate values at the cost of having greater indeterminacy. Usually, neutrosophic methods correlation are not expressed in the form of intervals, however, they can be considered as part of the Neutrosophic Statistics since the data are not numerical values as in classical statistics. Specifically, we have values in the form of single-valued neutrosophic numbers.

This paper consists of the following structure, section 2 is dedicated to offering the basic notions of Neutrosophic Statistics and Neutrosophic Correlation. Section 3 shows the results of the statistical calculations carried out in this research. The last section is dedicated to conclusions.

2 Materials and Methods

This section is dedicated to exposing the basic notions of Neutrosophic Statistics.

2.1 Basic Notions of Neutrosophic Statistics

Definition 1: ([17-19]) Let X be a universe of discourse. A *Neutrosophic Set* (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x) : X \rightarrow]^-0, 1^+[$, which satisfy the condition $^-0 \leq \inf u_A(x) + \inf r_A(x) + \inf v_A(x) \leq \sup u_A(x) + \sup r_A(x) + \sup v_A(x) \leq 3^+$ for all $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ are the membership functions of truthfulness, indeterminacy and falseness of x in A, respectively, and their images are standard or non-standard subsets of $]^-0, 1^+[$.

Definition 2: ([15-17]) Let X be a universe of discourse. A *Single-Valued Neutrosophic Set* (SVNS) A on X is a set of the form:

$$A = \{\langle x, u_A(x), r_A(x), v_A(x)\rangle : x \in X\} \quad (1)$$

Where $u_A, r_A, v_A : X \rightarrow [0,1]$, satisfy the condition $0 \leq u_A(x) + r_A(x) + v_A(x) \leq 3$ for all $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ denote the membership functions of truthfulness, indeterminate and falseness of x in A, respectively. For convenience, a *Single-Valued Neutrosophic Number* (SVNN) will be expressed as $A = (a, b, c)$, where $a, b, c \in [0,1]$ and satisfy $0 \leq a + b + c \leq 3$.

Neutrosophic Statistics extends classical statistics, such that we deal with set values rather than crisp values, ([15-17]). This definition agrees with the type of data used in this paper.

Neutrosophic Descriptive Statistics is comprised of all techniques to summarize and describe the neutrosophic numerical data characteristics.

Neutrosophic Inferential Statistics consists of methods that allow the generalization from a neutrosophic sampling to a population from which the sample was selected.

Neutrosophic Data is the data that contains some indeterminacy. Similarly to classical statistics it can be classified as:

- *Discrete neutrosophic data*, if the values are isolated points.
- *Continuous neutrosophic data*, if the values form one or more intervals.

Another classification is the following:

- *Quantitative (numerical) neutrosophic data*; for example a number in the interval (we do not know exactly), 47, 52, 67, or 69 (we do not know exactly);
- *Qualitative (categorical) neutrosophic data*; for example: blue or red (we don't know exactly), white, black or green or yellow (not knowing exactly).

The *univariate neutrosophic data* is a neutrosophic data that consists of observations on a neutrosophic single attribute [20].

Multivariable neutrosophic data is neutrosophic data that consists of observations on two or more attributes [21, 22].

A *Neutrosophical Statistical Number* N has the form $N = d + I$, where d is called the *determinate part* and I is called the *indeterminate part* [23].

A *Neutrosophic Frequency Distribution* is a table displaying the categories, frequencies, and relative frequencies with some indeterminacy. Most often, indeterminacies occur due to imprecise, incomplete, or unknown data related to frequency. As a consequence, relative frequency becomes imprecise, incomplete, or unknown too.

Neutrosophic Survey Results are survey results that contain some indeterminacy.

A *Neutrosophic Population* is a population not well determined at the level of membership (i.e. not sure if some individuals belong or do not belong to the population).

A *simple random neutrosophic sample* of size n from a classical or neutrosophic population is a sample of n individuals such that at least one of them has some indeterminacy.

A *stratified random neutrosophic sampling* is the pollster groups of the (classical or neutrosophic) population by a strata according to a classification; Then the pollster takes a random sample (of appropriate size according to a criterion) from each group. If there is some indeterminacy, we deal with neutrosophic sampling.

Additionally, we describe some concepts of interval calculus [24, 25].

Given $N_1 = a_1 + b_1 I$ and $N_2 = a_2 + b_2 I$ are two neutrosophic numbers, some operations between them are defined as follows:

$N_1 + N_2 = a_1 + a_2 + (b_1 + b_2)I$ (Addition),

$N_1 - N_2 = a_1 - a_2 + (b_1 - b_2)I$ (Difference),

$N_1 \times N_2 = a_1 a_2 + (a_1 b_2 + b_1 a_2 + b_1 b_2)I$ (Product),

$\frac{N_1}{N_2} = \frac{a_1+b_1 I}{a_2+b_2 I} = \frac{a_1}{a_2} + \frac{a_2 b_1 - a_1 b_2}{a_2(a_2+b_2)} I$ (Division).

