Section: Miscellaneous

Original Research Article

PROJECT SHAKTI: A PUBLIC HEALTH INITIATIVE TO COMBAT IRON DEFICIENCY AND ANAEMIA AMONG ADOLESCENT GIRLS IN PATIALA DISTRICT, PUNJAB

Showkat Ahmad Parray[1], Preeti Yadav[2], Nidhi Malhotra[3], Aman Dev Singh[4], Tanya Thakkar[5]

[1]*IAS, Former Deputy Commissioner, Patiala, Punjab, India*
[2]*IAS, Deputy Commissioner, Patiala, Punjab, India*
[3]*Punjab Good Governance Fellow, Patiala, Punjab, India*
[4]*Assistant Professor, Department of Community Medicine including Public Health, Government Medical College & Rajindra Hospital, Patiala, Punjab, India*
[5]*Assistant Professor, Department of Paediatrics, Government Medical College, Patiala, Punjab, India*

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Corresponding Author:
Dr. Aman Dev Singh,
Assistant Professor, Department of Community Medicine including Public Health, Government Medical College & Rajindra Hospital, Patiala, Punjab, India.
Email: adsingh44rssb@gmail.com

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ABSTRACT

Background: Anaemia, primarily caused by iron deficiency, remains a global health challenge, particularly in low- and middle-income countries like India. Adolescent girls in India are especially vulnerable, with the condition leading to growth retardation, impaired development, and future reproductive health issues. India's anaemia prevalence is high, with the national goal of reducing anaemia by 50% by 2025, especially among women and adolescent girls. This study addresses the prevalence of anaemia and the effectiveness of various interventions in a school-based setting in District Patiala, Punjab. The objective is to assess the prevalence of anaemia among adolescent girls and evaluate the effectiveness of various interventions—such as iron supplementation and nutritional kits—in improving haemoglobin levels and enhancing overall health outcomes.

Materials and Methods: A randomised interventional trial was conducted from July to October 2024 in 42 schools in the Rajpura block of Patiala District. A total of 1,327 adolescent girls were selected using convenience sampling, and schools were randomly assigned to one of three groups: Group A: Daily IFA supplementation with mid-day meal and an additional IFA tablet for home consumption. Group B: Daily IFA supplementation with mid-day meal, an additional IFA tablet for home consumption, and monthly nutritional kits. Group C: Routine weekly IFA supplementation under (control group). Baseline data were collected on haemoglobin levels, body mass index (BMI), dietary habits, and sociodemographic characteristics. Haemoglobin levels were assessed using the TrueHb hemoglobinometer, and statistical analysis was performed using SPSS.

Results: Significant improvements in haemoglobin levels were observed across all groups following the intervention. Group B showed the most substantial increase in haemoglobin, with a 71.7% resolution of mild anaemia, followed by Group A and Group C. BMI changes were minimal, with Group B exhibiting the greatest increase in participants with a normal BMI. Side effects such as abdominal pain and metallic taste were most common in Group B. Awareness of anaemia symptoms was highest in Group C. Statistical analysis revealed significant associations between age, BMI, and anaemia severity, with older age increasing the risk of moderate anaemia.

Conclusion: The combination of mid-day meal, iron supplementation with nutritional kits, as observed in Group B, was the most effective in reducing anaemia among adolescent girls. However, the minimal changes in BMI suggest that macronutrient deficiencies persist. The study emphasises the need for multifaceted, community-driven approaches that address both micronutrient deficiencies and socioeconomic factors to sustainably combat anaemia.

Keywords: Anaemia, Iron deficiency, Adolescent health, Nutritional interventions, Public health, Iron supplementation.

INTRODUCTION

Anaemia is a state in which the haemoglobin (Hb) level and/or red blood cells are insufficient to cope with the body's physiological needs. Globally, iron deficiency is the most common reason for anaemia. Though present widely across the globe, it is more pronounced in low- and middle-income countries. In India, it mainly affects women of reproductive age group, lactating women, children and adolescent girls. India is home to 243 million adolescents, comprising 21.4% of the country's population. Adolescence (10–19 years) is a unique phase of life where they experience brisk physical, cognitive and psychosocial growth. [1]

Deficient iron status or anaemia among adolescent girls is a major cause of growth retardation, impaired physical and mental development, delayed menarche, morbidity, and future poor reproductive outcomes. Besides inadequate iron consumption, other major direct causes of anaemia are high menstrual blood loss, malaria, and hookworm infestation. In addition to these direct causes, there are indirect socioeconomic factors such as illiteracy, poverty, and rural residence that affect anaemia. [2]

The 2016–2018 Comprehensive National Nutrition Survey of India found a high burden of anaemia (28.1%) and iron deficiency (41.5%) among 10–19-y-old adolescents.[3] Better childhood health and nutrition, extended education, delayed family formation, and new technologies offer the possibility of this being the healthiest generation of adolescents ever. However, adolescence is also the period when new and distinct health challenges—related to the onset of sexual activity, emotional regulation, and behaviour— typically emerge. [4]

