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Current Situation of the Use of Neutrosophy to Improve Medical Decision Making and Preventive Healthcare in Ecuador

Franklin Parrales-Bravo [1,2,*], Lorenzo Cevallos-Torres [1,2], Leonel Vasquez-Cevallos [3], Zulemma Bazurto-Blacio [2], Diana Minda-Gilces [2], Víctor Gómez-Rodríguez [4], Rosangela Caicedo-Quiroz [1], and Pedro García-Arias [2]

[1] Centro de Estudios en Tecnologías Aplicadas, Universidad Bolivariana del Ecuador, Guayaquil, Ecuador; frparralesb@ube.edu.ec, ljcevallost@ube.edu.ec, rcaicedoq@ube.edu.ec

[2] Grupo de Investigación en Inteligencia Artificial, Universidad de Guayaquil, Guayaquil, Ecuador; franklin.parralesb@ug.edu.ec , lorenzo.cevallost@ug.edu.ec, zulema.bazurtob@ug.edu.ec, diana.mindag@ug.edu.ec, pedro.garciaa@ug.edu.ec

[3] SIMUEES Simulation Clinic, Universidad Espíritu Santo, Samborondón , Ecuador; leonelvasquez@uees.edu.ec

[4] Instituto Superior Tecnológico Urdesa (ITSU), Guayaquil, Ecuador; vgomez@itsu.edu.ec

Abstract: This study systematically examines the applications of neutrosophic logic in Ecuadorian medicine, focusing on its role in improving medical decision making and preventive healthcare. By conducting a structured literature review selected articles, the research highlights how neutrosophic methods—such as Single-Valued Neutrosophic Sets (SVNS) and Neutrosophic Cognitive Maps (NCMs)—address uncertainty, indeterminacy, and contradictions inherent in clinical and public health data. Key contributions include improved diagnostic accuracy in maternal health, risk assessment for chronic diseases, and ethical decision making in telemedicine, demonstrating neutrosophic logic's superiority over traditional binary approaches. The findings advocate for a broader implementation of neutrosophic frameworks in Ecuador's healthcare system, while identifying challenges such as computational complexity and the need for standardized protocols. This work underscores the transformative potential of neutrosophic logic to foster precise, equitable, and resilient healthcare solutions.

Keywords: Neutrosophic logic; medical decision-making; preventive healthcare; uncertainty; Ecuadorian medicine.

1. Introduction

The evolution of medical decision-making has long been influenced by the development of advanced logical frameworks intended to optimize diagnostic processes and therapeutic interventions [1, 2]. During the past few decades, classical probability [3, 4] and fuzzy logic [5] have been utilized to improve diagnostic accuracy and treatment efficacy [6–8]. However, these models are often constrained by their inability to adequately address the inherent indeterminacy found in complex medical scenarios [9]. In response, neutrosophy and its technical derivative, neutrosophic logic, have emerged as promising frameworks capable of incorporating truth, falsehood, and indeterminacy into decision-making processes [10].

The growing adoption of neutrosophic logic to support medical analysis in Ecuador reflects its potential to enhance both clinical and public health outcomes. This article presents an integrative analysis of its applications across diverse medical domains, including COVID-19 response [11], intercultural care [12],

maternal health [13], chronic disease management [14], and mental health [15]. Through a structured literature review, we examine how neutrosophic techniques—such as Single- Single-valued neutrosophic Sets (SVNS) and Neutrosophic Cognitive Maps (NCMs)—improve diagnostic accuracy, risk assessment, and patient-centered care. By synthesizing empirical findings and theoretical insights, this study highlights the role of neutrosophic logic in bridging gaps left by traditional methodologies, ultimately advocating for its broader implementation in Ecuador's healthcare system.

2. Methodology

To systematically analyze the applications of neutrosophic logic in Ecuadorian analysis of medicine, a structured literature review was conducted. This methodology aims to identify, evaluate, and synthesize relevant studies while addressing gaps in traditional approaches to medical uncertainty. Below we describe the details.