Additionally, given $I_1 = [a_1, b_1]$ and $I_2 = [a_2, b_2]$ we have the following operations between them:

$I_1 \leq I_2$ if and only if $a_1 \leq a_2$ and $b_1 \leq b_2$.

$I_1 + I_2 = [a_1 + a_2, b_1 + b_2]$ (Addition);

$I_1 - I_2 = [a_1 - b_2, b_1 - a_2]$ (Subtraction),

$I_1 \cdot I_2 = [\min\{a_1{\cdot}b_1, a_1{\cdot}b_2, a_2{\cdot}b_1, a_2{\cdot}b_2\}, \max\{a_1{\cdot}b_1, a_1{\cdot}b_2, a_2{\cdot}b_1, a_2{\cdot}b_2\}]$ (Product),

$\frac{I_1}{I_2} = \left[\frac{a_1}{b_1}, \frac{a_2}{b_2}\right]$, always that $0 \notin I_2$ (Division).

$\sqrt{I} = \left[\sqrt{a}, \sqrt{b}\right]$, always that $a \geq 0$ (Square root).

$I^n = \underbrace{I \cdot I \cdot \dots \cdot I \cdot I}_{n\ \text{times}}$.

2.2 Neutrosophic Correlation

Definition 3: ([3, 26]) Let A and B be two single-valued neutrosophic sets in a finite space $X = \{x_1, x_2, \dots, x_n\}$. The *correlation between the two neutrosophic sets* A and B is defined below:

$$CN(A,B) = \sum_{i=1}^{n} [u_A(x_i) u_B(x_i) + r_A(x_i) r_B(x_i) + v_A(x_i) v_B(x_i)] \quad (2)$$

The *correlation coefficient* between A and B is defined by Equation 3.

$$R(A,B) = \frac{CN(A,B)}{\sqrt{T(A)T(B)}} \quad (3)$$

Where:

$T(A) = \sum_{i=1}^{n} [u_A^2(x_i) + r_A^2(x_i) + v_A^2(x_i)]$ and $T(B) = \sum_{i=1}^{n} [u_B^2(x_i) + r_B^2(x_i) + v_B^2(x_i)]$.

We would like to emphasize that originally this part was called statistics on neutrosophic data. But since it is neutrosophic data, it can also be classified as part of the Neutrosophic Statistics. If we want to be more rigorous in the concepts, each single-valued neutrosophic set can be decomposed into intervals using α-cuts and the proposed statistical methods can be applied to these values in the form of intervals.

3 Results of the statistical study

In the present investigation, numerical blood pressure data is collected from the participating older adults, which will be tabulated and analyzed statistically. Then, in the second experimental stage, an intervention consisting of a program of intermittent physical exercises of moderate intensity is applied.

The initial observational design will allow the sample to be characterized by baseline blood pressure levels. The analytical approach will seek to explore possible associations of this variable with other demographic and clinical factors.

Longitudinal monitoring throughout the exercise program aims to evaluate the effect of this intervention on blood pressure values over time. In this way, the quantitative approach will guide the entire research process from the systematic collection of measurements to the statistical analysis to test the hypothesis.

Selection of area or scope of study

- Field: Health,
- Aspects: Moderate intermittent exercise, blood pressure,
- Province, Canton: Tungurahua, Ambato,
- Place: Hogar Sagrado Corazón de Jesús,
- Time: September 2023-February 2024 Scope of study,
- Research line: Human Health.

For the creation of this degree project, the population will be 29 older adults, and people of both sexes who have blood pressure problems, between 60 and 100 years of age, will be taken into account.

Inclusion criteria

- Patients with controlled blood pressure before exercise,
- Patients who voluntarily sign the informed consent,
- Patients between 60 and 100 years of age.

Exclusion criteria

- Dependent older adults,
- Older adults with diseases such as diabetes mellitus,
- Older adults with a diagnosis of aneurysms,
- Older adults with varicose veins in the lower limbs,
- Older adults with isolated systolic arterial hypertension.

The detailed results of the study are summarized in Table 1.

Table 1. Evaluation of blood pressure in institutionalized older adults.

