Chapter 10

Neutrosophic diagnosis of rural women vulnerable to anemia

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10.1 Introduction and motivation

The domain of classical statistics dealing with deterministic observations of data plays a crucial role in drawing inferences from the collected research data. The ample availability of statistical testing methods smoothens the process of drawing inferences. Diagnostic tests are predominantly applied in the field of medicine and the related areas to diagnose especially the prevalence of diseases and disorders. Researchers of varied backgrounds have applied the classical diagnostic test for data analysis to conclude. To mention a few, Greiner et al. [1] analyzed veterinary data; Lalkhen et al. [2] examined the clinical data; and Leeflang et al. [3] studied the data on disease prevalence by making use of the diagnostic test in the classical sense.

The deterministic nature of data sets is always questionable, as the presence of uncertainty intervenes in the experimental scenario many times. To handle such uncertain instances, diagnostic test under a fuzzy environment was used by researchers to make inferences on disease data.

Hasima and Khan [4] used the fuzzy diagnostic test for identifying liver disease. A fuzzy logic-based medical expert system was developed by Jimmy et al. to diagnose chronic kidney disease. Sorina Zahana [5] applied score-based test under fuzzy logic and the pre-diagnosis test under fuzzy environment. Kim et al. [6] developed fuzzy rule-based system for liver diagnosis. Mumini et al. [7] constructed Genetic-Neuro-Fuzzy inferential model for diagnosing tuberculosis. Phelps and Hutson [8] applied the fuzzy gold standard method of a diagnostic test. Also, Castanho et al. [9],

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Smith and Slenning [10], and Bhise et al. [11] have applied fuzzy diagnostic tests to disease data.

In spite of the existing fuzzy diagnostic models, neutrosophic diagnostic tests are developed to handle the situations of indeterminacy, and the fuzzy logic is extended to neutrosophic logic to facilitate the management of indeterminacy. Neutrosophic sets are characterized by the values of truth, indeterminacy, and falsity. Neutrosophic statistics is an alternative to fuzzy statistics, and it helps in analyzing the data obtained from the population with fuzziness and indeterminacy. Smarandache [12] introduced neutrosophic statistics in which the statistical concepts were discussed under a neutrosophic environment.

Mumtaz Ali [13] has used neutrosophic recommender system for disease diagnosis. Basha et al. [14] have applied neutrosophic logic to construct a hybrid model for making inferences on X-rays. Muhammad Aslam [15] proposed a neutrosophic diagnostic test and a gold standard test. The test has been applied to identify the presence of diabetics. The proposed test has been validated by an example, but it has not been applied to research data as such to the best of our knowledge. The feasibility and the pragmatic nature of the neutrosophic diagnostic test developed by Muhammad Aslam [15] have made the authors apply the method to make the diagnostic study of anemic rural women with real-time data. Also, the neutrosophic diagnostic test was applied earlier only to diagnose the presence or the absence of diabetics, but in this paper, the neutrosophic gold standard diagnostic test was applied to diagnose the anemic and nonanemic persons and also the type of anemic present in the samples taken for study.

The paper is structured into many sections consisting of preliminaries, literature review, description of the study area, neutrosophic statistical analysis of the data, discussion of the results, conclusion, and future scope of the research work.

10.2 Background, definitions, and notations

The basic data representation and the preliminaries involved in the neutrosophic gold standard diagnostic test are presented in Tables 10.1 and 10.2.

10.3 Literature review and state of the art

The economic and social disparities have cleaved the populace into healthy and vulnerable groups in developing nations like India. The inadequate supply of nutritious foods and supplementary substances contributes to anemia, a serious health problem that affects the normal functioning of the human system, especially the womenfolk. Anemia is a hematological abnormality condition related to reduced oxygen transportation ability of the blood due to the reduction in red blood cells, packed cell volume, and hemoglobin. According to a statistical report of the World Health Organization, rural women of reproductive age are highly susceptible to anemia. Pregnant women face many health issues due to low levels of hemoglobin.

TABLE 10.1 Data representation under neutrosophic gold standard diagnostic test.