2. 1 Search Strategy

To conduct a comprehensive literature review on the applications of neutrosophic logic in Ecuadorian medicine, articles were systematically searched and extracted from reputable databases, including Scopus, Web of Science, PubMed, and Google Scholar. The search was performed using the following keywords and their combinations:

- Neutrosophic logic, neutrosophy
- Medical decision-making, preventive healthcare
- Ecuador, uncertainty in medicine
- Indeterminacy, clinical data analysis

Boolean operators (AND, OR) were employed to refine the search results. The search was limited to articles published in English and Spanish since 2020 to ensure relevance to contemporary medical practices.

2.2 Inclusion and Exclusion Criteria

Inclusion Criteria:

- Studies focusing on the application of neutrosophic logic in medical or healthcare contexts, particularly in Ecuador.
- Articles addressing topics such as diagnostic uncertainty, patient-centered care, public health, chronic diseases, mental health, or medical ethics.
- Peer-reviewed journal articles, conference proceedings, and book chapters with empirical or theoretical contributions.

Exclusion Criteria:

- Studies not related to neutrosophy or its applications in medicine.
- Articles lacking empirical data or clear methodological rigor.
- Duplicate publications or studies not available in full text.

2.3 Screening and Selection Process

The article selection process followed these stages:

- Initial Screening: Titles and abstracts of retrieved articles were screened for relevance based on the inclusion criteria.

- Full-Text Review: Potentially relevant articles were reviewed in full to assess their alignment with the study's objectives.
- Final Selection: Articles meeting all criteria were included in the review.

2.4 Results of Article Selection

The selection process yielded the following results:

Table 1. Article Selection Results

Selection Stage	Number of Articles
Total articles retrieved	123
Excluded after initial screening	72
Excluded after full-text review	31
Final included articles	23

The selected articles were categorized thematically to align with the manuscript's focus areas, such as COVID-19 and public health, intercultural care, maternal and adolescent health, chronic diseases, and mental health.

2.5 Data Extraction and Analysis

Data from the included articles were extracted using a standardized template, capturing:

- Study objectives, methodologies, and key findings
- Neutrosophic techniques employed (e.g., Single-Valued Neutrosophic Sets, Neutrosophic Cognitive Maps)
- Applications in medical decision-making and preventive healthcare

Thematic synthesis was performed to identify patterns, gaps, and innovations in the field, as presented in the Results section of the manuscript.

3. Results

The present study provides compelling evidence for the benefits of neutrosophic applications in Ecuadorian medicine. By incorporating indeterminacy into diagnostic and decision-making processes, neutrosophy addresses a critical gap in traditional methodologies that often overlook uncertain and contradictory clinical data [10] (Figure 2). At its core, neutrosophic logic facilitates the evaluation of patients' health by considering three components: truth, falsehood, and indeterminacy.

