Association of Hematological Parameters with Iron Deficiency Anemia among the Selected Adolescent College Going Girls in South Chennai

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Abstract: Background: Adolescence is a crucial developmental stage that brings about physical, mental, psychological, and social changes in the body.[1] Anemia is characterized as a condition where the number of circulating red blood cells is lower than the normal physiological limit for a particular age and gender of the individual. Thus, it reduces the ability of red blood cells to carry oxygen and eventually provide insufficient oxygen supply throughout the body.[2] According to the morphological/pathological classification of anemia, among the three types, microcytic hypochromic anemia is the most prevalent variant, especially among the women of developing nations.[3]Among the different causes of microcytic hypochromic anemia, iron deficiency is the major contributing factor.[4] Iron deficiency anemia (IDA) is a microcytic-hypochromic anemia that has major prevalence in African and South Asian countries including India.[5] An increase in iron deficiency in adolescents (15-19 years) is recorded in the National Family Health Survey 2019-21. A sharper rise was observed in girls. (59.1 percent) Rising urbanization with changes in dietary habits towards junk food is leading to faster increase in anemia in urban areas as compared to rural, according to the survey.[6]. **Objectives:** To assess the Hematological Parameters of the selected adolescent college going girls, To determine the association between Hematological Parameters with Iron Deficiency Anemia. **Methods:** This college based cross-sectional study was conducted among adolescent girls in the age group of 17–19 years from varied Under Graduate programsat Shrimathi Devkunvar Nanalal Bhatt Vaishnav College for Women, Chennai. Sample size was derived using appropriate formula. Purposive sampling method was adopted to select participants for the study. The study was carried out over a period of two months between June to July ,2025. Nine hundred and sixty-two subjects participated in the study depending on their availability and willingness to check their hematological parameters. Hemoglobin (Hb), Red Blood Cells (RBC), White Blood Cells (WBC), Platelet Count (PC), Hematocrit value, (HCT), Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC) and Red Cell Distribution Width (RDW-CV) were the key parameters. Venous blood samples were collected by trained professionals and analyzed for Hematological Parameters. Data were analyzed using IBM SPSS Statistics version 25. Descriptive statistics and chi-square tests were applied to assess association between variables. **Results:** Prevalence rate of anemia was 44.1 percent based on blood hemoglobin levels. A significant significant association was observed with Iron Deficiency Anemia and all the assessed hematological parameters except for White Blood Cells. **Conclusion:** Strategic focus on Iron Deficiency Anemia is crucial as it has detrimental effects on physical capacity, cognitive ability, pregnancy outcome and emotional wellbeing. The uncorrected phase results in intergenerational cycle of anemia and henceforth an intervention with holistic approach is the need of the hour.

Keywords: Adolescent girls, Anemia, Hemoglobin, RBC, PCV, PC, MCV, MCH,MCHC, RDW-CV

Introduction

In India every fifth person is between 10 to 19 years.If India utilizes the resource potential of thishuge number of adolescent population (253 million) effectively by keeping them safe, healthy, educatedand equipped them with life skills,it will benefit the nation socially, politically and economically.[7]

During adolescence, the body's demand for iron is increased due to the accelerated phase of growth spurt [8],Menstrual blood loss further aggravates the risk of Iron Deficiency Anemia. [9]The most frequent micronutrient shortage in the world is iron insufficiency, which ultimately leads to Iron Deficiency Anemia .[10]

Irondeficiency (ID) is the more prevalent micronutrient deficiency worldwide and the most common cause of anaemia [4,5]n .Iron Deficiency progresses through distinct stages, starting with the depletion of iron storesthat will proceed to iron-deficient eryth ropoiesis, and resulting in Iron Deficiency Anemiafinally[11]

Iron Deficiency can lead to reduced physical work capacity and endurance specifically for adolescents who are engaged in physical activities and sports [12]

