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Pioneering Early Diagnosis: A Comprehensive Analysis of Key Factors in Iron Deficiency Anemia Detection

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Abstract: ***Anemia is one of the most widespread blood diseases worldwide. The common condition of anemia is the insufficiency of red blood count or the reduction of oxygen carrying capacity, thereby affecting the eminence of life. Though there exists many different forms of anemia, the most general form is the Iron Deficiency Anemia (IDA) which nurtures commonly during the gestational period of a woman. Timely detection of IDA is crucial in terms of treating patients. Relying only on Haemoglobin (HB) will not be helpful to diagnose IDA. A comprehensive approach encompassing factors such as age, dietary habits, pregnancy stage, other physiological conditions and a Complete Blood Count (CBC) test is also essential for accurate diagnosis. Also, IDA can be distinguished in three stages viz. mild, moderate and severe based on the outcomes of the factors causing IDA. Failing to recognize and treat IDA promptly can lead to adverse consequences, particularly concerning maternal and neonatal outcomes [1]. Identifying the cause at an early stage and providing proper treatments will help the maternal women not to reach the moderate or severe stage of IDA. The present work focuses on identifying IDA at an early stage by deeply observing various factors like Mean corpuscular volume (MCV), Red blood cell distribution width (RDW), Platelet (Plt), Ferritin, Iron etc. Few statistical analyses were performed in this work and their results are discussed.***

Keywords: Iron Deficiency Anemia, Early diagnoses, Statistical Analysis

1. Introduction

The prevalence of IDA is high in India as stated in [2] and hence it is regarded as a global health issue which affects the well - being of the public. Its influence spans across developing and advanced nations, impacting human health, socio - economic progress, and broader societal dynamics. IDA emerges in all phases of the life cycle but shows higher prevalence in women [3]. Diagnosis of IDA differs among diverse populations, contingent on elements like age, sex, socio - economic standing, and ethnic background. Among women of reproductive age, research demonstrates that substantial menstrual bleeding is the primary underlying cause of IDA [4].

Numerous investigations have been carried out regarding anemia and hematologic ailments. A considerable area of focus is probing the anticipation of anemia based on the hue of Red Blood Cells (RBCs) [5]. Maternal as well as fetal mortality occur due to pregnancy related anemia [6]. The scientific study of anemia at the stage of pregnancy is delicate and possesses insufficiencies in various nutrients such as iron, folate and vitamin B12 as stated in [7]. Prolonged negative disproportion of iron as well as less amalgamation of consumed iron may result in IDA [8]. IDA has been characterized as a hidden threat among pregnant women, necessitating additional administration of iron supplements or therapy to boost hemoglobin levels. Inadequate consumption of micronutrients also holds significant implication. Moreover, genetic factors also play a crucial role in context of this.

Many researchers have employed statistical methods/tests for diagnosing health–related risks at an earlier stage. The dataset used by [9] was exploited in this work where a CBC examination was done for the cause of measuring some aspects of the blood such as Hemoglobin (HB), Mean Corpuscular Volume (MCV), Platelet count, White Blood Cell count (WBC), Ferritin, and Iron levels etc. Since HB is generally being considered as the common cause for IDA, a correlation to other factors with respect to HB has been performed with the three classes of IDA for the admit status taken as ‘y’ or ‘n’ in the dataset. The primary objective of this study was to determine the occurrence rate of iron deficiency anemia among pregnant women

2. Literature Review

In a study by Meena K et al. [10], data analytics were applied to healthcare systems to reduce the occurrence of blood - related conditions such as anemia. This approach involved incorporating medical insights to minimize the need for human intervention through the use of AI techniques. Anemia severity was assessed primarily by HB levels, where normal levels indicated good health in women, while severe levels signaled the presence of anemia. The study also considered the influence of pregnancy on a child's susceptibility to anemia. Analyzing preventive measures aimed to decrease the risk and prevalence of anemia, often associated with dietary and other factors. The prevalence of IDA in women, significantly impacts health. Ewelina Rogozinska et al. [11] conducted an assessment of various interventions for anemia in pregnant women. They evaluated randomized experiments to simultaneously compare the

effectiveness and safety of different iron therapies for pregnancy - related anemia.

Melda Kangalgil et al. [12] sought to explore the link between anemia and iron deficiency during pregnancy, considering sociodemographic factors, maternal variables, supplement utilization, and dietary habits. The prominent consideration was on managing and preventing anemia at the stage of pregnancy for safe - guarding the safety of the mother and the fetus. Routine iron supplementation was a key part of prenatal care. Diana Mansour et al. [13] noted that IDA often goes under - diagnosed and under - treated in patients with heavy menstrual bleeding (HMB). Challenges in managing women with HMB included the involvement of multiple healthcare professionals without clear directives or designated responsibilities for addressing resulting IDA. The study stressed the need for comprehensive HMB management to improve health outcomes for affected patients.

