NSS

Neutrosophic Sets and Systems, Vol. 73, 2024

University of New Mexico

Study of the immunoserological patterns of respiratory infections in children under 15 years of age in the Riobamba region based on Refined Neutrosophic Statistics

Lizbeth Geovanna Silva Guayasamín[1], Christian Andrés Silva Sarabia[2], Lisbeth Josefina Reales Chacón[3], Isaac Germán Pérez Vargas[4], Natalia Eliana Cáceres Cadena[5], Cesar Lenin Pilamunga Lema[6], Carlos Antonio Escobar Suárez[7], and María José Terán Bejarano[8]

[1, 2, 3] Faculty of Health Sciences, National University of Chimborazo, Riobamba, Ecuador.
E-mail: [1] lizbethg.silva@unach.edu.ec; [2] christian.silvasarabia@unach.edu.ec; [3] lisbeth.reales@unach.edu.ec
[4] Faculty of Education Sciences, Humanities and Technologies, National University of Chimborazo, Riobamba, Ecuador. E-mail: iperez@unach.edu.ec
[5] Gad parish Totoras - MIES, Riobamba, Ecuador. Email: cacerescapu@gmail.com
[6] Faculty of Public Health, Higher Polytechnic School of Chimborazo, Riobamba, Ecuador.
E-mail: cesar.pilamunga@espoch.edu.ec
[7] Autonomous Regional University of Los Andes, Ambato, Ecuador. E-mail: caes2050@hotamil.com
[8] Popular Medical Specialties Center, Ambato, Ecuador. E-mail: majosteran@hotmail.com

Abstract. Acute respiratory infection (ARI) is an important cause of consultation in the emergency room and depending on the general condition of the person; it can become complicated and life-threatening. The general objective of this study is to identify the immunoserology of acute respiratory infections in children under 15 years of age in the city of Riobamba, Ecuador in 2023; it consists of a statistical study in 85 children and adolescents. This research made it possible to identify the presence or absence of acute respiratory infections. The infections found are provoked by viruses, atypical bacteria, or a combination of both pathogens. These diseases may have an atypical origin due to previously unknown or little-known pathogens. Another indetermination is caused by the lack of knowledge of how the individuals studied were infected. That is why we use Refined Neutrosophic Statistics to study the collected data. This theory allows us to make the study more flexible, where the indeterminacy caused by ignorance is included, either about the biological origin of the diseases or about the immunological origin in the transmission of the disease. Specifically, we use the chi-square test for Contingency Tables for data processing.

Keywords: Acute respiratory infection (ARI), immunoserology, neutrosophy, refined neutrosophic statistics, contingency table, chi-square test.

1 Introduction

Acute Respiratory Infections (ARIs) are a group of diseases that occur in the respiratory system caused by various viral and bacterial agents, with an insidious onset that lasts less than two weeks. These types of infections are highly frequent and represent a public health problem.

Most of these infections are mild; however, complications may arise depending on the immune status of the vulnerable person or group, including cases of pneumonia, which can even lead to death. This type of disease is more aggressive in the extreme ages of the population, both in pediatric and elderly patients. The symptoms of ARI can vary and include fever, cough and often sore throat, dyspnea, wheezing, or difficulty breathing.

Among the acute respiratory infections of the lower respiratory tract, pneumonia stands out due to its incidence, severity, high mortality, resource consumption, and the epidemiological changes of

the microorganisms causing it. Added to this is the growing bacterial resistance to antimicrobials. Pneumonia is a common and potentially serious infection with a significant prevalence in childhood, causing the highest morbidity and mortality in the world in children under 5 years of age, especially in children in developing countries, whose sociodemographic conditions and health indicators pose risks to their quality of life.

Epidemiological systems have been prepared for common viral and/or bacterial infectious conditions, but changes in lifestyle and health conditions have been determined that lead to new disease conditions, which is why it is necessary to recognize the new pathogens that are part of this infection.