As per WHO, India belongs to high anaemia prevalent areas where ≥40% of menstruating adult women and adolescent girls (AGs) are anaemic. India ranked 170 out of 180 countries for anaemia among women in the Global Nutrition Survey, 2016. It makes India far away from the attainment of Sustainable Development Goals by 2030. Combating iron deficiency anaemia (IDA) in these groups is crucial, as it is an underlying cause of maternal morbidity and mortality and can also negatively impact their offspring. [5]

To achieve the targets of World Health Assembly of 50% reduction of anaemia in women of reproductive age by 2025 and POSHAN Abhiyan (2018-2022) to reduce the prevalence amongst young children (6-59 months), adolescents and women of reproductive age groups (15-49 years) by three percent per year, Anaemia Mukt Bharat has been designed. The operational guidelines were launched by the Hon'ble Prime Minister, Shri Narendra Modi, on 14th April 2018 in Bijapur, Chhattisgarh. The beneficiaries are children 6-59 months, children 5-9 years, adolescent boys 10-19 years, adolescent girls 10-19 years, women of reproductive age (20-49 years), pregnant women and lactating women (0-6 months).[6]

However, the focus of AMB primarily revolves around iron and folic acid supplementation for iron deficiency anaemia. Nutritional anaemia is multifactorial, involving deficiencies in micronutrients such as Iron, Vitamin B12, Vitamin A, Vitamin D and Zinc. While iron deficiency is the most common cause, it is crucial to explore other factors contributing to anaemia prevalence. [7]

With the above context in mind, we conducted a randomised interventional trial among adolescent girls to assess the prevalence of anaemia and the effect of various interventions among them.

MATERIALS AND METHODS

Study Type: A Randomised Interventional Trial.

Study Duration: 3 months, from August to October 2024.

Study Setting: 42 schools in Rajpura block in the District Patiala.

Sample Size: Convenience sampling technique was used, and all adolescent girls in 42 selected schools of the Rajpura block of Patiala district, were included in the analysis after obtaining parental consent and participant assent.

Randomisation: A neutral member of the health department, not involved in the study, randomly assigned the 42 schools into three groups: Group A, Group B, and Group C.

The procedure was as follows:

1. The names of all 42 schools were written on individual chits and placed in a bowl.
2. Chits were drawn one by one in sequence:
   - Schools drawn on even-numbered turns were assigned to Group A (n = 477).
   - Schools drawn on odd-numbered turns were assigned to Group B (n = 483).
3. This process continued until 40 schools were distributed between Group A and Group B.
4. The remaining two schools were assigned to Group C (n = 367).

This method ensured random allocation while maintaining fairness and impartiality. Total pre intervention sample size was 1327 students.

As per pre decided protocol following interventions were implemented –

1) **Group A** – All adolescent girls in this group received mid-day meal daily and IFA tablet daily after mid-day meal under direct supervision of the school teacher .and one IFA tablet was provided to be taken at home.
2) **Group B** - All adolescent girls in this group received mid-day meal daily and IFA tablet daily under direct supervision of school teacher and one IFA tablet was provided to be taken at home. In addition, three nutritional

kits were distributed, to be consumed at home over a period of three months, one kit per month, in any form the participants preferred.

3) **Group C** – Routine weekly IFA supplementation was continued as per the existing Rashtriya Bal Swasthya Karyakram (RBSK) programme.

The composition of the nutritional kit was decided by the involved paediatricians and nutritionists, and is as follows –

Food Component	Quantity (g/kg)
Soya Chunk	500 g
Dates (Omani)	300 g
Jaggery	1 kg
Bengal Gram	400 g
Fox Nut	100 g
Channa	400 g

Inclusion Criteria

All adolescent girls whose parents gave consent were included in study.

Exclusion Criteria

1) Girls whose parents did not provide consent were excluded from the study.
2) Normal Hb and Severe anaemia cases were excluded.
3) Any dropouts or transferred cases were also excluded from the final analysis.

Data Collection: Data was collected using a pre-designed, semi-structured questionnaire that included sections on personal history, sociodemographic details, and the participants' knowledge of anaemia. Each student's haemoglobin level was also recorded in the same questionnaire.

Haemoglobin estimation by TrueHb- The TrueHb Hemoglobinometer is a portable, battery-operated, point-of-care device that uses dry reagent strips to estimate haemoglobin levels through reflectance photometry. In a comparative validation study by Neogi et al., TrueHb demonstrated a strong correlation (r > 0.98) with the gold-standard Sysmex haematology analyzer. The device also showed high sensitivity and specificity for detecting anaemia in community and clinical settings, making it suitable for field applications and resource-limited environments. Its compact design, ease of use, and quick result turnaround enhance its applicability in mobile health programmes and screening camps. [8]

Statistical Analysis: The collected data was cleaned and coded into Microsoft Excel 2021 for analysis. Descriptive and inferential statistics were applied wherever applicable. SPSS trial version 26 was used for regression analysis.