		Factual diagnosis				
		Disease +	**Disease −**	**Uncertainty positive**	**Uncertainty negative**	**Total**
Factual test reports	Disease +	$[O_L, O_U]$	$[M_L, M_U]$	$[P_L, P_U]$	$[p_L, p_U]$	$[O_L + M_L + P_L + p_L, O_U + M_U + P_U + p_U]$
	Disease -	$[V_L, V_U]$	$[W_L, W_U]$	$[Y_L, Y_U]$	$[y_L, y_U]$	$[V_L + W_L + Y_L + y_L, V_U + W_U + Y_U + y_U]$
	Uncertainty positive	$[d_L, d_U]$	$[e_L, e_U]$	$[G_L, G_U]$	$[g_L, g_U]$	$[d_L + e_L + G_L + g_L, d_U + e_U + G_U + g_U]$
	Uncertainty negative	$[k_L, k_U]$	$[q_L, q_U]$	$[Z_L, Z_U]$	$[z_L, z_U]$	$[k_L + q_L + Z_L + z_L, k_U + q_U + Z_U + z_U]$
	Total	$[O_L + V_L + d_L + k_L, O_U + V_U + d_U + k_U]$	$[M_L + W_L + e_L + q_L, M_U + W_U + e_U + q_U]$	$[P_L + Y_L + G_L + Z_L, P_U + Y_U + G_U + Z_U]$	$[p_L + y_{L+} g_L + z_L, p_U + y_{U+} g_U + z_U]$	N_N

TABLE 10.2 Basic terms of neutrosophic gold standard diagnostic test.

Terminology	Definition	Formula
Neutrosophic sensitivity	Percentage of right identification of the diseased persons in consensus with the test results	$\frac{[O_L,O_U]}{[O_L+V_L+d_L+k_L,\ O_U+V_U+d_U+k_U]}$
Neutrosophic practitioner sensitivity	Percentage of the persons being accepted by the practitioner to be diseased under uncertainty and with the test indicating the presence of disease	$\frac{[P_L,P_U]}{[P_L+Y_L+G_L+Z_L,\ P_U+Y_U+G_U+Z_U]}$
Neutrosophic test sensitivity	Percentage of the persons being accepted by the practitioner to be diseased and the tests indicating the presence of disease under uncertainty	$\frac{[d_L,dU]}{[O_L+V_L+d_L+k_L,\ O_U+V_U+d_U+k_U]}$
Neutrosophic practitioner-test sensitivity	Percentage of the diseased persons for which the practitioner and the test are under uncertainty	$\frac{[G_L,G_U]}{[P_L+Y_L+G_L+Z_L,\ P_U+Y_U+G_U+Z_U]}$
Neutrosophic specificity	Percentage of right identification of the non-diseased persons in consensus with the test results	$\frac{[W_L,W_U]}{[M_L+W_L+e_L+q_L,\ M_U+W_U+e_U+q_U]}$
Neutrosophic practitioner specificity	Percentage of the persons being accepted by the practitioner to be non-diseased under uncertainty and with the test indicating the absence of disease	$\frac{[y_L,y_U]}{[p_L+y_L+g_L+z_L,\ p_U+y_U+g_U+z_U]}$
Neutrosophic test specificity	Percentage of the persons being accepted by the practitioner to be non-diseased and the tests indicating the absence of disease under uncertainty	$\frac{[q_L,q_U]}{[M_L+W_L+e_L+q_L,\ M_U+W_U+e_U+q_U]}$
Neutrosophic practitioner-test specificity	Percentage of the non-diseased persons for which the practitioner and the test are under uncertainty	$\frac{[z_L,z_U]}{[p_L+y_L+g_L+z_L,\ p_U+y_U+g_U+z_U]}$
Neutrosophic practitioner positive predictiveValue	Percentage of diseased persons accepted by the practitioner under uncertainty	$\frac{[P_L,P_U]}{[O_L+M_L+P_L+p_L,\ O_U+M_U+P_U+p_U]}$
Neutrosophic test positive predictive value	Percentage of persons tested positive under uncertainty and are actually diseased	$\frac{[d_L,d_U]}{[d_L+e_L+G_L+g_L,\ d_U+e_U+G_U+g_U]}$

Premature births, low birth weight, postmartum hemorrhage are some of the most common consequences of anemic disorder. The prevalence of anemic is classified into severely anemic, moderately anemic, and less anemic based on the levels of hemoglobin.