The incidence of respiratory viruses in the 21st century includes H1N1 pmd09, AH3N2, and Influenza B1. In the case of bacterial agents, an increase has been seen in *Pseudomonas aeruginosa*, *Staphylococcus aureus,* and *Streptococcus pneumoniae*.

When the etiological factors of the infection are recognized, this health problem could decrease since there are means for its prevention, through immunizations and viral or antibiotic treatment according to the evidence of the pathogen.

The pediatric population is strongly affected by ARIs. In children under 5 years of age, 95% of ARIs are caused by viruses, and a smaller percentage may present complications such as otitis, sinusitis, and pneumonia. In this context, a group of bacteria with particular microbiological and clinical characteristics are known as "atypical" agents, which include: *Mycoplasma pneumoniae*, *Chlamydophila pneumoniae,* and *Legionella pneumophila*, which should be investigated particularly to achieve a timely diagnosis and adequate antibiotic treatment.

In bacterial pneumonia, the main etiological agent is *Streptococcus pneumoniae*. However, due to the introduction of previous vaccines and the use of molecular biology techniques, the etiological agents detected have varied, and new pathogens have been identified in recent decades.

To identify etiologic agents, tests are performed that have allowed us to identify a broad spectrum of pathogens in the population. This knowledge is used to create effective treatment lines. Due to these findings, serology was the diagnostic method of choice for a long time. This technique is based on the detection of *IgM antibodies* that generally appear 10 days after infection, as well as *IgG antibodies* that can be found approximately 3 weeks after infection. The presence of *IgM antibodies* indicates recent infection, but they can persist for several months.

However, along with the development of science and technology, new methods have been applied in the diagnosis of infections. Immunoserology is a method of diagnosing infectious and viral diseases through direct observation and detection of serological components to investigate antibodies of the *IgA*, *IgG,* and *IgM types*.

In Latin America, ARIs are the main cause of consultation and hospitalization in pediatric patients. Therefore, there is interest in responding to these conditions that cause mortality and illness in children; for this reason, a pertinent response must be taken, using antivirals, antibiotics, and resources for the health care of these patients. In addition, it affects work absenteeism and crises in parents when children become ill, this being a social problem.

The main objective of this article is to identify the immunoserology of acute respiratory infections in children under 15 years of age in Riobamba, Ecuador during the year 2023. Other objectives that we propose are:

- To characterize the population with acute respiratory infections in children under 15 years of age.
- To identify the presence of atypical viruses and bacteria causing acute respiratory infections in children under 15 years of age using the indirect immunofluorescence technique.
- Relate bacterial and viral incidence according to the characterization of the population with acute respiratory infections.

The task we propose is broad since it is not enough to know what is happening with the current pediatric population of Riobamba in terms of the incidence of respiratory diseases, since the behavior of these diseases itself is a question. Some bacteria were believed to be eliminated and have emerged

due to the loss of sensitivity to medications. Human populations have spread to areas where there were previously only wild animals and this has caused the infection of humans with zoonotic diseases such as the COVID-19 virus. Contact between humans from different countries due to increased international transportation has caused infection with viruses such as the COVID-19 pandemic itself that hit all countries in the world. So, there are still unknown aspects within this subject, nor can the infection from one population to another be controlled, nor can it even be specified how this occurs. Therefore, Neutrosophy is the appropriate theoretical framework to carry out the study.

Neutrosophy is the branch of philosophy that studies neutrality, but also the indeterminacy caused by the unknown, the contradictory, the paradoxical, the inconsistent, and so on [1, 2]. Neutrosophic Statistics extends classical statistical methods to data or parameters in interval form, or when the population or sample size is not exactly known [1-4]. This is very common in the problem we are studying, which is why the tool chosen for the study is Refined Neutrosophic Statistics [1, 2].