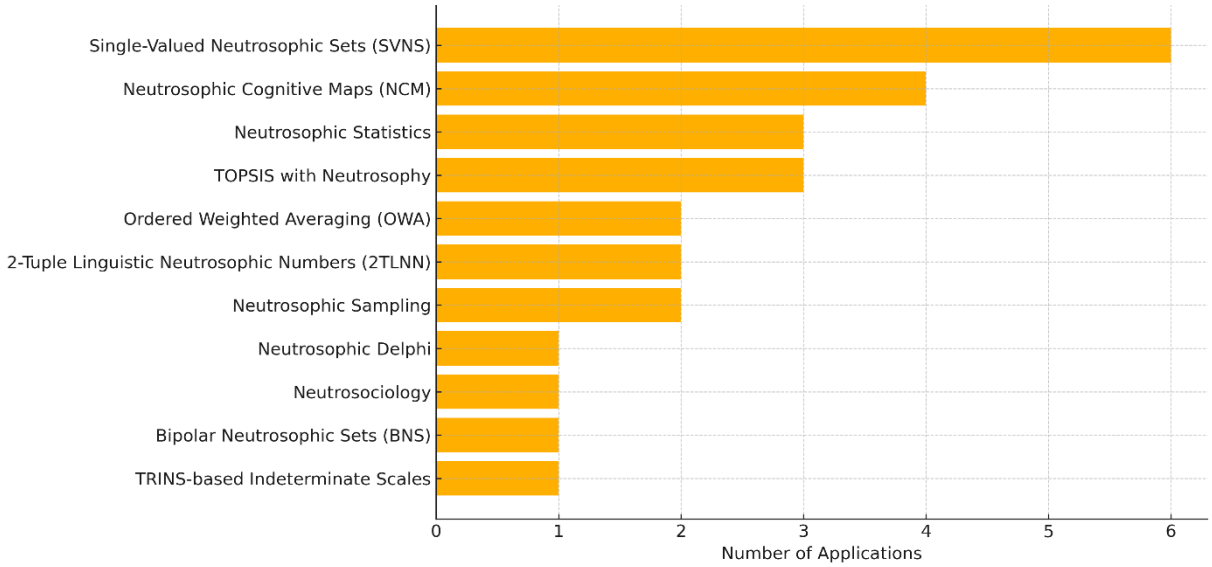

Figure 1. Neutrosophic Techniques in Ecuadorian Medical Studies

Frequency of different neutrosophic techniques identified in reviewed Ecuadorian medical research. Single-Valued Neutrosophic Sets (SVNS) and Neutrosophic Cognitive Maps (NCMs) are the most frequently applied methods, reflecting a strong focus on modeling uncertainty in both quantitative and qualitative contexts.

In the following lines, we present in a categorized way the applications of neutrosophic logic in Ecuadorian clinical practice that we have identified from the selected articles, highlighting the techniques used, the motivation behind the use of neutrosophy, and the most relevant findings from their studies.

3.1 COVID-19 and Public Health

Price speculation and health rights during COVID-19: The work presented by [11] analyzed the relationship between price speculation in medical supplies/hospital services and its impact on health rights. To this end, their work considered: a mixed approach (theoretical, empirical, statistical-mathematical), neutrosophic statistical analysis, descriptive statistics (frequency distribution), documentary review (media, legal regulations), and interviews with health professionals. Neutrosophic logic allowed them to manage uncertainty and imprecision in data (e.g. fluctuating prices), model indeterminacies in economic and health variables, analyze contradictions (e.g. public/private cost disparities), and integrate ambiguous qualitative and quantitative aspects. Based on their results, they found a public perception of abuse in private billing. However, no clear evidence of profiteering in ICU services was found (private and public costs were similar). Furthermore, they found large variations in drug prices (e.g., midazolam increased by 1383%). High demand and shortages drove price increases.

Public procurement corruption during COVID-19: The work presented by [16] investigated the causes of corruption in medical supply procurement using neutrosociology. For this they used Neutrosociology (triadic analysis: <A>, <neut A>, <anti A>), Single-Valued Neutrosophication Sets (SVNS), Survey with probabilistic scoring, and a de-neutrosophication process. Neutrosophic logic allowed them to handle survey responses that involve uncertainty, contradictions, and indeterminacy. They carried it out through a triadic analysis that models complex human opinions more accurately than classical methods. Furthermore, neutrosociology captures vague, incomplete, or biased sociological data. According to their results, the main cause was the interference of public servants as partners in medical supply companies (72% truth value). Other causes were the lack of SERCOP control (46%) and the monopolization of contracts

(54%). Furthermore, legal gaps in procurement norms were not recognized as a significant cause.

Healthcare system resilience post-COVID-19: The work presented by [17] evaluated programs to improve resilience using neutrosophic multi-criteria decision-making. To do this, they used neutrosophic statistics, including the neutrosophic probability distribution, neutrosophic mean, variance, and coefficient of variation (NCV). They considered neutrosophic statistics since classical statistics cannot handle indeterminate, ambiguous, or incomplete data. Neutrosophic methods account for uncertainty (T, I, F) in clinical decisions. Furthermore, neutrosophic statistics provide a framework for analyzing data with contradictions or lack of consensus. According to their results, pancreatic cancer screening had the highest indeterminacy (69.9%). Furthermore, routine screening for dementia required fewer clinical studies to reach a consensus. Finally, neutrosophic statistics revealed contradictions and uncertainties in clinical decisions.