Ethical Clearance: The study was granted ethical approval by Institutional Ethics Committee of Government Medical College Patiala vide letter no **Trg 9(310)2024/16819-21.**

RESULTS

Baseline Characteristics [Table 1]

Demographics

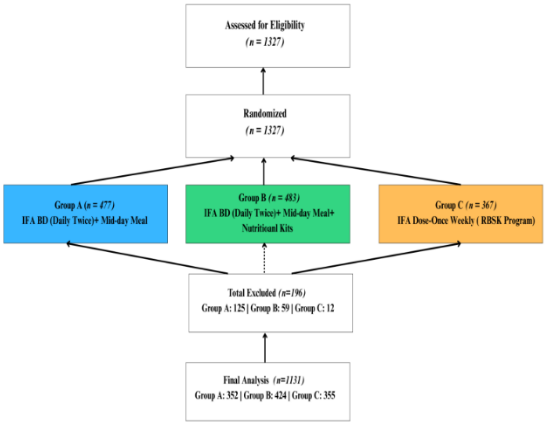
The age distribution varied significantly among the groups (p<0.001). Group C had the highest proportion (58.3%) of participants aged 13–16 years compared to Group A (38.6%) and Group B (41.3%). The mean age was highest in Group C (13.04 ± 1.57 years), followed by Group B (12.12 ± 1.84 years) and Group A (12.05 ± 1.79 years).

Anthropometric Measures

Significant differences were observed in height and weight across groups (p<0.001). The mean height was highest in Group C (148.6 ± 9.34 cm), followed by Group A (143.7 ± 14.63 cm) and Group B (141.58 ± 13.41 cm). Similarly, Group C had the highest mean weight (37.84 ± 9.06 kg), compared to Group B (35.38 ± 10.61 kg) and Group A (34.24 ± 9.27 kg).

Class Distribution

The distribution of participants across academic classes varied significantly (p<0.001). Group C had a higher representation of students from senior classes (Classes 6 to 10) compared to Groups A and B.



The Consort Diagram is given in [Figure 1].

Health and Nutrition

Pre- and Post-Haemoglobin Levels

Pre-intervention haemoglobin levels were similar across groups (p=0.727), with mean values of 10.19 ± 1.13 g/dL in Group A, 10.09 ± 1.04 g/dL in Group B, and 10.04 ± 0.86 g/dL in Group C. Post-intervention, significant improvements were observed (p<0.001). Group C had the highest percentage of mild anaemia resolution (80%), followed by Group B (71.7%) and Group A (50%). Group A had the highest change in haemoglobin levels post-intervention, with an increase of +1.68 g/dL compared to Groups B and C.

Body Mass Index (BMI)

Significant differences in BMI changes were observed (p=0.02). The proportion of participants with BMI <18.5 decreased across all groups post-intervention. Group B showed the largest increase in participants with BMI in the 18.5–24.9 range (from 28.1% to 30.4%).

Iron and Folic Acid Supplementation

Compliance with iron and folic acid supplementation, as outlined in the intervention plan, was 100% in all groups. All participants consistently took the tablets after meals.

Side Effects of Iron and Folic Acid Tablets

The prevalence of side effects varied significantly (p<0.001). Abdominal pain was most frequent in Group C (24.2%), while metallic taste was reported most often in Group B (53.5%).

Identification of the Colour of Iron Tablets by Participants

All participants (100%) uniformly identified the iron and folic acid tablets as blue across all groups.

Awareness of Anaemia

Awareness of anaemia was highest in Group C (100%), followed by Group A (98.6%) and Group B (93.2%) (p < 0.001). Awareness of symptoms like paleness of the skin and palms was similarly higher in Group C (30.7%) than in Group B (20.8%) and Group A (16.8%) (p < 0.001).

Parental Characteristics

Educational Qualifications

Fathers in Group B had the highest educational attainment, with 3.1% being graduates, compared to 0.0% in Group A and 1.1% in Group C (p = 0.001). Mothers' education also varied significantly (p = 0.029), with Group C showing a higher proportion of postgraduates (1.7%) compared to Groups A (0.9%) and B (1.2%).

Occupations

Fathers in Group A were predominantly engaged in Class V occupations (92.3%), while Group C had a slightly higher representation in Class IV and above (11.8%; p < 0.001). Mothers were primarily homemakers across all groups, with Group B having the highest proportion (84.9%; p < 0.001).

Dietary Habits and Medical History

Food Preferences

Vegetarian diets were most common in Group B (83.5%), while Group C had the highest proportion of participants consuming non-vegetarian diets (16.1%; p=0.044).

Junk Food Consumption

Frequent consumption of junk food was lowest in Group C (2.5%), compared to Groups A (7.1%) and B (8.5%; p=0.02).

Past Medical History

No major medical history was reported in any group.

Menstrual Health

Among female participants, the mean age of menarche was consistent across groups (p=0.362). Regular menstruation was reported by the majority, with Group C showing the highest proportion of regular cycles (80.3%; p<0.001).