In a study by Rajan Vohra et al. [14], a major public health issue was addressed, where patients may not be aware of the presence of anemia at certain stages. The main objective of this work was on focusing the use of Machine Learning (ML) techniques for categorizing the patients based on the severity of anemia. Jiran Meitei and his team [15] assessed the effectiveness of ML algorithms and the extraction of insights from relational data. Their outcome revealed the fact that anemia occurrence in solely dependent on age and socioeconomic status. Additionally, ML algorithms demonstrated the capability to detect trends and patterns in various illnesses, including cardiovascular disease and lung carcinoma.

3. Materials and Methods

The current study is centered on examining the correlation between HB and several other factors, including MCV, RDW, PLT, Ferritin and Iron levels. Jiran Meitei et al. [15] in their study discovered that the occurrence of anemia is influenced by various factors such as age, gender, and socioeconomic status. Our study considers the above parameters for the categories (Category - I & Category - II) based on the admission status (yes or no) of the patients.

The dataset entries have been organized into two distinct categories, Category I and Category II, which are differentiated by the severity of anemia, specifically categorized into three classes: mild (Class A), modest (Class B) and high (Class C). Initially, the mean values for all the above mentioned parameters for both categories were determined. Detailed information regarding the characteristics and attributes of Category I and Category II can be found in the following table, Table - I. This table provides a comprehensive breakdown of the data specific to each category, facilitating a deeper understanding of the study's findings.

Table I: Characteristics/mean values of in each category with respect to the specified parameters

Parameters/ Categories	Category – I (Admit = y)	Category – II (Admit = y)
Age	45	37
HB	8	9
MCV	66	68
RDW	20	19
Plt	348	340
Ferritin	34	12
Iron	30	25

The conducted statistical analyses encompassed the following: (i) Analysis of Variance (ANOVA) (ii) Correlation testing (iii) Linear Regression analysis. To ascertain the statistical significance of the study, the aforementioned tests were conducted to evaluate the intended null hypothesis, which posits the presence of a strong mutual association between HB with other parameters. In general, as it is widely acknowledged that HB is the primary contributor to IDA, exploring the relationships between HB and other parameters is valuable for early problem diagnosis. As a result, the following table, Table - II which is structured based on patient admission status (yes or no) and the three classes of HB levels: mild, moderate, and high for both categories has been evaluated.

Table II: Computed mean values of factors having correlation with HB for Category – I (Admit=y) & Category – II (Admit=n)

Classes/ Mean Values	Mean Ferritin		Mean MCV		Mean RDW		Mean Plt		Mean Iron	
	Category I	Category II	Category I	Category II	Category I	Category II	Category I	Category II	Category I	Category II
A	13	17	76	74	16	17	316	310	40	32
B	59	12	69	68	19	19	345	347	39	24
C	9	4	62	65	21	21	356	318	19	20

4. Results and Discussion

Upon closer look into Table - I, some observations could be made based on the given categories. The mean age of Category - I is 45 while it is 37 for Category - II, indicating the fact that young women who have the problem of IDA and whose age lesser than 40 could be treated by medications itself without the need of admitting them in hospitals. This category of women also possesses HB more than that of the other category, but both are not in the expected range. Though MCV, RDW and Iron values are almost the same for both the categories, they are not in normal range in both. The Plt content is in normal range indicating the fact that this factor is not much significant in identifying IDA in women. Ferritin content is very low for Category - II and is abnormal in this category whereas it is in the normal range for the first category.

As HB is considered as the main factor for IDA in many research articles in the literature, this has been taken as the primary factor and all the other factors are tested based on the HB level. This has been classified into three classes viz. Class A in which the HB level is between 11 – 12 g/dl (mild anemia), Class B where HB level is between 8 to 11 g/dl

(fair anemia) and Class C where it is less than 8 g/dl (high anemia). Based on this classification, on examining Table - II, the Ferritin and Iron contents are very low for Category - I and Category - II for all the three classes indicating that these two factors have high correlation with HB. The RDW value is negatively correlated with HB, plt is always within the range for all the classes and MCV is significantly reducing for the three classes.

Further investigation is done by performing Correlation Analysis for all the 205 female patients. In the dataset, based on the outcomes, the above parameters are considered as influential parameters and the remaining parameters such as WBC (White Blood Count), tibc (Total iron binding capacity), b12, folate and IDH (Isocitrate dehydrogenase) are considered as non - influential parameters for the cause of IDA. The influential parameters such as MCV, Ferritin and Iron are positively correlated while the other parameters RDW and Plt are negatively correlated with HB. In particular, MCV possess a high correlation with HB indicating the aspect that this parameter is also a more influential parameter for IDA. Among the non - influential parameters, WBC and b12 show positive correlation with HB though not in a high range. Others show negative impact only. These observations are depicted in the following figures, Fig.1 & Fig.2.