3.2 Intercultural and Patient-Centered Care

Intercultural medical care relevance: The work presented by [12] assessed healthcare professionals' perceptions of intercultural treatments. For this end, they considered neutrosophic sampling (interval-based population calculation), Survey with neutrosophic Likert scale, Pearson correlation test, and Theoretical methods (analytical-synthetic, inductive-deductive, systemic). Neutrosophic logic allowed them to handle uncertainty in cultural perceptions (truth / indeterminacy / falsity), model ambiguity in Likert-scale responses via SVNNs (Single-Valued Neutrosophic Numbers), address partial knowledge about traditional medicine adoption, and quantify subjective assessments of "relevance" with linguistic neutrosophic scales. They found that 36.6% considered intercultural treatments "somewhat relevant" (primary finding), 23.3% viewed them as "not relevant". Furthermore, strong correlations ($r > 0.9$) between survey questions validated the instrument. Finally, younger professionals showed more openness to intercultural approaches.

Patient-Centered Care (PCC) acceptance: The work presented by [18] evaluated positive/negative aspects and patient perceptions of PCC. To do this, they used the Neutrosophic IADOV method, surveys, and qualitative analysis. They considered neutrosophic techniques because they capture the degrees of truth, indeterminacy, and falsehood in patient perceptions, providing a multidimensional analysis of PCC acceptance. Based on their results, Personal Experience (PE) is the predominant factor in PCC acceptance. Furthermore, positive experiences (e.g. effective communication) enhance acceptance, while negative experiences reduce it. Finally, variability in experiences contributes to indeterminacy.

3.3 Maternal and Adolescent Health

Adolescent pregnancy factors: The work presented by [13] analyzed socioeconomic and educational factors that contribute to adolescent pregnancy. For this they made use of neutrosophic statistics (interval-based analysis), Single-Valued Neutrosophic Numbers (SVNNs), Neutrosophic frequency distributions, Coefficient of Variation (CV) analysis, Expert surveys with linguistic neutrosophic scales. They considered neutrosophy to model uncertainty in survey responses (truth/indeterminacy/falsity), handle vagueness in socioeconomic and psychological factors, quantify linguistic assessments (e.g., "severely deteriorated" = (0.3,0.75,0.8)), analyze contradictory data (e.g., partial acceptance of responsibility), and address incomplete knowledge of risk conditions.

Hypothyroidism complications in pregnancy: The work presented by [19] estimated risks like preeclampsia using neutrosophic multicriteria analysis. To do this, they used the following techniques: 2-tuple linguistic neutrosophic numbers (2TLNNs), Multi-criteria decision-making (MCDM), Neutrosophic statistical aggregation, and scoring and accuracy functions. They considered neutrosophic logic since medical evaluations involve uncertainty and subjective judgments. Thus, through 2TLNNs truth,

indeterminacy, and falsity in expert opinions are modeled, making it suitable for integrating heterogeneous data (numerical/linguistic) from multiple criteria. Based on their results, the key complications are preeclampsia (highest risk), preterm labor, and recurrent UTIs. The 2TLNN technique effectively prioritized complications using expert evaluations. This case study demonstrated its clinical applicability for risk assessment.

3.4 Chronic and Non-Communicable Diseases

Cerebral Palsy risk factors: The work presented by [14] identified perinatal risks (e.g., hypoxia, sepsis) using neutrosophic fuzzy logic. For this, they used Compensatory Fuzzy Logic (CFL) with neutrosophic extension. They considered neutrosophic techniques since they handle indeterminacy and linguistic evaluations, and integrate expert opinions with quantitative data for robust analysis. They found that the highest incidence of risk factors was in the perinatal period (36%). In addition, they found the following key factors: severe hypoxia at birth, neonatal convulsions, sepsis, and preterm delivery.

Hypertension rehabilitation outcomes: The work presented by [20] assessed long-term efficacy of rehabilitation programs. For this purpose, they considered the following techniques: Neutrosophic sampling (n=[10.1,30.6]), Pearson correlation, Triad assessment (HR, SBP, DBP), Neutrosophic p-values. Neutrosophic techniques allowed them to handle uncertainty in post-rehabilitation outcomes, model indeterminate patient responses, and capture variability in treatment efficacy across indicators.