In Refined Neutrosophic Statistics, data are represented as products of real values by interval-like elements that signify various forms of truthfulness, indeterminacy, or falsity [1, 2]. In this case, we want to represent the data in the form of refined neutrosophic numbers, where one part represents the indeterminacy due to ignorance, divided into two types: biological ignorance due to the type of virus, unexplained disease, among others, and on the other hand epidemiological ignorance, due to a component of lack of knowledge of how the disease is transmitted from one individual to another.

This paper is divided into a section of Preliminaries where Refined Neutrosophic Statistics is recalled. The following section contains the details of the study carried out. We conclude the article with the Conclusion section.

2 Refined Neutrosophic Statistics

Definition 1: ([1, 2]) Let X be a universe of discourse. A *Neutrosophic Set* (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x) : X \to \,]^-0, 1^+[$, 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: ([1, 2]) 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 $u_A, r_A, v_A : X \to [0,1]$, 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 [1, 2, 5-7].

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 do not 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.

Multivariable neutrosophic data is neutrosophic data that consists of observations on two or more attributes.

A *Neutrosophical Statistical Number* N has the form $N = d + I$, [5-7], where d is called the *determinate part* and I is called the *indeterminate part*.

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 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, which should be useful in this paper.

Given $N_1 = a_1 + b_1 I$ and $N_2 = a_2 + b_2 I$ two neutrosophic numbers, some operations between them are defined as follows, [1,2, 5-7]:

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

1. $I_1 \leq I_2$ if and only if $a_1 \leq a_2$ and $b_1 \leq b_2$.
2. $I_1 + I_2 = [a_1 + a_2, b_1 + b_2]$ (Addition);
3. $I_1 - I_2 = [a_1 - b_2, b_1 - a_2]$ (Subtraction),
4. $I_1 \cdot I_2 = [\min\{a_1 \cdot b_1, a_1 \cdot b_2, a_2 \cdot b_1, a_2 \cdot b_2\}, \max\{a_1 \cdot b_1, a_1 \cdot b_2, a_2 \cdot b_1, a_2 \cdot b_2\}]$ (Product),
5. $\frac{I_1}{I_2} = \left[\frac{a_1}{b_1}, \frac{a_2}{b_2}\right]$, always that $0 \notin I_2$ (Division).
6. $\sqrt{I} = [\sqrt{a}, \sqrt{b}]$, always that $a \geq 0$ (Square root).
7. $I^n = \underbrace{I \cdot I \cdot \cdots \cdot I \cdot I}_{\text{n times}}$.

Smarandache also defined types of truth, indeterminacy, and falsity in a symbolic way beyond the T, I, and F. He called this refinement, where T is divided into $T_1, T_2, \ldots, T_p$; $I_1, I_2, \ldots, I_q$; $F_1, F_2, \ldots, F_r$, which depend on the problem [8-17]. Specifically, he extended the numbers of the form given in Equation 1, to represent the Refined Neutrosophic Numbers.

Definition 3: ([8-10]) Given $I_1, I_2, \dots, I_q$, with $q \geq 1$, a *Refined Neutrosophic Number* is obtained from the set above as $N_q = a + b_1 I_1 + b_2 I_2 + \cdots + b_q I_q$, where a is the determinate part and $b_j I_j$ ($j = 1,2, \dots, q$) are the indeterminate parts, such that $a, b_1, b_2, \dots, b_q$ are real or complex numbers.

Some properties that are fulfilled are those shown below:

- $mI_k + nI_k = (m + n)I_k$,
- $0I_k = 0$,
- $I_k^n = I_k$,
- I_k / I_k = undefined,
- $I_j I_k$ with $j \neq k$ is defined depending on the problem being addressed.

3 Results

The final eligible population for this study was made up of a total of 400 patients, all under 15 years of age, with an acute respiratory infection, located in Riobamba. A prior estimate is necessary and if it is difficult to obtain it, a proportion of 50% is usually taken, that is, p = q = 0.5. Simple random sampling was used.