Despite national programs to tackle anemia, severe anemia (hemoglobin (Hb)levels<7 g/dl) continues to be a substantial problem in Indianwomen. [13,14,15]

Iron deficiency anemia in adolescence also has a wide range of consequences, such as impaired physical and mental growth and development as well as reduced physical fitness, work capacity, and school performance [16]

Iron is essential for hemoglobin production and enzyme function. Pregnant women, children under five, adolescent girls and women are more vulnerable to Iron Deficiency Anemia due to their increased nutritional requirements for iron [17,18,19]

Adolescents are vulnerable to ID because of increased iron requirements related to rapid growth. Iron needs are highest in males during peak pubertal development owing to a greater increase in blood volume and myoglobin. After menarche, iron needs continue to remain high in females on account of monthly menstrual blood loss, which averages about 20 mg per month, but may be as high as 58 mg in some individuals. In-spite of increased iron needs, many adolescents, particularly females, may have iron intake of only 10-11 mg per day, out of which 1mg will be absorbed approximately. [20,21,22]

Due to rapid growthspurt, iron requirements are increased during the crucial phase ofadolescence. Iron requirements remain high after menarchein females due to monthly menstrual loss that averages about 20 milligrams per month andeven it will be as high as 58 milligrams in some individuals. Despite the iron needs, the intake is very low among many adolescent girlsand it is only between 10-11 milligrams per day out of which only one milligram will be absorbed approximately [20,21,22]

Given the high prevalence of nutritional anemia in low- and middle-income countries like India, where Iron deficiency has been identified as the main cause, it is crucial to accurately evaluate the actual occurrence of iron deficiency. Iron deficiency is ranked

ninth among the 26 modifiable risk factors for death included in the Global Burden of Disease research, and untreated iron deficiency leads to Iron Deficiency Anemia[23].
Hematological markers, such as serum ferritin, transferrin, zinc porphyrin are traditionally used biochemical markers to diagnose Iron Deficiency Anemia. Butthese tests can be expensive and may not be readily accessible in resource-limited settings like many parts of India. Inaddition, the interpretation is often challenging in regions with high infection rates, as conditions like inflammation can affects their accuracy.
On contrary to these hematological tests based on characteristics of red blood cells, i.e., hemoglobin concentration, hematocrit and red blood cell distribution width are easily available at lower cost than biochemical tests.[24]
The present study was under taken to assess the association of various hematological parameters like Hemoglobin (Hb), Red Blood Cell (RBC) count, White Blood Cells (WBC),Platelet Count (PC) Hematocritvalue (HCT),Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC) and Red Cell Distribution Width (RDW-CV) with Iron Deficiency Anemia.

Methods

The study was conducted in Shrimathi Devkunvar Nanalal Bhatt Vaishnav College for Women, Chennai using a cross-sectional observational design. Sample size of 962 was derived using appropriate formula
The standard formula for calculating sample size in prevalence studies is:

$$n = \frac{Z^2 \cdot p \cdot (1-p)}{d^2}$$

Where:

- n = required sample size
- Z = Z-score for the desired confidence level (1.96 for 95%)
- p = estimated prevalence (as a decimal, 65.7% = 0.657)
- d = margin of error (as a decimal, 5% = 0.05)

The sample size was calculated to estimate the prevalence of anemia among college students using the pooled prevalence of 65.7% reported among adolescent girls in India by Daniel et al. in 2023.[25]
Purposive sampling was adopted to select participants for the study. Adolescent girls who had attained menarche and were in the age category of 17-19 years were included for the study. Adolescent girls who were diagnosed with endocrine disorders, genetic disorders, especially abled and on chronic treatment were excluded from the study. Sample collection was initiated only after obtaining approval from the institutional ethics committee. Written and informed consent was obtained from both the parents and participants who met the inclusion criteria to assure that confidentiality was maintained throughout the study. Venous blood sample was collected from all the

participants by trained professionals at free of cost and the Hematological Parameters were assessed through Automated Hematology Analyzers.