Obesity determinants: The work presented by [21] analyzed sociocultural and lifestyle factors using Neutrosophic Cognitive Maps (NCMs). For this purpose, they considered the following techniques: Hermeneutical method, Neutrosophic Cognitive Maps (NCMs), Static analysis (indegree, outdegree, total centrality), de-neutrosophication process. They used these techniques since: Hermeneutical analysis introduces subjectivity and uncertainty, NCMs handle indeterminacy (T, I, F) in causal relationships. All of them provide a framework to integrate diverse perspectives (medical, non-medical, patient) and quantify their influence. They found the following key causal factors: sociocultural-economic factors, sedentary lifestyle, and unhealthy eating. Furthermore, they found variability in rankings across medical experts, non-medical experts, and patients. Therefore, they proposed the following strategies: communication campaigns, nutritional guides, regulation of unhealthy food sales, and educational programs.

Autism Spectrum Disorder (ASD) causal factors: The work presented by [22] identified key factors (e.g., premature birth) via NCMs. For this they used Neutrosophic Cognitive Maps (NCMs), Static analysis (indegree, outdegree, total centrality), De-neutrosophication process, and expert interviews and clinical reviews. They considered neutrosophic techniques since the diagnosis of ASD involves high uncertainty and subjective interpretations. NCMs handle indeterminacy (T, I, F) in causal relationships, making them suitable for integrating diverse expert opinions and quantifying influence in complex, uncertain scenarios. They found the following key causal factors: premature birth (highest influence), family history of autism, and cesarean birth/traumatic delivery. Other notable factors were: exposure to electronic devices with blue light and advanced parental age. Their recommendations included further study on the impact of reducing exposure to blue light devices.

3.5 Nursing and Healthcare Workflows

Nursing Care Process in Education: The work presented by [23] highlighted training gaps in nursing diagnostics using neutrosophic methods. To do this, they used the following techniques: Single-Valued Neutrosophic Sets (SVNS), and TOPSIS method. They considered neutrosophic techniques since they handle indeterminacy in expert and student responses; integrates linguistic evaluations for nuanced decision-making. According to their results, formulating nursing diagnoses was the most challenging

component; neutrosophic analysis highlighted gaps in training.

Assertive communication in nurses: The work presented by [24] evaluated competencies using Neutrosophic Cognitive Maps. To do this, they used surveys, expert assessment, and Neutrosophic Cognitive Maps (NCMs). Neutrosophic techniques allow them the modeling of indeterminacy and uncertainty inherent in human communication behaviors, which classical models cannot fully capture. They found that nurses showed moderate to high assertive communication levels. Furthermore, key influencing factors were identified through NCM analysis.

Nursing workflow optimization: The work presented by [25] proposed strategies to address barriers like unequal nurse distribution. The following techniques were considered: Neutrosophic MOORA method, SVNN (Single-Valued Neutrosophic Numbers). Neutrosophic techniques allowed them to handle indeterminacy in policy effectiveness across regions, in addition to modeling truth/falsehood/uncertainty in workflow barriers and quantifying linguistic expert evaluations via SVNN. In their results, they identified the following key barriers: unequal nurse distribution (urban/rural), low automation, varied training quality. Additionally, they found the following top strategies: education / training improvement (Strategy 2) and staff retention policies (Strategy 4). Based on this, they proposed an automated monitoring system for workflow optimization.

3.6 Mental Health and Psychology

Depression severity evaluation: The work presented by [15] classified depression levels using neutrosophic numbers. To do this, they considered neutrosophic numbers to model uncertainty, in addition to the Ordered Weighted Average (OWA) operator for aggregation and a multi-expert multi-criteria approach. They considered neutrosophic techniques since the symptoms of depression involve inherent uncertainty and vagueness. Neutrosophic logic handles truth, falsehood, and indeterminacy simultaneously, providing a flexible framework for modeling subjective and ambiguous clinical data. According to their results, the method successfully classified the patient's depression level as "Severe depression", demonstrating its applicability in clinical settings.

Emotional Intelligence (EI) in students: The work presented by [26] classified EI states (e.g., indeterminate traits) via neutrosophic psychology. For this, they used the neutrosophic trait operator, a survey with 7 variables (V1-V7), and a bipolar scaling [-1,1] for EI classification. They considered neutrosophic techniques since they capture indeterminate states between EI and non-EI, in addition to modeling dynamic transitions in EI traits, allowing the management of borderline cases in psychological assessments.