The following calculation was made for the study:

N= 400,
p= q= 0.5 → 50% of the population has the characteristic studied,
Z= 2; 95.5% probability that the results obtained in the sample are valid,
E= 5%→ 0.05 valid error allowed.

$$n = \frac{p.q.N.Z^2}{E^2.(N-1)+p.q.Z^2} \qquad (2)$$

To characterize the population with acute respiratory infections, frequencies, relative frequencies, and analysis of these were calculated in the information collected from the population under study, see Table 1.

Table 1. Characteristics of the population studied with Acute Respiratory Infection. Source: Prepared by the authors.

Feature	Total patients (n= 85)
Sex	
Male	34 (40%)
Female	51 (60%)
Age range	
Less than 5 years old	2 (2.4%)
5 to 10 years	33 (38.8%)
11 to 15 years	33 (38.8%)
Over 15 years old	17 (20%)
Influenza Vaccination	
	12 (14%)
	73 (86%)
Poultry farming	
	21 (25%)

	64 (75%)
Pig farming	
	5 (5.8%)
	80 (94.2%)

For the study we carried out we have identified the following variables.

Nominal variable: immunoserology of acute respiratory infections,

Conceptual variable: immunoserology, with which studies are carried out aimed at diagnosing human infectious and viral diseases using direct observation and component detection methodologies.

Operational variable: the process of immunoserology of acute respiratory infections through indirect immunofluorescence for the detection of atypical agents, can determine the relationship between the causal agents of the infections, and the viral or bacterial etiology.

For more details on the variables see Table 2.

Table 2. Operationalization of Variables. Source: Own elaboration.

Aim	Variable	Dimensions	Indicators
To characterize the population with acute respiratory infections in children under 15 years of age.	Sex	Men Women	Frequency
	Age	Years compliments	Average Standard deviation Age groups
	Exposure	Presence of exhibition	Poultry farming Pig farming
	Vaccination	Condition Vaccine	Vaccinated Not vaccinated
To identify the presence of viruses and bacteria causing acute respiratory infections in children under 15 years of age using the indirect immunofluorescence technique.	Etiology of Acute Respiratory Infection	Viral Bacterial Mixed	Incidence of Viral Etiology Incidence of bacterial etiology Incidence of Mixed Etiology (Viral and Bacterial)
Relate bacterial and viral incidence according to the characterization of the population with acute respiratory infections.	Relationship of variables	Bacterial, viral, and mixed incidence according to population characterization variables	Bacterial, viral, and mixed incidence according to sex. Bacterial, viral, and mixed incidence according to age. Bacterial, viral, and mixed incidence according to exposure. Bacterial, viral, and mixed incidence according to vaccination.

The pathogens to be studied are summarized in Table 3.

Table 3. Viruses and bacteria that cause ARIs to be detected in the study using indirect immunofluorescence. Source: Own elaboration.

Pathogen	Type of pathogen
LEGIONELLA PNEUMOPHILA SG 1	Bacteria
MYCOPLASMA PNEUMANIAE	
COXIELLA BURNETTI	
CHLAMYDOPHILA PNEUMONIAE	
ADENOVIRUS	Virus
RESPIRATORY SYNCYTIAL VIRUS	
INFLUENZA A	
INFLUENZA B	
PARAINFLUENZA 1, 2 and 3	

The data obtained is represented by Refined Neutrosophic Numbers of the form $p = \alpha + \beta I_1 + \gamma I_2$, where α is the determined part, βI_1 is the indeterminate part produced by biological or clinical indeterminacy, for example, if there are doubts about the real presence or not of the disease. γI_2 is the indeterminate part obtained from indeterminacy for epidemiological reasons, for example, due to a lack of explanation on how people became infected. We have, $\alpha, \beta, \gamma \in \mathbb{R}$ and in general to convert p to intervals we have $I_1 = [0,1]$ and $I_2 = [0,1]$.