Although numerous public health initiatives have been undertaken, progress in reducing the prevalence of anemia has been limited. Relying solely on hemoglobin levels to screen for anemia misses a significant portion of the population who have iron deficiency without anemia.[36]

The red blood cell parameters and platelet count in anemic patients are important to identify and understand their association with clinical implications. Such correlation will enable physicians to make diagnoses and administer treatments.[35]

The other hematological parameters assessed in the present study were Hemoglobin, Red Blood Cell count, White Blood Cells, Platelet Count, Hematocrit value, Mean Corpuscular Volume, Mean Corpuscular Hemoglobin, Mean Corpuscular Hemoglobin Concentration and Red Cell Distribution Width

Statistical Analysis

The collected data were entered and analyzed using IBM SPSS Statistics version 25. Descriptive statistics such as frequencies, percentages, means, and standard deviations were used to summarize the study variables. To examine association between selected factors chi-square tests were performed. A p-value <0.05 was considered statistically significant.

Results

Hematological Details of Participants (N=962)

Blood Hemoglobin

Various studies in community settings in India have mainly chosen the capillary Hemoglobin measurement method due to its feasibility in field areas [28,29].

World Health Organization's Hemoglobin cut-off values for anemia were used to define normal Hemoglobin values for the study: non-pregnant women≥12 g/dl and pregnant women≥11 g/dl.[26]

Clinically, anemia is conventionally determined when Hemoglobin levels fall below the established normal threshold for age, sex, and physiological status [27, 28].

In the present study more than half of the subjects (five hundred and thirty-eight) had their normal blood hemoglobin levels (55.9 percent) as per World Health Organization cut off standards. It was noted that four hundred and twenty-four subjects had low blood hemoglobin levels (44.1 percent). Prevalence rate of iron deficiency anemia in the present study is 44.1 percent. This was slightly lower than the prevalence rate of study conducted by Haripriya et al (47.9 percent) this year. [29] Research published by Kulkarni et al., by compiling the reports of National Family Health Survey -3, 4, and 5, illustrated the prevalence of anemia as 56.5%, 53.5%, and 59.1%, respectively [30], which were higher estimates compared to the present study results. The observed national

estimates of the prevalence of anemia were deviated from our present study due to the implementation of an institution-based study design

Red Blood Celland Hematocrit

With respect to the count of Red Blood Cells only 1.8 percent of the subjects had lower count and 0.4 percent of the subjects had higher count than normal. Nine hundred and forty-one subjects (97.8 percent) had normal red blood cell count. Hematocrit value was low for two hundred and eighty-two subjects (29.3) while majority of the subjects (70.7 percent) had normal level.

White Blood Cell and Platelet count

White Blood Cell count was normal for 82.8 percent of the subjects. Elevated count was observed in 17.2 percent of the subjects.

Table: 1 Hematological Details of Participants (N=962)

Hematological Parameters	Category	N	%
Hemoglobin (Hb)	Low	424	44.1
	Normal	538	55.9
Red Blood Cells (RBC)	Low	17	1.8
	Normal	941	97.8
	High	4	0.4
Hematocrit (HCT)	Low	282	29.3
	Normal	680	70.7
White Blood Cells (WBC)	Normal	797	82.8
	High	165	17.2
Platelet Count (PC)	Low	2	0.2
	Normal	761	79.3
	High	197	20.5
Mean Corpuscular Volume (MCV)	Low	101	10.5
	Normal	859	89.4
	High	1	0.1
Mean Corpuscular Hemoglobin (MCH)	Low	94	9.8
	Normal	866	90.0
	High	2	0.2

Mean Corpuscular Hemoglobin Concentration (MCHC)	Low	22	2.3
	Normal	940	97.7
Red Cell Distribution Width (RDW-CV)	Normal	490	50.9
	High	472	49.1

Similarly, platelet count was low for only two subjects and197 subjects (20.5 percent) had elevated level. Seven hundred and sixty-one subjects (79.3 percent)had normal platelet count.