Researchers have made a descriptive study on the prevalence of anemic among rural people of India, especially with a special focus on women. Bentley and Griffiths [16] have investigated the occurrences and causative factors of anemia among women in Andhra Pradesh, a state in South India. It was inferred that rural women are greatly affected in comparison to urban women, and especially, the factors contributing to such health burden are low income and low body mass index. Anu Rammohan [17] studied the impact of vegetarianism on the iron deficiency of women in India and discussed the dietary impacts. Maninder Kaur and Kochar [18] stated the causative reasons for anemia in rural women in Haryana, a state in North India. Sharadamani [19] conducted a research study on the people of Karaikudi and inferred that women are highly vulnerable to anemia. From the literature on rural women and anemia, it was inferred that the rural womenfolk of reproductive age are greatly suffering from this anemic disorder, and to the best of our knowledge, only descriptive study has been done so far using classical statistical tools. Henceforth, this paper attempts to make a diagnostic study on the presence or absence of anemia and the types of anemia using neutrosophic diagnostic tests.

10.4 Problem definition

To investigate the problem of diagnosis of anemia and the types of anemia of the rural womenfolk, the research study is conducted in Karumathur, a gram panchayat located in Chellampatti block in the Madurai district of Tamil Nadu state in India. The total geographical area is around 1630.3 hectares with a population of around 6737 and 1,902 housing settlements as per the 2011 census. The total male population is 3559, and the female population is 3178. The total literacy rate is 65.6%, and concerning females, it is 26.1%. The total working population is 55.1%. Agriculture and livestock rearing are the primary occupations of the people. The study area was economically and socially underdeveloped a few decades back with dominant practices of female infanticide and child marriage system, but presently, the establishment of schools and colleges has enlightened the people of this region. In spite of such developments, the practice of the girl's early marriage system still exists, and this has many consequential impacts on women health.

The subjects of the study are the women belonging to the age group of 18–40, and around 62.9% of the female population belongs to this group. The samples were chosen by the method of systematic sampling. This research study aims to categorize whether the subjects investigated are anemic or not. The hemoglobin levels are obtained from the subjects through

clinical tests. If Hb levels are below the standard levels, then the subject is presumed to be anemic. But many times, there may arise certain discrepancies between investigation and the clinical test results. To handle such instances, the method of gold standard test under neutrosophic environment is used to make statistical analysis.

10.5 Analysis

Tables 10.3, 10.4, 10.5, and 10.6 represent the neutrosophic data

The results obtained by using the method of neutrosophic gold standard diagnostic test are presented in Table 10.7

10.6 Discussion

The neutrosophic sensitivity indeterminacy interval values from 61.58% to 63.39% under anemia represent that the woman has anemia, and certainly, the test results hold to be positive. The neutrosophic practitioner sensitivity indeterminacy interval values from 7.5% to 8.57% represent the percentage of women being accepted by the practitioner to be anemic under uncertainty and with the test indicating the presence of anemia. The neutrosophic test sensitivity indeterminacy interval values from 0.12% to 0.175% under anemia represent the percentage of women being accepted by the practitioner to be anemic and the tests indicating the presence of anemia under uncertainty. The neutrosophic practitioner-test sensitivity interval values from 32.5% to 34.28% under anemia represent the percentage of the anemic women for which the practitioner and the test are under uncertainty. In a similar fashion, the neutrosophic specificity indeterminacy interval values from 58.82% to 58.48% under anemia represent that the women have no anemia and the test will result negative.

The neutrosophic practitioner specificity indeterminacy interval values from 19.23% to 20.69% represent the percentage of women being accepted by the practitioner to be nonanemic under uncertainty and with the test indicating the absence of anemia. The neutrosophic test specificity indeterminacy interval values from 0.17% to 0.34% under anemia represent the percentage of women being accepted by the practitioner to be non-anemic, and the tests indicate the absence of anemia under uncertainty. The neutrosophic practitioner-test specificity interval values from 11.54% to 17.24% under anemia represent the percentage of the nonanemic women for which the practitioner and the test are under uncertainty. The neutrosophic practitioner positive predictive indeterminacy interval values from 0.149% to 0.15% represents the percentage of anemic women accepted by the practitioner under uncertainty, and the neutrosophic test positive predictive indeterminacy interval values from 6.45% to 8.82% represent the percentage of persons tested positive under uncertainty are anemic. Similarly, the same way of analysis shall be made for the category of mild, moderate, and severe anemic women.

TABLE 10.3 Neutrosophic data of anemia diagnosis.