To process the data we de-neutrosophy them using Equation 3 ([1, 2]):

$$\lambda([a,b]) = \frac{a+b}{2} \qquad (3)$$

Data are quantities of individuals that fall into certain categories.

The next step is to place the cases in contingency tables, and then apply the chi-square test [18].

The final results are shown in Tables 4-10. Table 4 contains the results of the biological origin of ARI concerning the four age ranges of the patients and the p-value of applying the Chi-square test.

Table 4. Origin of Acute Respiratory Infection as a Function of Age. In parentheses, the value de-neutrosiphied appears. Source: Own elaboration.

Feature	Total patients	Diagnosis				p-value*
		Bacterial	Viral	Mixed	Negative	
Age						**0.29227**
Less than 5 years	4	0	1	1	1	
5 to 10 years	$33 + 6I_1(36)$	$6 + 2I_1(7)$	$3 + 2I_1(4)$	$21 + 2I_1(22)$	1	
11 to 15 years	32	4	2	20	6	
Over 15 years old	$17 + 4I_1(19)$	$2 + 2I_1(3)$	0	$10 + 2I_1(11)$	2	

Table 5 represents the contingency table of biological disease origin versus vaccination. Note the p-value of applying the Chisquare test.

Table 5. Diagnosis of Acute Respiratory Infection based on Immunization in pediatric patients studied. The de-neutrosiphied value appears in parentheses. Source: Own elaboration.

Feature	Total patients	Diagnosis				p-value*
		Bacterial	Viral	Mixed	Negative	
Influenza Vaccination						**0.25635**
Yes	12	0	0	10	2	
No	$68 + 10I_1(73)$	$12 + 4I_1(14)$	$6 + 2I_1(7)$	$52 + 4I_1(54)$	8	

Table 6 relates the raising of poultry or pigs in the patient's home against the origin of the disease and the p-value of the test. This is because some ARIs have a zoonotic origin.

Table 6. Diagnosis of Acute Respiratory Infection according to the condition of living with animals (poultry and pigs) in pediatric patients studied. The de-neutrosiphied values appears in parentheses. Source: Own elaboration.

Feature	Total patients	Diagnosis				p-value*
		Bacterial	Viral	Mixed	Negative	
Poultry farming						**0.15556**
Yes	$20 + 6I_1(23)$	$2 + 2I_1(3)$	$2 + 2I_1(3)$	$16 + 2I_1(17)$	0	
No	$62 + 4I_1 + 2I_2(65)$	$10 + 2I_1 + I_2$ (11.5)	4	$38 + 2I_1 + I_2(39.5)$	10	
Pig farming						**0.81367**
Yes	5	1	0	3	0	
No	$76 + 8I_1 + 2I_2$ (81)	$11 + 4I_1 + I_2(15.5)$	6	$49 + 4I_1 + I_2(52)$	10	

Tables 7-10 contain the relationship of pathogens against the sex of the patient, immunization, presence of poultry raising in the home, and presence of pig raising in the home, respectively.

Table 7. Etiological agents are identified according to the sex of pediatric patients.

Etiological Agent/Total patients			
	Man	**Women**	**p-value***
Legionella pneumophila	27	39	0.51112
Mycoplasma pneumoniae	3	7	
Coxiella Burnetti	0	3	
Chlamydophila Pneumoniae	0	5	
Adenovirus	1	4	
V. Respiratory syncytial	1	1	
Influenza A	4	4	
Influenza B	19	36	

Etiological Agent/Total patients			
	Man	**Women**	**p-value***
Parainfluenza 1,2 and 3	15	33	

Table 8. Established etiologic agents in pediatric patients with influenza immunization. Source: Elaboration own.

Influenza Vaccination	**Yes**	**No**	**p-value***
Legionella pneumophila	8	58	
Mycoplasma pneumoniae	3	7	
Coxiella Burnetti	0	3	
Chlamydophila Pneumoniae	0	5	
Adenovirus	0	5	0.57102
V. Respiratory syncytial	1	1	
Influenza A	1	7	
Influenza B	9	46	
Parainfluenza 1,2 and 3	8	40	

Table 9. Etiological agents were identified among groups exposed and not exposed to poultry farming. Source: Prepared by own.