Table 1: BASELINE CHARACTERISTICS

VARIABLES	GROUPS (1131)						p-value
	GROUP A(352)		GROUP B(424)		GROUP C (355)		
	n	%	n	%	n	%	
AGE-GROUP							
Less than 10	23	6.5	37	8.7	0	0	**<0.001**
10-13	187	53.1	204	48.1	130	36.6	
13-16	136	38.6	175	41.3	207	58.3	
>=16	6	1.7	8	1.9	18	5.1	
Mean ± S.D.	12.05±1.79		12.12±1.84		13.04±1.57		
Median(I.Q.R.)	12(10-14)		12(11-14)		13(12-14)		
HEIGHT							
<100 cm	0	0	3	0.7	0	0	**<0.001**
100-130 cm	58	16.5	73	17.2	12	3.4	
130-160 cm	251	71.3	313	73.8	295	83.1	
>=160 cm	43	12.2	35	8.3	48	13.5	
Mean ± S.D.	143.7±14.63		141.58±13.41		148.6±9.34		
Median(I.Q.R.)	146(133.5-154.8)		143(133-151)		150(142-155)		
WEIGHT							
10-30 kg	115	32.7	136	32.1	54	15.2	
30-60 kg	233	66.2	277	65.3	291	82	
>=60 kg	4	1.1	11	2.6	10	2.8	
Mean ± S.D.	34.24±9.27		35.38±10.61		37.84±9.06		**<0.001**
Median(I.Q.R.)	34(28-40)		34(28-41.6)		37(31-42)		
CLASS							
2	3	0.9	4	0.9	0	0	**<0.001**
3	6	1.7	12	2.8	0	0	
4	41	11.6	38	9	0	0	
5	51	14.5	39	9.2	0	0	
6	47	13.4	69	16.3	78	22	
7	50	14.2	53	12.5	56	15.8	
8	70	19.9	76	17.9	75	21.1	
9	44	12.5	61	14.4	76	21.4	
10	40	11.4	72	17	70	19.7	
PRE_HB TEST							
Mild	214	60.8	265	62.5	225	63.4	0.727
Moderate	136	38.6	157	37	130	36.6	

Severe	2	0.6	2	0.5	0	0	
Normal	0	0	0	0	0	0	
Mean ± S.D.	10.19±1.13		10.09±1.04		10.04±0.86		
Median(I.Q.R.)	10.2(9.4-11.2)		10.2(9.5-10.88)		(9.6-10.6)		
POST_HB TEST							
Mild	176	50	304	71.7	284	80	**<0.001**
Moderate	11	3.1	4	0.9	0	0	
Normal	165	46.9	116	27.4	71	20	
Mean ± S.D.	11.87±1.08		11.48±0.96		11.37±0.77		
Median(I.Q.R.)	11.8(11-12.6)		11.3(10.8-12)		11.3(10.8-11.8)		
PRE_BMI							
<18.5	289	82.1	289	68.2	264	74.4	**<0.001**
>30.0	2	0.6	3	0.7	5	1.4	
18.5-24.9	58	16.5	119	28.1	83	23.4	
25.0-29.9	3	0.9	13	3.1	3	0.8	
POST_BMI							
<18.5	270	76.7	281	66.3	259	73.0	**0.02**
>30.0	2	0.6	3	0.7	5	1.4	
18.5-24.9	76	21.6	129	30.4	88	24.8	
25.0-29.9	4	1.1	11	2.6	3	0.8	
FATHER'S EDUCATIONAL QUALIFICATION							
Graduate	0	0.0	13	3.1	4	1.1	**0.001**
Up to 10th Class	148	42.0	198	46.7	177	49.9	
Up to 5th Class	141	40.1	161	38	117	33	
Illiterate	63	17.9	52	12.3	57	16.1	
MOTHER'S EDUCATIONAL QUALIFICATION							
Post Graduate	0	0.0	1	0.2	2	0.6	0.029
Graduate	3	0.9	5	1.2	6	1.7	
Up to 10th Class	121	34.4	157	37.0	155	43.7	
Up to 5th Class	151	42.9	195	46.0	125	35.2	
Illiterate	77	21.9	66	15.6	67	18.9	
FATHER'S OCCUPATION							
Class II	0	0.0	4	0.9	10	2.8	**<0.001**
Class III	0	0.0	7	1.7	10	2.8	
Class IV	6	1.7	13	3.1	32	9.0	
Class V	325	92.3	386	91.0	280	78.9	
Does not Work, Manages House	21	6.0	14	3.3	23	6.5	
MOTHER'S OCCUPATION							
Class II	1	0.3	0	0.0	3	0.8	**<0.001**
Class III	0	0.0	0	0.0	3	0.8	
Class IV	2	0.6	2	0.5	5	1.4	
Class V	105	29.8	62	14.6	75	21.1	
Does not Work, Manages House	244	69.3	360	84.9	269	75.8	
AGE AT MENARCHE							
0	157	44.6	189	44.6	70	19.7	0.362
9	0	0	0	0	1	0.3	
10	3	0.9	4	0.9	10	2.8	
11	40	11.4	56	13.2	54	15.2	
12	86	24.4	79	18.6	99	27.9	
13	55	15.6	88	20.8	92	25.9	
14	10	2.8	8	1.9	25	7	
15	1	0.3	0	0	4	1.1	
Mean ± S.D.	12.16±0.88		12.17±0.89		12.27±1.05		
Median(I.Q.R.)	12(12-13)		12(11-13)		12(12-13)		
ANY HISTORY OF EXCESSIVE BLEEDING DURING MENSES?							
NA	157	44.6	189	44.6	70	19.7	
NO	195	55.4	235	55.4	285	80.3	
YES							
ARE YOUR PERIODS REGULAR?							
NA	157	44.6	189	44.6	70	19.7	**<0.001**
NO	2	0.6	2	0.5	0	0	
YES	193	54.8	233	55	285	80.3	
HAS THE CHILD TAKEN ALBENDAZOLE IN THE PAST?							
Yes, within the last 6 months	352	100.0	424	100	355	100	
HAVE YOU TAKEN IRON FOLIC ACID TABLET AT SCHOOL OR AT HOME IN THE PAST?							
Yes , for more than 3 months	352	100.0	424	100	355	100	
IF IRON AND FOLIC ACID (IFA) WAS TAKEN WITHOUT THE SUPERVISION, WAS IT TAKEN-							
After a meal	352	100.0	424	100	355	100	
HOW OFTEN DOES CHILD EAT JUNK FOOD?							