		Factual diagnosis				
		Anemia +	**Anemia −**	**Uncertainty positive**	**Uncertainty negative**	**Total**
Factual test reports	Anemia +	[1050,1053]	[950,950]	[3,3]	[4,4]	[2007,2010]
	Anemia −	[650,650]	[1350,1355]	[3,4]	[5,6]	[2008,2015]
	Uncertainty positive	[2,3]	[3,4]	[12,13]	[14]	[31,34]
	Uncertainty negative	[3,4]	[4,8]	[17,20]	[3,5]	[27,37]
	Total	[1705,1710]	[2307,2317]	[35,40]	[26,29]	[4073,4096]

TABLE 10.4 Neutrosophic data of mild anemia diagnosis

		Factual diagnosis				
		Mild Anemia +	Mild Anemia −	UncertaintyPositive	UncertaintyNegative	Total
Factual test reports	Mild anemia +	[210,211]	[840,842]	[2,2]	[3,3]	[1055,1058]
	Mild anemia −	[130,130]	[520,522]	[2,4]	[3,5]	[655,661]
	Uncertainty positive	[2,2]	[2,3]	[7,8]	[10]	[21,23]
	Uncertainty negative	[2,4]	[3,5]	[12,15]	[2,4]	[19,28]
	Total	[344,347]	[1365,1372]	[23,29]	[18,22]	[1750,1770]

TABLE 10.5 Neutrosophic data of moderate anemia diagnosis.

		Factual diagnosis				
		Moderate anemia +	**Moderate anemia −**	**Uncertainty positive**	**Uncertainty negative**	**Total**
Factual test reports	Moderate anemia +	[420,421]	[630,632]	[2,3]	[3,3]	[1055,1059]
	Moderate anemia −	[260,260]	[390,392]	[1,3]	[4,5]	[655,660]
	Uncertainty positive	[1,2]	[1,3]	[10,13]	[10,11]	[22,29]
	Uncertainty negative	[2,3]	[3,4]	[11]	[2,3]	[18,21]
	Total	[683,686]	[1024,1031]	[24,30]	[19,22]	[1750,1769]

TABLE 10.6 Neutrosophic data of severe anemia diagnosis.

		Factual diagnosis				
		Severe anemia +	**Severe anemia -**	**Uncertainty positive**	**Uncertainty negative**	**Total**
Factual test reports	Severe anemia +	[315,316]	[735,737]	[2,2]	[1,1]	[1053,1056]
	Severe anemia –	[195,195]	[455,458]	[3,4]	[4,4]	[657,661]
	Uncertainty positive	[2,3]	[3,4]	[9,10]	[10]	[24,27]
	Uncertainty negative	[1,2]	[2,3]	[6,7]	[3,3]	[12,15]
	Total	[513,516]	[1195,1202]	[20,23]	[18]	[1746,1759]

TABLE 10.7 Results of neutrosophic gold standard diagnostic test.

Calculated values of neutrosophic statistical analysis	Anemia	Mild anemia	Moderate anemia	Severe anemia
Neutrosophic sensitivity	[61.58,63.39]	[61.05,60.81]	[61.49,61.37]	[61.4,61.2]
Neutrosophic practitioner sensitivity	[8.57,7.5]	[8.7,6.89]	[8.33,10]	[10,8.69]
Neutrosophic test sensitivity	[0.12,0.175]	[0.58,0.576]	[0.146,0.29]	[0.38,0.58]
Neutrosophic practitioner-test sensitivity	[34.28,32.5]	[30.43,27.58]	[41.67,43.33]	[45,43.5]
Neutrosophic specificity	[58.52,58.48]	[38.09,38.05]	[38.09,38.02]	[38.07.38.10]
Neutrosophic practitioner specificity	[19.23,20.69]	[16.67,22.72]	[21.05,22.73]	[22.22,22.22]
Neutrosophic test specificity	[0.17,0.34]	[0.22,0.36]	[0.29,0.233]	[0.167,0.24]
Neutrosophic practitioner-test specificity	[11.54,17.24]	[11.14,18.18]	[10.53,13.64]	[16.67,16.67]
Neutrosophic practitioner positive predictive value	[0.15,0.149]	[0.18,0.19]	[0.18,0.28]	[0.18,0.19]
Neutrosophic test positive predictive value	[6.45,8.82]	[9.52,8.69]	[4.55,6.89]	[0.33,11.11]

10.7 Conclusion

This research work applies the neutrosophic gold standard diagnostic test proposed to determine the presence and absence of anemic disease in rural women. The neutrosophic diagnostic test is more compatible, and it helps in analyzing the uncertain environment. It is inferred that rural women are

greatly affected by anemic disease, and also, a majority of rural women are highly affected by moderate anemia as neutrosophic sensitivity of moderate anemia is higher in comparison with other types of anemia. The research work can be extended by exploring the factors contributing to anemic in rural women, and also, the vulnerability of urban women to anemic shall be compared concerning rural women.

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