Poultry farming	**Yes**	**No**	**p-value***
Legionella pneumophila	18	48	
Mycoplasma pneumoniae	0	10	
Coxiella Burnetti	0	3	
Chlamydophila Pneumoniae	1	4	
Adenovirus	1	4	0.59874
V. Respiratory syncytial	0	2	
Influenza A	2	6	
Influenza B	16	39	
Parainfluenza 1,2 and 3	15	33	

Table 10. Etiological agents were identified among groups exposed and not exposed to pig farming. Source: Prepared by own.

Pig farming	**Yes**	**No**	**p-value***
Legionella pneumophila	4	62	
Mycoplasma pneumonia	1	8	
Coxiella Burnetti	0	3	
Chlamydophila Pneumoniae	0	5	0.96521
Adenovirus	0	5	
V. Respiratory syncytial	0	2	
Influenza A	0	8	

Pig farming	Yes	No	p-value*
Influenza B	2	52	
Parainfluenza 1,2 and 3	3	45	

Conclusion

In this paper, we conducted a study on a group of patients up to 15 years of age from the city of Riobamba, Ecuador during the year 2023, who suffer from Acute Respiratory Infections. 85 patients were analyzed as a random sample from a potential population of 400 children and adolescents. The data were statistically processed using Refined Neutrosophic Statistics. This mathematical tool allowed us to take into account imprecise cases due to uncertainty about the etiology of the disease or uncertainty due to epidemiological factors related to the source of infection. Based on the results obtained, we reached the following conclusions:

1. Pediatric patients in the study are most frequently in the 11-15-year age range with a low influenza vaccination rate.
2. Among the etiological agents of acute respiratory infections analyzed through indirect immunofluorescence are: *Legionella pneumophila sg 1*, *Mycoplasma pneumoniae*, *Coxiella burnetti*, *Chlamydophila pneumoniae*, *Adenovirus*, *Respiratory syncytial virus*, *Influenza a*, *Influenza b* and *Parainfluenza 1, 2 and 3*; it is found that for viral etiology the most contagious per patient are *influenza b* and *parainfluenza*; in addition, in bacterial etiology the most frequent is *Legionella pneumophila sg 1*.
3. The incidence of *Legionella pneumophila SG 1* is extremely important because it is present in all the applied categorizations: all age groups, vaccinated and unvaccinated, as well as its high frequency; and it is associated with bacterial pneumonia. This timely diagnosis can improve the health condition of the pediatric patient and generate appropriate treatment options.
4. In general terms, infections transmitted by patients have a mostly viral rather than bacterial etiology, however, there is a tendency that as the patient's age increases, the bacterial load increases but without becoming greater than the viral load.
5. In the pediatric patients in the study, a smaller proportion of healthy groups are present, in the absence of contagion with the infections in the test. Another minority group is morbidity, associated with mono-infection in respiratory disease. Morbidity is mostly of bacterial rather than viral etiology and is completely absent when patients receive the influenza vaccine. The largest group of pediatric patients present in the study shows a co-infection of approximately 70%, generally including co-infection of viruses, bacteria, or viruses and bacteria. The category of co-infection of viruses and bacteria in the same patient is associated with contagion by viral etiology and then complications due to bacterial superinfections throughout the epidemic.
6. After the application of the flu vaccine, it is mostly in the category of co-infection. This co-infection is most frequent in two and one bacteria, a combination corresponding to *Legionella pneumophila sg 1*, *influenza b*, and *parainfluenza*.
7. The application of the vaccine suppresses some bacterial pathogens (*Coxiella burnetti* and *Chlamydophila pneumoniae*), and a virus (*Adenovirus*) in infected patients, observing up to a co-infection of three viruses and one bacteria. However, no significant relationship is found in the percentage differentiation of respiratory disease infections per patient between individuals who were exposed to the vaccine and those who were not exposed.