	Age	Categorization of the Elderly	SBP	DBP	Categorization of the blood pressure
P1	88	Adult elderly fragile	130	80	Prehypertension
P2	98	Adult elderly fragile	126	78	Prehypertension
P3	85	Adult elderly fragile	120	84	Prehypertension
P4	81	Elderly intermediate	130	70	Prehypertension
P5	82	Elderly intermediate	130	66	Prehypertension
P6	90	Adult elderly fragile	120	60	Prehypertension
P7	97	Adult elderly fragile	110	50	Normotension
P8	93	Adult elderly fragile	140	70	Hypertension stage 1
P9	90	Adult elderly fragile	126	86	Prehypertension
P10	71	Adult elderly young	120	80	Prehypertension
P11	88	Adult elderly fragile	130	68	Prehypertension
P12	88	Adult elderly fragile	130	72	Prehypertension
P13	89	Adult elderly fragile	130	70	Prehypertension
P14	87	Adult elderly fragile	130	70	Prehypertension
P15	87	Adult elderly fragile	164	68	Hypertension stage 2
P16	87	Adult elderly fragile	116	66	Normotension
P17	60	Adult elderly young	130	70	Prehypertension
P18	95	Adult elderly fragile	120	70	Prehypertension
P19	81	Elderly intermediate	130	70	Prehypertension
P20	65	Adult elderly young	120	74	Prehypertension
P21	95	Adult elderly fragile	120	70	Prehypertension
P22	83	Intermediate older adult	110	68	Normotension
P23	83	Intermediate older adult	130	70	Prehypertension

	Age	Categorization of the Elderly	SBP	DBP	Categorization of the blood pressure
P24	90	Fragile older adult	120	70	Prehypertension
P25	80	Intermediate older adult	120	84	Prehypertension
P26	94	Fragile older adult	114	68	Normotension
P27	70	Young senior adult	124	70	Prehypertension
P28	78	Intermediate older adult	150	90	Stage 1 hypertension
P29	88	Fragile older adult	130	70	Prehypertension

Data on systolic blood pressure (SBP) and diastolic blood pressure (DBP) were obtained before performing moderate intermittent exercises. The study involved 29 older adults, observing a predominance of frail older adults (≥85 years) in the sample, highlighting the prehypertension category.

Table 2. Variation of SBP and DBP before and after the intermittent exercises.

	SBP			DBP		
Patient	Before	After	SBP variation	Before	After	DBP variation
P1	130	128	-2	80	80	0
P2	126	130	4	78	80	2
P3	120	120	0	84	80	-4
P4	130	128	-2	70	72	2
P5	130	130	0	66	62	-4
P6	120	120	0	60	70	10
P7	110	110	0	50	70	20
P8	140	142	2	70	74	4
P9	126	128	2	86	66	-20
P10	120	118	-2	80	64	-16
P11	130	130	0	68	90	22
P12	130	130	0	72	76	4
P13	130	130	0	70	70	0
P14	130	130	0	70	66	-4
P15	164	160	-4	68	72	4
P16	116	118	2	66	60	-6
P17	130	128	-2	70	70	0
P18	120	120	0	70	70	0
P19	130	128	-2	70	66	-4
P20	120	120	0	74	70	-4
P21	120	120	0	70	72	2
P22	110	110	0	68	70	2
P23	130	130	0	70	70	0
P24	120	120	0	70	70	0
P25	120	120	0	84	80	-4
P26	114	112	-2	68	70	2
P27	124	120	-4	70	70	0
P28	150	150	0	90	88	-2
P29	130	128	-2	70	68	-2

Table 2 shows the variation of the SBP and DBP values before and after the execution of the intermittent exercises. Variation values were calculated using the values after the exercises, subtracted from the values measured before performing the exercises.

Patients who showed negative variations (marked in red) showed lower SBP and DBP values after the exercises performed. On the other hand, patients who present positive variations (marked in green) show that the SBP and DBP values were higher after the exercises performed. Likewise, some patients did not show variation (marked yellow).

Figure 1 represents the membership, indeterminacy, and non-membership functions of the normal DBP. Figure 2 represents the same functions corresponding to SBP.

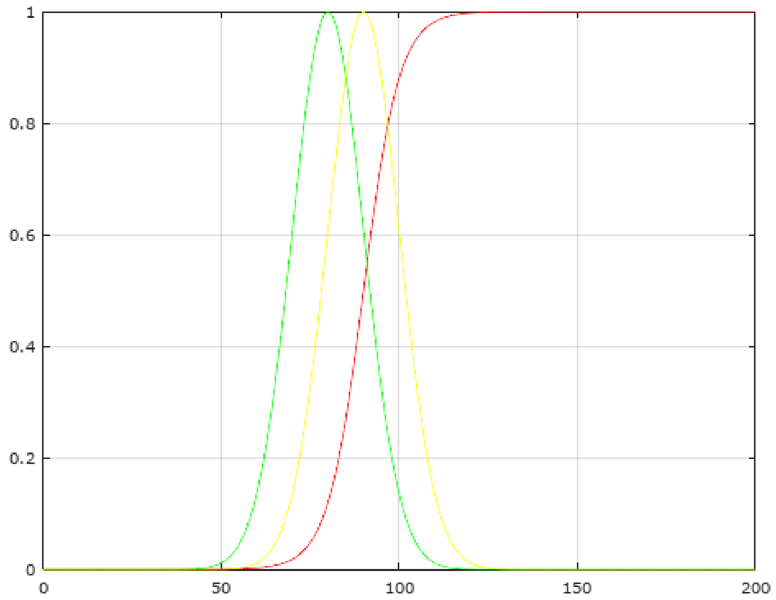

Figure 1: Membership functions $u_A(x)$ (green), indeterminacy $r_A(x)$ (yellow), and non-membership $v_A(x)$ (red) for the DBP.