Frequently(4-5 times a week)	25	7.1	36	8.5	9	2.5	0.02
Occasionally(1-2 times a week)	327	92.9	388	91.5	346	97.5	
ANY PAST MEDICAL HISTORY OF THE CHILD?							
No	350	99.4	422	99.5	323	99.4	
Asthma	0	0.0	0	0	1	0.3	
TB	1	0.3	1	0.2	0	0	
Epilepsy	1	0.3	0	0	1	0.3	
Heart disease	0	0.0	1	0.2	0	0	
HAS THE CHILD EXPERIENCED ANY SIDE EFFECTS FROM IFA TABLETS?							
Abdominal pain	47	13.4	48	11.3	86	24.2	**<0.001**
constipation	22	6.3	40	9.4	15	4.2	
dark coloured stools	82	23.3	66	15.6	36	10.1	
loose stools	7	2.0	8	1.9	14	3.9	
Metallic taste	125	35.5	227	53.5	155	43.7	
Nausea	43	12.2	28	6.6	37	10.4	
Vomiting	26	7.4	7	1.7	12	3.4	
FOOD PREFERENCE							
Non-Veg	51	14.5	53	12.5	57	16.1	0.044051
Veg	271	77.0	354	83.5	279	78.6	
Veg but eat egg	30	8.5	17	4	19	5.4	
HAVE YOU HEARD ABOUT ANAEMIA?							
No	5	1.4	29	6.8	0	0	**<0.001**
Yes	347	98.6	395	93.2	355	100	
WHAT ARE THE SYMPTOMS OF ANAEMIA?							
Body-aches	131	37.2	142	33.5	114	32.1	**<0.001**
Fainting	13	3.7	4	0.9	8	2.3	
Headache	28	8.0	32	7.5	29	8.2	
Increased Heart Rate	3	0.9	2	0.5	0	0	
Irritability	25	7.1	27	6.4	8	2.3	
Loss of Appetite	33	9.4	44	10.4	33	9.3	
Loss of Concentration	6	1.7	9	2.1	1	0.3	
Paleness of Skin, Palms	59	16.8	88	20.8	109	30.7	
Nothing	54	15.3	76	17.9	53	14.9	
DO YOU THINK ANAEMIA NEEDS TREATMENT?							
NO	352	100.0	424	100	355	100	
Iron rich foods							
Egg	5	1.4	6	1.4	5	1.4	**<0.001**
Grains-wheat, Jowar, Bajra, Sprouted Pulses, Ground Nut, Sesame, Jaggery, Dried Fruits	199	56.5	161	38	106	29.9	
Green Vegetables and Fruits	137	38.9	244	57.5	227	63.9	
Liver, Fish, Meat	11	3.1	13	3.1	17	4.8	
WHAT IS THE COLOUR OF THE IFA TABLET?							
Blue	352	100.0	424	100	355	100	

Factors Associated with Mild Anaemia [Table 2]

The odds of mild anaemia were significantly influenced by age (p=0.006). With every one-year increase in age, the odds of mild anaemia increased by 10.9% (Adjusted Odds Ratio [AOR] = 1.109; 95% CI: 1.03–1.193). Body Mass Index (BMI) did not show a significant association with mild anaemia (p=0.247).

Parental education levels had no statistically significant impact on the likelihood of mild anaemia. For instance, fathers' educational attainment up to the 10th class (AOR = 0.985; 95% CI: 0.609–1.593; p=0.95) and mothers' education up to the postgraduate level (AOR = 0.663; 95% CI: 0.056–7.863; p=0.745) were not significant predictors compared to the illiterate reference category.

Factors Associated with Moderate Anaemia [Table 2]

Age and BMI were significant predictors of moderate anaemia. With every one-year increase in age, the odds of moderate anaemia increased by 51% (AOR = 1.51; 95% CI: 1.08–2.109; p=0.016). Conversely, an increase in BMI reduced the odds of moderate anaemia by 23% (AOR = 0.77; 95% CI: 0.612–0.97; p=0.026).

Fathers' educational qualifications showed a near-significant trend for graduates having higher odds of moderate anaemia (AOR = 16.032; 95% CI: 0.833–308.47; p=0.066). However, other educational levels for both parents did not exhibit statistically significant effects on moderate anaemia.