References

[1] Smarandache, F. (2022). Neutrosophic Statistics is an extension of Interval Statistics, while Plithogenic Statistics is the most general form of statistics (second version). Infinite Study.
[2] Smarandache, F. (2022). Neutrosophic Statistics is an extension of Interval Statistics, while Plithogenic Statistics is the most general form of statistics (Third version). Bulletin of Pure & Applied Sciences-Mathematics and Statistics, 41, 172-183.
[3] Woodall, W. H., Driscoll, A. R., and Montgomery, D. C. (2022). A review and perspective on neutrosophic statistical process monitoring methods. IEEE Access, 10, 100456-100462.
[4] AlAita, A., and Aslam, M. (2023). Analysis of covariance under neutrosophic statistics. Journal of Statistical Computation and Simulation, 93, 397-415.
[5] Aslam, M., and Albassam, M. (2020). Presenting post hoc multiple comparison tests under neutrosophic statistics. Journal of King Saud University-Science, 32, 2728-2732.
[6] Afzal, U., Alrweili, H., Ahamd, N., and Aslam, M. (2021). Neutrosophic statistical analysis of resistance depending on the temperature variance of conducting material. Scientific reports, 11, 23939.
[7] AlAita, A., Talebi, H., Aslam, M., and Al Sultan, K. (2023). Neutrosophic statistical analysis of split-plot designs. Soft Computing, 27, 7801-7811.
[8] Sankari, H., and Abobala, M. (2020). n-Refined Neutrosophic Modules. Neutrosophic Sets and Systems, 36, 1-11.
[9] Abobala, M. (2021). Semi Homomorphisms and Algebraic Relations Between Strong Refined Neutrosophic Modules and Strong Neutrosophic Modules. Neutrosophic Sets and Systems, 39, 107-120.
[10] Smarandache, F., and Abobala, M. (2024). Operations with n-Refined Literal Neutrosophic Numbers using the Identification Method and the n-Refined AH-Isometry. Neutrosophic Sets and Systems, 70, 350-358.
[11] Deli, I. (2016). Refined neutrosophic sets and refined neutrosophic soft sets: theory and applications. In Handbook of research on generalized and hybrid set structures and applications for soft computing (pp. 321-343). IGI Global.
[12] Concepción, I. P., Aldaz, E. M., Flores, L. G., and Caballero, E. G. (2020). Neutrosophic Scale to Measure Psychopathic Personalities Based on Triple Refined Indeterminate Neutrosophic Sets. Neutrosophic Sets and Systems, 37, 61-70.
[13] WB, V., Kandasamy, I., Smarandache, F., Devvrat, V., and Ghildiyal, S. (2020). Study of imaginative play in children using single-valued refined neutrosophic sets. Symmetry, 12, 402.
[14] Uluçay, V. (2021). Some concepts on interval-valued refined neutrosophic sets and their applications. Journal of Ambient Intelligence and Humanized Computing, 12, 7857-7872.
[15] Tan, R. P., and Zhang, W. D. (2021). Decision-making method based on new entropy and refined single-valued neutrosophic sets and its application in typhoon disaster assessment. Applied Intelligence, 51, 283-307.
[16] Abobala, M., and Ibrahim, M. (2021). An introduction to refined neutrosophic number theory. Neutrosophic sets and systems, 45, 40-53.
[17] Alhasan, Y. A., and Abdulfatah, R. A. (2023). Division of refined neutrosophic numbers. Neutrosophic Sets and Systems, 60, 1-5.
[18] Tamayo, D. S. P. O., Monteca, S. A., and Zambrano, J. C. A. (2021). Neutrosophic Statistics applied in Social Science. Neutrosophic Sets and Systems, 44, 01-09.

Received: July 01, 2024. Accepted: August 26, 2024