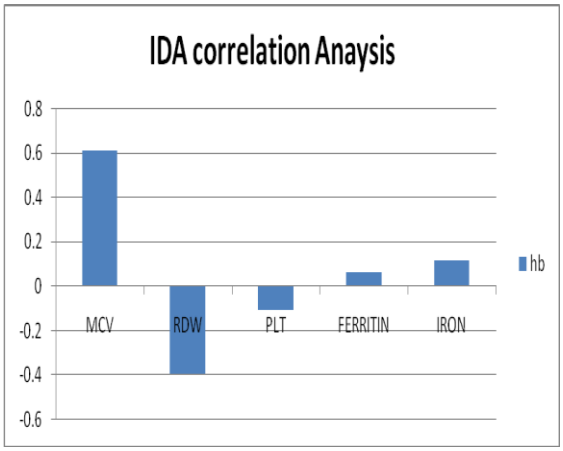

Figure 1: Pearson Correlation between MCV, RDW, PLT, FERRITIN, IRON with HB Level

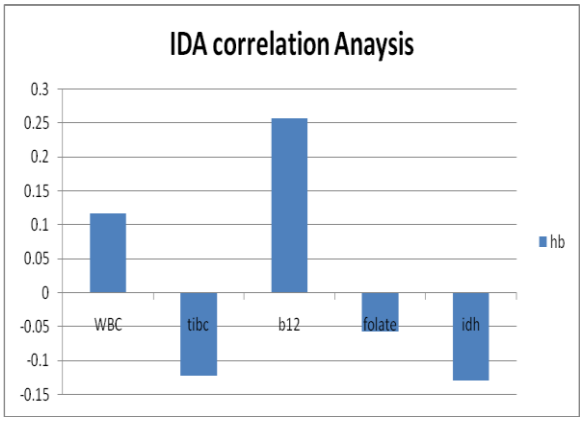

Figure 2: Pearson Correlation between WBC, TIBC, B12, Folate, IDH with HB Level

The ANOVA analysis serves the purpose of comparing averages across various groups and detecting statistical variances among the means. Its primary purpose is to evaluate the statistical significance among these group means by calculating the p - value. A significance level of 0.05 signifies a 5% risk, implying a 5% probability of concluding dissimilarity when none exists. If the computed p - value falls below this significance level, it leads to the rejection of the null hypothesis, indicating a significant difference among the group means. The detailed p - values from the ANOVA tests are provided in Table III. From this table it could be noted that the p - value being 1.0 for MCV and more than 0.85 for RDW indicate that the relationship of these parameters with IDA is strong and that for other parameters also the p - value is greater than α =.05 and hence we cannot reject the null hypothesis since there is a strong evidence to say that there is a statistical difference between the means of the groups.

Table III: Results of the ANOVA experiments

Influential Parameters mean values for Category I & Category II	*p - value*
Ferritin	0.38665
MCV	1.0
RDW	0.86621
Plt	0.44117
Iron	0.39458

In the above statistical tests, it can be seen that MCV has got higher impact on HB which is regarded as the major cause for IDA. On considering this, the Linear Regression test has been carried out between HB and MCV for the Category - I of the dataset. The obtained R - value of this category for the most influential parameters HB and MCV is 0.63 which again indicates that there is a strong linear relationship between the variables that are taken for consideration. The result of the Linear Regression performed is shown in Fig.3.

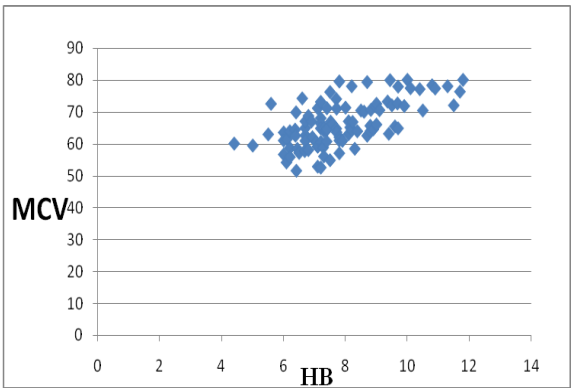

Figure 3: Linear Regression Test for Category - I (for HB Vs MCV) of the data set

HB is a more important factor on IDA. On viewing the outputs of various statistical experiments, the fact that is being explored is that the study should be extended further by including other important parameters like age, sex and socio economic and some other factors for exploring the problem of identifying IDA at an early stage for women.

5. Conclusion

This study aimed on identifying IDA in women, a prevalent issue for women over 35 worldwide hence if treated early, this could be circumvent and complications with regards to

this could be avoided. In view of this, this work investigated the problem and performed some statistical analyses for finding the factors causing IDA. As HB is considered as the main cause for iron deficiencies, investigations such as correlation, regression and ANOVA were performed for finding the impact of other factors like MCV, RDW, PLT, Ferritin, Iron, WBC, TIBC, B12, Folate and IDH with HB. Among all other parameters, MCV emerged as notably significant in causing IDA due to its strong correlation with HB. Considering these findings, the study suggests further exploration using machine learning algorithms and feature selection techniques. This approach aims to accurately pinpoint the crucial factors, thereby simplifying the investigation process and enhancing the precision of the results.

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