Table 2: LOGISTIC REGRESSION ANALYSIS

VARIABLES	P-VALUE	ADJUSTED ODDS RATIO	95% C.I. for EXP(B)	
			LOWER	UPPER
MILD				
AGE	0.006	1.109	1.03	1.193
BMI	0.247	0.982	0.953	1.012
FATHER'S EDUCATIONAL QUALIFICATION				
Graduate	0.73	1.234	0.374	4.079
Up to 10th Class	0.95	0.985	0.609	1.593
Up to 5th Class	0.449	1.194	0.754	1.892
Illiterate*				
MOTHER'S EDUCATIONAL QUALIFICATION				
Post Graduate	0.745	0.663	0.056	7.863
Graduate	0.264	0.513	0.159	1.655
Up to 10th Class	0.205	0.74	0.465	1.179
Up to 5th Class	0.359	0.816	0.529	1.26
Illiterate*				
Moderate				
AGE	0.016	1.51	1.08	2.109
BMI	0.026	0.77	0.612	0.97
FATHER'S EDUCATIONAL QUALIFICATION				
Graduate	0.066	16.032	0.833	308.47
Up to 10th Class	0.623	1.645	0.227	11.945
Up to 5th Class	0.375	2.282	0.369	14.127
Illiterate*				
MOTHER'S EDUCATIONAL QUALIFICATION				
Post Graduate				
Graduate				
Up to 10th Class	0.24	0.363	0.067	1.966
Up to 5th Class	0.342	0.483	0.108	2.166
Illiterate*				

Body Mass Index (BMI) [Table 3]
At baseline, 74.4% of participants were underweight (BMI <18.5). Following the intervention, this proportion decreased slightly to 71.6%. In contrast, the proportion of participants with normal BMI (18.5–24.9) increased from 23.0% to 25.9%. Minimal changes were observed in the overweight (25.0–29.9) and obese (BMI >30.0) categories, which remained consistently low (<2%). The mean BMI increased significantly from 17.04 ± 4.17 pre-intervention to 17.3 ± 4.21 post-intervention ($p < 0.001$). Similarly, the median BMI also showed a significant increase from 16.41 (IQR: 14.72–18.55) to 16.65 (IQR: 15–18.9) ($p < 0.001$). [Table 3]

Haemoglobin (HB): [Table 3]
The intervention resulted in substantial improvements in haemoglobin levels. At baseline, 62.2% of participants had mild anaemia, while 37.4% had moderate anaemia. Post-intervention, the proportion of individuals with mild anaemia increased to 67.6%, whereas those with moderate anaemia dropped drastically to 1.3%. Severe anaemia (0.4% at baseline) was completely resolved post-intervention. Importantly, 31.1% of participants achieved normal haemoglobin levels post-intervention, compared to none at baseline. The mean haemoglobin levels improved significantly from 10.1 ± 1.07 to 11.57 ± 0.97 ($p < 0.001$). Similarly, the median haemoglobin levels increased from 10.2 (IQR: 9.5–10.8) to 11.5 (IQR: 10.8–12.1) ($p < 0.001$). [Table 3]

Table 3: WILCOXON SIGNED RANK TEST COMPARISON OF BMI AND HAEMOGLOBIN LEVELS BEFORE AND AFTER INTERVENTION

BASELINE	PRE-INTERVENTION		POST INTERVENTION		p-value
	n	%	n	%	
BMI					
<18.5	842	74.4	810	71.6	<0.001
>30.0	10	0.9	10	0.9	
18.5-24.9	260	23.0	293	25.9	
25.0-29.9	19	1.7	18	1.6	
Mean ± S.D.	17.04±4.17		17.3±4.21		
Median (I.Q.R.)	16.41(14.72-18.55)		16.65(15-18.9)		
HB					
Mild	704	62.2	764	67.6	<0.001
Moderate	423	37.4	15	1.3	
Severe	4	0.4	0	0.0	
Normal	0	0	352	31.1	
Mean ± S.D.	10.1±1.07		11.57±0.97		
Median (I.Q.R.)	10.2(9.5-10.8)		11.5(10.8-12.1)		

DISCUSSION

The findings from this study reinforce the multifaceted nature of anaemia among adolescent girls and underscore the importance of integrated nutritional and health interventions. Across all groups, significant improvements in haemoglobin (Hb) levels were observed post-intervention, demonstrating the effectiveness of both supplementation and dietary interventions. This discussion elaborates on the implications, comparisons, and broader insights from this research, integrating findings from prior studies to provide a comprehensive understanding of anaemia management.

When compared to previous research, our results reveal a comparatively higher efficacy in improving haemoglobin status. For instance, Selvaraj et al. reported modest improvements in rural Tamil Nadu, noting compliance issues due to gastrointestinal side effects and lack of perceived need. In contrast, the relatively high adherence observed in our cohort may be attributed to prior sensitization of both beneficiaries and gatekeepers, structured delivery mechanisms, and regular biochemical feedback. This aligns with the assertion by Vir et al. (2008), who emphasised that supplement uptake improves significantly when accompanied by behavioural reinforcement and structured counselling.[9,10]

Chakma et al., studying tribal populations in Madhya Pradesh, highlighted cultural and logistical barriers that diluted programme impact, despite adequate infrastructure. Our findings suggest that tailoring delivery methods—such as aligning supplement distribution with the school calendar and leveraging trusted community figures—can mitigate such barriers. Moreover, unlike the Kotecha et al. study in Gujarat, which relied on monthly distribution and passive compliance tracking, our intervention emphasised weekly follow-ups and objective haemoglobin measurements, resulting in stronger compliance and outcome tracking.[11,12]