3.7 Dental and Oral Health

Dental fluorosis prevalence: The work presented by [27] investigated triggers such as the use of mouthwash. To do this, they applied the following: surveys to parents (17 questions), dental photographic analysis (TF Index), and neutrosophic statistics (Chi-square test). Neutrosophic techniques allowed them to handle indeterminacy in survey responses (e.g., unclear toothpaste brands), and ambiguity in data (e.g., multiple possible answers). All this given that neutrosophic statistics handles imprecise/indeterminate data better than classical methods. In their results, they did not find a significant relationship between fluorosis and most variables (diet, toothpaste use). In contrast, a significant relationship was found between fluorosis and mouthwash use (p-value < 0.05). Additionally, 82.6% of children had fluorosis (TF1–TF9).

Dental implant success criteria: The work presented by [28] prioritized factors (e.g., absence of pain) using neutrosophic evaluation. To do this, they considered neutrosophic numbers to model uncertainty, Ordered Weighted Average (OWA) operator for aggregation, and a multi-expert multi-criteria approach. They considered neutrosophic techniques since the symptoms of depression involve inherent uncertainty

and vagueness. Neutrosophic logic handles truth, falsehood, and indeterminacy simultaneously, providing a flexible framework for modeling subjective and ambiguous clinical data. The work mentions that the method successfully classified the patient's depression level as "Severe depression", demonstrating applicability in clinical settings.

Knowledge of dental emergencies: The work presented by [29] assessed the impact of first aid training on dentistry students. For this they used Single-Valued Neutrosophic Sets (SVNS), SVNWA operator, and hierarchical clustering. They considered neutrosophic techniques to handle uncertainty and linguistic evaluations in open-ended responses. The results showed that the majority (65%) had negative evaluations; students with first aid courses performed better (88% effectiveness).

3.8 Ethical and Educational Assessments

Medical ethics and bioethics: The work presented by [30] analyzed challenges in Ecuador using neutrosophic Delphi methods. To do this, they used the Neutrosophic Delphi method, Single-Valued Neutrosophic Numbers (SVNNs), Expert competence coefficient (KN), and a consensus-based evaluation (Torgerson scale). They considered neutrosophic techniques to manage indeterminacy in expert opinions and ethical dilemmas, in addition to ambiguity in evaluating qualitative factors (e.g., cultural values). Neutrosophic methods handle uncertainty and partial truths in expert judgments. Indeed, SVNNs capture truth, indeterminacy, and falsity in responses. They found the following findings: Subset 3 (Education in medical ethics/bioethics) was most impactful. Subsets 1 (Legal framework) and 5 (Culture/social values) were secondary.

Ethical factors in telemedicine: The work presented by [31] evaluated autonomy and decision-making in remote care. For this they used Bipolar neutrosophic sets (BNS), TOPSIS method in a bipolar neutrosophic environment, and a multi-criteria decision-making (MCDM). They considered neutrosophic techniques since ethical dilemmas in telemedicine involve inherent ambiguity and uncertainty. Bipolar neutrosophic numbers capture the polarity of linguistic information, enhancing decision-making. According to their results, "Patient autonomy in remote decision-making" was the most influential ethical factor. The method provided a robust and equitable tool for addressing ethical complexity in telemedicine.

Self-medication knowledge/attitudes: The work presented by [32] studied prevalence and risks using indeterminate Likert scales. For this, they used the Indeterminate Likert Scale (TRINS-based), Neutrosophic Similarity measures, Triple Refined Indeterminate Neutrosophic Sets (TRINS), and statistical analysis of survey data. They used neutrosophic techniques to handle ambiguity in survey responses (e.g., mixed attitudes), in addition to the need to capture partial truths in Likert-scale answers. The TRINS models refined indeterminacy (positive/negative leanings), while neutrosophic similarity allowed them to convert fuzzy responses to actionable data. Their results found a 64.8% prevalence of self-medication, while 53% had poor knowledge about the risks. They also found a strong correlation with favorable attitudes (70.9%), and a higher prevalence among older adults (83.9%) and those with lower education.