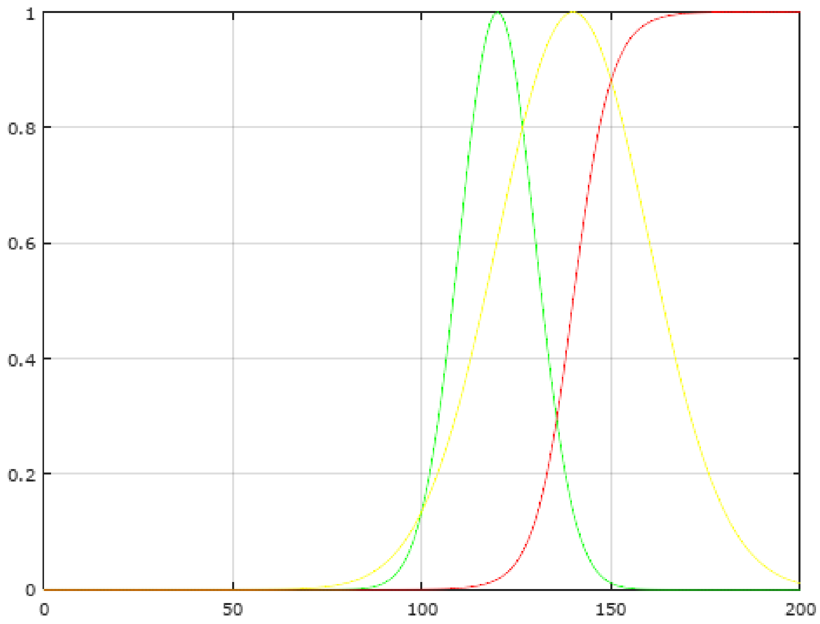

Figure 2: Membership $u_A(x)$ functions (green), indeterminacy $r_A(x)$ (yellow), and non-membership $v_A(x)$ (red) for the SBP.

The calculations carried out with the help of Equation 3 gave the results:

$R(DBP_{before}, DBP_{after}) = 0.87515,$

$R(SBP_{before}, SBP_{after}) = 0.99650.$

This means that there is a great correlation between both values for both DBP and SBP.

On the other hand, when finding the averages of the variations, it was obtained that the average variation of SBP was -0.4137931 and the average variation of DBP was 0.13793103. To find out if this is in line with what normal blood pressure should be, we use Equation 4 shown below, which is the so-called Score Function ([27]):

$$N_{PB}(A,x) = \frac{2+u_A(x)-r_A(x)-v_A(x)}{3} \qquad (4)$$

To aggregate the results for all values in Equation 4, Equation 5 is used.

$$\overline{N}_{PB}(A) = \text{mean}_{x\in X} N_{PB}(A,x) \qquad (5)$$

In the case of DBP before, it was obtained $\overline{N}_{PB}(DBP_{before}) = 0.76018$ and for DBP afterward it was obtained $\overline{N}_{PB}(DBP_{after}) = 0.76897$, that is, there was better.

Regarding SBP, we have $\overline{N}_{PB}(SBP_{before}) = 0.61606$ and $\overline{N}_{PB}(SBP_{after}) = 0.62056$, which also indicates an improvement.

Conclusion

Blood pressure is one of the parameters to be followed by current medical treatment. This is an important parameter because an imbalance in it can cause serious consequences for human health. It has been shown that in today's world population, this is a considerable health problem. The treatment of this situation is commonly carried out with medications, which affect the patient's finances and also have side effects on them. A more positive solution is to perform physical exercises as a complementary solution. In the case studied in this article we focus on 29 elderly patients institutionalized in a shelter for older adults in Ecuador. The treatment consisted of moderate exercise for a short period. The results before and after applying the treatment were measured in terms of the patients' DBP and SBP. It was concluded that there was an improvement in the average of the elderly studied in both parameters. For the study, we used the neutrosophic correlation coefficient which demonstrated a high correlation between both parameters. Improvement results were also obtained when DBP and SBP were studied in terms of what is considered normal in a person.

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