Mean Corpuscular Volume and Mean Corpuscular Hemoglobin Concentration

Win trobe in 1929 first introduced Mean Corpuscular Volume, Mean Corpuscular Hemoglobin, and Mean Corpuscular Hemoglobin Concentration to define the size and hemoglobin content of red blood cells. These red cell indices are useful in explaining the causative factors of anemia. With the known values of hemoglobin, hematocrit and red blood cell count red cell indices can be calculated. Now a days due to the availability of electronic cell counters red cell indices are automatically measured.[31]

Mean Corpuscular Volume was normal for 859 (89.4 percent) subjects. It was low for 101 subjects and high for only one subject. Except 22 subjects (2.3 percent), Mean Corpuscular Hemoglobin Concentration was normal for all.

Red Cell Distribution Width

Four hundred and seventy-two subjects (49.1 percent) had high Red Cell Distribution Width. While the remaining four hundred and ninety subjects had normal level.

Table 2: Association between Hematological Parameters and Iron Deficiency Anemia (N=962)

In adolescents, anemia can negatively impact physical development during their critical development period, increase the risk of infection, and poor pubertal and neurocognitive growth [37].

The diagnostic indices such as Red Cell Distribution Width Index, Srivastava Index, Mentzer Index, and Sridhar Index, utilize commonly measured Hematological Parameters like Mean Corpuscular Hemoglobin, Mean Corpuscular Hemoglobin Concentration, Red Blood Cell count and Hemoglobin to diagnose iron deficiency [38].

Red Blood Cell and Hematocrit

Among seventeen subjects who had low red blood cellcount, sixteen were anemic. Among four subjects who had higher red blood cell level, three subjects belonged to the category of Iron Deficiency Anemia. Four hundred and five anemic subjects (43 percent) had normal red blood cell count. The results are highly significant statistically. Hematocrit value was low for two hundred and eighty-two subjects. Among them two hundred and seventy-six subjects (97.9 percent) were anemic and showed a strong association.

White Blood Cell and Platelet count

In the parameter of white blood cell count44.3 percent of anemic subjects had normal white blood cell count and 43 percent had higher count. The results were not significant statistically.

Hematological Parameters	Category	Iron Deficiency Anemia		Normal		Chi-square value p value
		N	%	N	%	
Red Blood Cells (RBC)	Low	16	94.1	1	5.9	19.233 (0.000)
	Normal	405	43.0	536	57.0	
	High	3	75.0	1	25.0	
Hematocrit (HCT)	Low	276	97.9	6	2.1	468.426 (0.000)
	Normal	148	21.8	532	78.2	
White Blood Cells (WBC)	Normal	353	44.3	444	55.7	0.088 (0.767)
	High	71	43.0	94	57.0	
Platelet Count (PC)	Low	1	50.0	1	50.0	30.391 (0.000)
	Normal	301	39.6	460	60.4	
	High	121	61.4	76	38.6	
Mean Corpuscular Volume (MCV)	Low	97	96.0	4	4.0	124.957 (0.000)
	Normal	326	38.0	533	62.0	
	High	1	100.0	0	0.0	
Mean Corpuscular Hemoglobin (MCH)	Low	94	100.0	0	0.0	132.307 (0.000)
	Normal	329	38.0	537	62.0	
	High	1	50.0	1	50.0	

Mean Corpuscular Hemoglobin Concentration (MCHC)	Low	18	81.8	4	8.21	13.091 (0.000)
	Normal	405	43.1	535	56.9	
Red Cell Distribution Width (RDW-CV)	Normal	93	19.0	397	81.0	253.179 (0.000)
	High	330	69.9	142	30.1	

With respect to Platelet Count, one subject each in anemic and normal group had lower level. High platelet count was observed in 61.4 percent of the anemic subjects and 38.6 percent of the normal subjects. The results showed a strong association.