Medical students' NCD knowledge: The work presented by [33] self-assessed knowledge levels using neutrosophic linguistic scales. For this they used Neutrosophic Likert scale, surveys, Pearson correlation, descriptive statistics, and Euclidean distance clustering. Neutrosophic techniques allowed them to capture uncertainty in self-assessment by modeling truth, indeterminacy, and falsehood in responses. The linguistic scale provides nuanced evaluation of subjective knowledge levels. Their results showed that students self-assessed their knowledge of NCD classification, treatment, and prevention as predominantly "Medium" (33.4-50%), with significant variability. Strong correlations ($r > 0.9$) were found between all knowledge domains.

4 Discussion

4.1 Neutrosophic Logic in Preventive Healthcare

Preventive healthcare, a cornerstone of public health strategies, relies extensively on the early detection and management of risk factors for chronic diseases. In traditional systems, uncertainty in patient data and variability in physiological indicators often lead to suboptimal preventive measures.

The integration of neutrosophic logic into preventive healthcare represents a paradigm shift in addressing uncertainty, indeterminacy, and contradictory data inherent in clinical and public health decision-making. As demonstrated in the reviewed studies, neutrosophic methods– grounded in the triad of truth (T), indeterminacy (I), and falsity (F)–provide a robust framework for modeling complex, ambiguous scenarios where traditional binary or probabilistic approaches fall short [34,35].

Managing Uncertainty in Risk Assessment and Screening: Neutrosophic logic excels in preventive applications such as risk stratification and early disease detection. For instance, in maternal health [19] employed neutrosophic multicriteria analysis to evaluate hypothyroidism-related complications (e.g., preeclampsia), capturing subjective expert judgments and heterogeneous data through 2-tuple linguistic neutrosophic numbers (2TLNNs). This approach prioritized risks more accurately than conventional methods by quantifying indeterminacy in clinical opinions. Similarly, [17] used neutrosophic statistics to analyze contradictions in cancer and dementia screening programs, revealing high indeterminacy (69.9% in pancreatic cancer screening) due to conflicting expert consensus. Such findings underscore neutrosophic logic's capacity to identify gaps in preventive protocols and refine screening guidelines.

Enhancing Public Health Interventions: In public health, neutrosophic methods address indeterminacy in socio-cultural and behavioral determinants of disease. The study on obesity determinants [21] applied Neutrosophic Cognitive Maps (NCMs) to model causal relationships between lifestyle factors (e.g., sedentary behavior) and health outcomes, integrating divergent perspectives from medical experts and patients. The results highlighted variability in risk perceptions, advocating for tailored communication campaigns—a critical insight for preventive strategies. Likewise, [13] leveraged neutrosophic statistics to analyze adolescent pregnancy drivers, quantifying linguistic ambiguities (e.g., "severely deteriorated" socioeconomic conditions = (0.3, 0.75, 0.8)) and enabling policymakers to target interventions more effectively.

Strengthening Ethical and Patient-Centered Prevention: Neutrosophic logic also bridges ethical and practical challenges in preventive care. For example, [18] evaluated Patient-Centered Care (PCC) acceptance using neutrosophic IADOV methods, revealing those personal experiences (e.g., communication quality) significantly influence preventive health engagement. This aligns with the neutrosophic Delphi analysis of medical ethics presented in [30], where education in bioethics (Subset 3) emerged as pivotal for equitable preventive care delivery. By formalizing subjective patient and provider perspectives, neutrosophic logic fosters culturally sensitive prevention frameworks [36].

Despite its promise, neutrosophic applications in prevention face challenges. First, the complexity of neutrosophic algorithms may hinder widespread adoption in resource-limited settings [10]. Second, while studies like [27] (dental fluorosis) and [22] (ASD risk factors) demonstrate methodological rigor, broader validation through longitudinal data is needed. Future research should explore hybrid models combining neutrosophic logic with machine learning to automate indeterminacy handling in large-scale preventive datasets [16, 21].