The broader literature continues to stress the disconnect between policy design and field-level execution. Malhotra et al. documented administrative resistance and fragmented stakeholder coordination during national rollouts. Our field experience supports this observation: interventions with decentralised control, local resource mobilization, and feedback loops tend to outperform top-down models. This supports the call for adaptive frameworks over static, prescriptive protocols. [13]

Additionally, while our intervention did not explicitly focus on dietary modification, anecdotal evidence from fieldworkers indicated a spontaneous improvement in iron-enhancing dietary practices among some participants. This reinforces the conclusions of Susheela et al., who demonstrated that diet counselling acts as a synergistic adjunct to pharmacological supplementation. [14]

Our results echo the insights from Aguayo et al. (2013), who noted that multi-pronged, communication-driven strategies are essential to breaking the intergenerational cycle of anaemia. The relatively short duration of our study nonetheless yielded outcomes comparable to longer-term programme, underscoring the potential of focused, high-intensity models in anaemia control. [15]

Dhikale et al. observed substantial improvements in Hb status among adolescents in Pondicherry following a structured Weekly Iron and Folic Acid Supplementation (WIFS) rollout. Their emphasis on rural outreach and institutional engagement parallels our experience, reinforcing that outcome variability is frequently linked not to the composition of the intervention, but to the strength of its implementation architecture like in our study. [16]

Gupta et al. offer a more nuanced lens by examining the impact of daily supervised supplementation that also included vitamin B12 alongside IFA. While their cluster-randomised trial demonstrated significant Hb gains, our study achieved comparable improvements using weekly IFA alone, suggesting that frequency of administration may be less critical than supervision and compliance in resource-limited settings. [17]

CONCLUSION

This study highlights the effectiveness of combining iron and folic acid (IFA) supplementation with nutritional support in reducing anaemia among adolescent girls. Group B, receiving both interventions, showed the most improvement in haemoglobin levels. However, minimal changes in BMI suggest persistent macronutrient deficiencies. High compliance due to supervised delivery emphasizes the importance of implementation quality. Age and BMI were significant predictors of anaemia severity, indicating the need for targeted strategies. The findings reinforce the value of integrated, community-driven interventions that address both nutritional and socioeconomic factors for sustainable anaemia control in adolescents, especially in resource-constrained, rural settings.

Strength and Limitations

This study demonstrates a robust, randomised design across a large sample, ensuring reliability and minimizing selection bias. Comprehensive baseline data collection, including haemoglobin levels and BMI, allowed for accurate pre- and post-intervention comparisons. The integration of locally sourced nutritional kits in Group B represents a culturally adaptable and cost-effective model, potentially scalable for resource-constrained settings. High compliance across all groups, facilitated by direct supervision, enhances the study's credibility in evaluating intervention efficacy.

The three-month duration of the intervention is insufficient to assess long-term sustainability and potential relapse rates of anaemia. The study's focus on adolescent girls limits the generalizability of findings to other high-risk groups such as pregnant women and young children. BMI changes, though observed, were minimal, suggesting that the intervention's impact on overall nutritional status was limited. The study relied on self-reported data for dietary habits and side effects, which may introduce reporting bias. Socioeconomic factors, while acknowledged, were not comprehensively addressed, limiting insights into the structural barriers exacerbating anaemia prevalence. Finally, the observed side effects in Group B, possibly due to the higher dosage of IFA and additional nutrients, underscore the need for a balanced approach to supplementation.

Future Directions

Future research should focus on longitudinal studies assessing the sustainability and scalability of integrated interventions in diverse socio-cultural settings. Investigations into personalised supplementation strategies, combining macronutrient and micronutrient interventions, may provide holistic solutions to the dual burden of malnutrition. Expanding the scope to include other high-risk groups, such as pregnant women and children, will enhance the generalizability of findings.

Additionally, exploring community-driven approaches, incorporating nutritional education and poverty alleviation measures, can address structural barriers. Optimizing supplementation regimens to reduce side effects while preserving efficacy will enhance compliance and improve overall outcomes of the intervention.

