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Iron-deficiency anemia among adolescents: A global public health concern

Alisha Aggarwal, Anisha Aggarwal, Sanjiv Goyal and Saroj Aggarwal

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Alisha Aggarwal
MBBS, Ph. D., Department of Health Services Research Administration & Policy, College of Public Health, University of Nebraska Medical Center, Omaha, 68131, United States

Anisha Aggarwal
MD, Assistant Professor, Department of Community Medicine, MMIMSR, MMDU, Mullana, 133203, India

Sanjiv Goyal
MBBS, Senior Medical Officer, Community Health Center, Raipur Rani, Haryana-134204, India

Saroj Aggarwal
MBBS, DCP&M, Senior Consultant, Department of Immuno-Hematology, Civil Hospital, Panchkula, 134106, India

Corresponding Author:
Alisha Aggarwal
MBBS, Ph. D., Department of Health Services Research Administration & Policy, College of Public Health, University of Nebraska Medical Center, Omaha, 68131, United States

Abstract
Iron deficiency Anemia is a global public health concern. We aim to assess a national program for Weekly Iron and Folic-acid Supplementation (WIFS) to address this concern among adolescents in India. A longitudinal interventional community-based study was conducted with 1100 school-going adolescents. A questionnaire regarding socio-demographic profile, anthropometric details, and clinical examination, hemoglobin levels, and WIFS supplementation were conducted to collect information at 0, 3, 6, 9, and 12 months. The mean age of adolescents was 13.7 years. Anemia among students reduced from 95.8% to 75% post-intervention. The mean level of hemoglobin was 9.69 g/dL at 0 months and improved to 11.29 g/dL at 12 months for adolescents. The prevalence of anemia reduced significantly with WIFS over one year. Education and awareness for dietary diversification, increasing bioavailable iron, fortified food for full-term infants and children, and additional supplements are crucial to prevent iron deficiency anemia.

Keywords: Adolescents, Iron deficiency, Health Policy, Public health, Anemia, Iron and folic acid

1. Introduction
World Health Organization (WHO) coined the term nutritional anemia in 1968 and defined it as ‘a condition in which the hemoglobin content of the blood is lower than normal as a result of a deficiency of one or more essential nutrients, regardless of the cause of such deficiency’ [1]. However, with advancements in medicine, iron and serum B-12 were diagnosed as the main deficiency among the patients. Thereafter, another term was coined as Iron-Deficiency Anemia. Iron deficiency anemia causes a significant decrease in the productivity of an individual by affecting the transport of oxygen across the tissues. Iron deficiency anemia occurs in multiple stages (i) Iron stores of the body for hemoglobin synthesis are reduced (ii) Insufficient Iron is transported to bone marrow (iii) Deficient red blood cells (RBC) enter individuals' blood circulation and replace the normal RBCs [2].

In 1993, a WHO, United Nations International Children’s Emergency Fund (UNICEF), and United Nations University (UNU) consultation made another change from iron-deficiency anemia to iron deficiency as the main problem [1]. Anemia was then considered as an indicator of iron deficiency instead of iron deficiency being a contributing factor of anemia. The level of hemoglobin and severity of anemia can be assessed by the hemoglobin levels of an individual and have been recommended by WHO according to age and severity (Fig. 1) [3].

Population	Non-Anemia*	Mild Anemia*	Moderate Anemia*	Severe Anemia*
6-59 months of age	≥ 11	10-10.9	7-9.9	<7
5-11 years of age	≥ 11.5	11-11.4	8-10.9	<8
12-14 years of age	≥ 12	11-11.9	8-10.9	<8
Non-pregnant women (≥ 15 years)	≥ 12	11-11.9	8-10.9	<8
Pregnant women	≥11	10-10.9	7-9.9	<7
Men (≥ 15 years)	≥13	11-12.9	8-10.9	<8

Fig 1: WHO classification of anemia according to age and severity

Iron-deficiency anemia has emerged as a global public health concern. Research from both developed and developing nations have shown iron deficiency to be the leading cause of anemia among children of all ages and pregnant women. Also, iron deficiency is one of the major reasons for impaired cognitive development and lower school achievement [4]. Iron deficiency is one of the most prevalent nutritional disorders with several adverse health consequences such as decreased physical capacity and work performance, impaired cognitive performance, behavior, and growth. The most recent WHO and UNICEF estimates suggest that the number of children with iron deficiency anemia is approximately 750 million [5].