Mean Corpuscular Volume and Mean Corpuscular Hemoglobin Concentration

If the levels of Mean Corpuscular Hemoglobin are low, it is a standard to diagnose iron-deficiency anemia [31] The Mean Corpuscular Volume and Mean Corpuscular Hemoglobin values can identify iron deficiency in the body.[32]

Ninety-seven anemic subjects (96 percent) had low Mean Corpuscular Volume while it was only four percent in normal category.

With respect to Mean Corpuscular Hemoglobin values, ninety-four anemic subjects had low values while all the subjects in the non-anemic group had normal values. Eighteen anemic subjects (81.8) had low values for Mean Corpuscular Hemoglobin Concentration and only four subjects (8.2) in the non-anemic group had low values.

Red Cell Distribution Width

The diagnostic value of Red Cell Distribution Width is moderate but when it combines with hemoglobin the detection of Iron Deficiency Anemia is enhanced. This dual parameter approach is simple and cost effective. This efficient screening tool for rural settings where advanced diagnostic methods are unavailable.[24]

In the present study also 69.9 percent of the anemic subjects had high Red Cell Distribution Width levels. 69.9 percent of the anemic subjects had high values for Red Cell Distribution Width while 30.1 percent of the subjects in the normal category had higher values.

The main findings of the study conducted by Alsafi et al ,2024 were higher RDW and lower levels of hemoglobin, MCV, MCH, and MCHC in adolescents with iron deficiency; fair accuracy of hemoglobin, MCHC, and RDW in the diagnosis of iron deficiency; and good accuracy of MCV and MCH in diagnosing iron deficiency [33]These results were similar with a large study among 1443 healthy children aged 6 months to 18 years by Zhan et al in China, which showed higher RDW and lower

MCV and MCHC values in children with iron deficiency.[34]Findings of our present study also aligned with the above results.

Table 18
Mean and Standard Deviation of the hematological parameters of the participants (N=962)

Hematological Parameters	Minimum	Maximum	Mean	Std. Deviation
Hemoglobin (gm/dl)	4.3	15.3	11.86	1.51
RBC (millions/c.mm)	2.64	5.82	4.45	0.38
Packed cell volume (HCT) %	10	46.3	36.94	4.06
Total leucocytes (cell/c.mm)	4650	16920	9290.06	2006.1
Platelet (lakhs /c.mm)	0.7	9.39	3.6	1.07
MCV (FL)	23	113.7	83.23	9.05
MCH (pg.)	12.5	52.9	26.8	3.6
MCHC (%)	12.9	35.1	31.82	1.92
RDW-CV (%)	11.6	28.5	14.6	2.01

Mean Hemoglobin level was 11.86. This mean value was lower than the normal standard. Mean Red Blood Cell count was 4.45 and hematocrit was 36.94

Conclusion

In the present study more than half of the subjects (five hundred and thirty-eight) had their normal blood hemoglobin levels (55.9 percent) as per World Health Organization cut off standards. It was noted that four hundred and twenty-four subjects had low blood hemoglobin levels (44.1 percent).A significant association was observed with Iron Deficiency Anemia and all the assessed hematological parameters except for White Blood Cells. Hematological parameters serve as an effective tool in diagnosing iron deficiency anemia. Holistic approach involving parents, adolescentgirls, institution and community will be an effective approach to treat Iron Deficiency Anemia

Limitations

- Serum iron, serum total iron binding capacity, and serum transferrin saturation were not assessed because of financial constrain

- As our study is confined to single institution, findings may not be generalizable due to sociodemographic variations across the state. Our study did not measure iron, folate, vitamin B12, vitamin A, zinc, and helminth infestation, which are essential to investigate micronutrient deficiencies and causes of anemia in our population.

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