All in all, neutrosophic logic offers a transformative tool for preventive healthcare by systematically addressing uncertainty, contradictions, and sociocultural variability. From risk assessment to ethical policy design, its triadic framework enhances the precision and inclusivity of preventive interventions. Further interdisciplinary collaboration—spanning medicine, statistics, and AI—will be essential to unlock its full potential in global health contexts.

4.2 Implications for Medical Decision-Making Systems

The incorporation of neutrosophic logic into medical decision-making systems offers a more nuanced approach to patient care. By enabling clinicians to consider indeterminacy as a fundamental component of diagnostic reasoning, these systems facilitate more informed and accurate clinical judgments. The improvements in diagnostic accuracy and preventive care observed in this study suggest that neutrosophic applications can significantly enhance the overall quality of patient care. In practice, neutrosophic decision-making systems integrate data from multiple sources—including patient records, laboratory results, and even anecdotal clinical observations—to compute a more comprehensive risk profile for each patient. This multi-dimensional approach aids in distinguishing between patients who require immediate intervention and those whose clinical data presents manageable uncertainties.

Enhanced Diagnostic Accuracy: Neutrosophic logic has demonstrated significant potential in improving diagnostic accuracy by accommodating partial or ambiguous information. For instance:

- In depression severity evaluation, neutrosophic numbers enabled accurate classification by accounting for symptom vagueness [15].
- For maternal health, 2-tuple linguistic neutrosophic numbers (2TLNNs) improved risk assessment of hypothyroidism complications during pregnancy [19].

Handling Contradictions and Variability: Medical data frequently involve contradictions addressed by:

- Single-valued neutrosophic Sets (SVNS) for synthesizing conflicting expert opinions [16, 23, 29]
- Neutrosophic Cognitive Maps (NCMs) analyze obesity determinants through multiperspective integration [21]

Ethical and Patient-Centered Decision-Making: Applications include:

- Bipolar neutrosophic sets for telemedicine ethics [31]
- Neutrosophic IADOV method capturing patient-centered care perceptions [18]

Despite its demonstrated advantages, the widespread adoption of neutrosophic logic in clinical decision support systems faces several significant challenges.

First, there exists a pressing need to develop standardized protocols for implementing neutrosophic approaches across diverse medical applications, as current methodologies often vary between research groups. The computational complexity of neutrosophic algorithms also presents a practical barrier, particularly for real-time clinical applications where processing speed is critical. Furthermore, seamless integration with existing electronic health record (EHR) systems remains technically challenging due to differences in data structures and the need for specialized interpretation frameworks.

Future research should prioritize the development of optimized algorithms to reduce computational overhead while maintaining analytical precision. Additionally, large-scale validation studies across multiple clinical domains will be essential to establish generalizability and build clinician confidence in these methods. The creation of user-friendly software interfaces and clinician training programs will be equally important to facilitate the transition from theoretical frameworks to routine clinical practice. Addressing these challenges systematically could unlock the full potential of neutrosophic systems to enhance medical decision-making in complex, real-world healthcare environments[37].

5 Conclusion

The integration of neutrosophic logic into Ecuadorian medicine represents a significant advancement in addressing the complexities of medical decision-making, particularly in contexts fraught with uncertainty, ambiguity, and contradictory data. By incorporating the triad of truth (T), indeterminacy (I), and falsity (F), neutrosophic methods provide a robust framework that surpasses traditional binary and

probabilistic approaches. The reviewed studies demonstrate its transformative potential across diverse domains, from COVID-19 response and intercultural care to chronic disease management and mental health. These applications highlight how neutrosophic logic enhances diagnostic accuracy, risk assessment, and patient-centered care, offering a more nuanced and inclusive approach to healthcare challenges.

Despite its promise, the widespread adoption of neutrosophic logic faces challenges, including computational complexity and the need for standardized protocols. Future research should focus on optimizing algorithms, conducting large-scale validation studies, and developing user-friendly interfaces to facilitate integration into clinical practice. Interdisciplinary collaboration—spanning medicine, artificial intelligence, and ethics—will be essential to unlock the full potential of neutrosophic systems. As Ecuador and other regions grapple with evolving healthcare demands, neutrosophic logic stands as a pivotal tool for fostering resilience, equity, and precision in medical decision-making, ultimately improving outcomes for patients and healthcare systems alike.

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