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REFERENCES

1. Daniel, R. A., Kalaivani, M., Kant, S., & Gupta, S. (2023). Prevalence of anaemia among adolescent girls (10-19 years) in India: A systematic review and meta-analysis. The National medical journal of India, 36(4), 233–240. https://doi.org/10.25259/NMJI_637_21
2. Bharati, P., Shome, S., Chakrabarty, S., Bharati, S., & Pal, M. (2009). Burden of Anaemia and its Socioeconomic Determinants among Adolescent Girls in India. Food and Nutrition Bulletin, 30(3), 217–226. https://doi.org/10.1177/156482650903000302
3. Rai, R. K., Shinde, S., De Neve, J., & Fawzi, W. W. (2023). Predictors of Incidence and Remission of Anaemia among Never-Married Adolescents Aged 10–19 Years: A Population-Based Prospective Longitudinal Study in India. Current Developments in Nutrition, 7(3), 100031. https://doi.org/10.1016/j.cdnut.2023.100031
4. Patton, G. C., Sawyer, S. M., Santelli, J. S., Ross, D. A., Afifi, R., Allen, N. B., Arora, M., Azzopardi, P., Baldwin, W., Bonell, C., Kakuma, R., Kennedy, E., Mahon, J., McGovern, T., Mokdad, A. H., Patel, V., Petroni, S., Reavley, N., Taiwo, K., . . . Viner, R. M. (2016). Our future: a Lancet commission on adolescent health and wellbeing. The Lancet, 387(10036), 2423–2478. https://doi.org/10.1016/s0140-6736(16)00579-1
5. Kulkarni, P., Bhawalkar, J., & Jadhav, A. (2022). Anaemia control program in India needs to be more comprehensive. Indian Journal of Public Health, 66(3), 358. https://doi.org/10.4103/ijph.ijph_1918_21
6. Bhatia, V., Sahoo, D. P., & Parida, S. P. (2018). India steps ahead to curb Anaemia: Anaemia Mukt Bharat. Indian Journal of Community Health, 30(4), 312–316. https://doi.org/10.47203/ijch.2018.v30i04.002
7. Chinnadurai, A., & Raja, S. (2024). Need to Look go Beyond Iron Supplementation for 'Anaemia Mukt Bharat' amongst Children under 19 Years – An Ecological Study. Deleted Journal, 1(6), 277–281. https://doi.org/10.4103/pmrr.pmrr_58_24
8. Neogi, S. B., Negandhi, H., Sharma, J., Ray, S., & Sethy, G. (2016). Diagnostic accuracy of haemoglobin colour strip (HCS-HLL), a digital haemoglobinometer (TrueHb) and a non-invasive device (TouchHb) for screening patients with anaemia. Journal of Clinical Pathology, 69(2), 164–170. https://www.researchgate.net/publication/281081753
9. Selvaraj, K., Arumugasamy, P., & Sarkar, S. (2017). Compliance and patterns of iron-folic acid intake among adolescent girls and antenatal women in rural Tamil Nadu. CHRISMED Journal of Health and Research, 4(2), 87. https://doi.org/10.4103/cjhr.cjhr_88_16
10. Vir, S. C., Singh, N., Nigam, A. K., & Jain, R. (2008). Weekly Iron and Folic Acid Supplementation with Counseling Reduces Anemia in Adolescent Girls: A Large-Scale Effectiveness Study in Uttar Pradesh, India. Food and Nutrition Bulletin, 29(3), 186–194. https://doi.org/10.1177/156482650802900304
11. Chakma, T., Rao, P. V., & Meshram, P. K. (2012). Factors associated with high compliance/feasibility during iron and folic acid supplementation in a tribal area of Madhya Pradesh, India. Public Health Nutrition, 16(2), 377–380. https://doi.org/10.1017/s1368980012002704
12. Kotecha, P. V., Nirupam, S., Karkar, P. D., USAID Micronutrient & Child Blindness Project, UNICEF/ Myanmar, Health & Nutrition, UNICEF Gandhinagar, UNICEF, Gujarat, & Department of Preventive & Social Medicine, Medical College Vadodara. (2009). Adolescent girls' anaemia control programme, Gujarat, India. In Indian J Med Res (Vols. 130–130, pp. 584–589) No DOI available; retrieved from journal site.
13. Malhotra, S., Yadav, K., Kusuma, Y. S., Sinha, R., Krishnan, A., Kant, S., & Pandav, C. S. (2015).Challenges in scaling up successful public health interventions: Lessons learnt from resistance to a nationwide roll-out of the weekly iron-folic

acid supplementation programme for adolescents in India. The National Medical Journal of India, 28(4), 209–212.https://www.researchgate.net/publication/284159706
14. ANDEZHATH, K., SUSHEELA, GUPTA, R., & MONDAL, NISITH. K. (2016). Anaemia in adolescent girls: An intervention of diet editing and counselling. In THE NATIONAL MEDICAL JOURNAL OF INDIA (Vol. 29, Issue 4, pp. 200–204) [Journal-article]. https://fluoridealert.org/wp-content/uploads/susheela-2016.pdf
15. Aguayo, V. M., Paintal, K., & Singh, G. (2013). The Adolescent Girls' Anaemia Control Programme: a decade of programming experience to break the inter-generational cycle of malnutrition in India. Public Health Nutrition, 16(9), 1667–1676. https://doi.org/10.1017/s1368980012005587
16. Dhikale, P., Suguna, E., Thamizharasi, A., & Dongre, A. (2015). Evaluation of Weekly Iron and Folic Acid Supplementation program for adolescents in rural Pondicherry, India. International Journal of Medical Science and Public Health, 4(10), 1360. https://doi.org/10.5455/ijmsph.2015.14042015280
17. Gupta, A., Kant, S., Ramakrishnan, L., Pandey, R. M., Khandelwal, R., Kapil, U., & Sachdev, H. S. (2021). Impact of daily-supervised administration of a package of iron and folic acid and vitamin B12 on hemoglobin levels among adolescent girls (12–19 years): a cluster randomized control trial. European Journal of Clinical Nutrition, 75(11), 1588–1597. https://doi.org/10.1038/s41430-021-00878-6