India has an estimated population of 253 million in the adolescent age group of 10-19 years [6]. These adolescents demand adequate nutrition, education, counseling, and guidance to ensure optimal development. Deficiency of any single component makes them prone to multiple health issues such as unintentional teen pregnancy, sexually transmitted diseases, malnutrition, anemia, obesity, alcohol, tobacco and drug abuse, mental health concerns, injuries, and violence. Realizing the importance of health-seeking attitudes among adolescents, the Government of India directed its focus on health programs aimed to cater to this specific population. The Ministry of Health and Family Welfare launched Rashtriya Kishor Swasthya Karyakram (RKSK) in January 2014 to reach out to adolescents irrespective of gender or socioeconomic status, with a special focus on vulnerable and underserved groups [7]. The national program covers a wide array of adolescent health concerns in India such as sexual and reproductive health, nutrition, injuries and violence (including gender-based violence), non-communicable diseases, mental health, and substance abuse. Interventions include reaching out to the children/ adolescents in schools, social and behavior change, community-level interactions, educational awareness, and building adolescent-friendly health centers. Trained doctors, health workers, and counselors provide counseling and treatment services. Four adolescents per 1000 population in each village are identified and trained to provide continuous peer education. Adolescent Health Days are held quarterly where Iron and Folic Acid tablets, sanitary napkins, contraceptives, anti-helminthic, anti-spasmodic and a regular health check-up are provided to all adolescents.

As adolescents are not classified as adults, the RKSK involves parents/ guardians for informed decision making. Under the umbrella of RKSK, an intervention program for Weekly Iron and Folic-acid Supplementation (WIFS) was launched to address the public health concern due to the high prevalence of iron deficiency anemia among the adolescent population [8]. WIFS program involves supervised weekly ingestion of iron (100mg) and folic acid (500µg) supplementation along with bi-annual helminthic control medication (Albendazole; 400mg) for de-worming. The main target population was the school-going male and female adolescents, and out of school adolescent girls. Also, educational sessions regarding dietary modifications and preventing intestinal infections are provided to these children. Certain guidelines have been formed to ensure the maximum effectiveness of the WIFS. These include (i) iron-folic acid tablets are meant to be consumed after meals (approximately one hour) to prevent side effects such as nausea and vomiting (ii) anyone suffering from side effects can consume supplements after dinner or before sleeping (iii) food rich in vitamin C such as citrus fruits, lemon, etc. aid in better absorption of iron (iv) iron vessels should be used for cooking purposes (v) avoid tea or coffee within an hour of meals (vi) follow hygienic practices in daily routine and avoid walking barefoot.

To the best of our knowledge, this is the first study to evaluate the effectiveness of WIFS intervention in school-going adolescents in India. Our study aims to (i) estimate the prevalence of anemia in school-going adolescents (ii) assess the association between epidemiological correlates of anemia (iii) evaluate the effectiveness of WIFS intervention to treat iron deficiency anemia as a part of a national program in India. The goal of this study is to provide an example for global policymakers to design and implement strategies to help treat and prevent iron deficiency anemia.

2. Materials and Methods

We conducted a community based longitudinal study with intervention over one year from January 2019 through December 2019. The study protocol was approved by the Institutional Ethics committee. Students in the age group of 10-18 years were selected randomly from government-funded senior secondary schools in rural areas of the State of Haryana. These students were also enrolled in weekly iron and folic acid supplementation (WIFS) program by the health personnel. The children were enrolled for the study in the first two months of the year and were followed up until the 12th month. Taking into reference the prevalence of anemia and considering loss on follow up, we included 1200 children in our study. About 100 students per school were enrolled with consent from parents or guardians. In addition, permissions were obtained from the district education officers and principals of respective schools.

A questionnaire was framed to get detailed information about these children to obtain information on socio-demographic characteristics, anthropometric details, clinical examination (included signs, symptoms, and intervention), and knowledge on dietary sources of iron. Variables such as name, age, gender, and rural/ urban address were collected and verified from records available at each school. Additional demographic variables included the level of education of both parents, the employment status of both parents, family type (joint/ nuclear), number of family members, and annual family income. The households were categorized based on BG Prasad socioeconomic classification for rural areas [9]. The anthropometric variables included weight (kilograms), height (centimeters, rounded off to nearest whole number), BMI (calculated using an Excel calculator) which was further classified based on CDC standards for BMI grading [10]. Clinical signs related to iron-deficiency anemia were noted at the beginning of the study. The signs included pallor (paleness at lower palpebral conjunctiva and nail beds), koilonychia (inward curving of nails forming a ‘spoon like’ shape), and sore tongue (localized swelling, inflammation or soreness on tongue). Students were questioned and examined for symptoms like fatigue, loss of weight, shortness of breath, restlessness, loss of concentration, and dizziness.

Hemoglobin levels were measured using Sahli’s method for every student enrolled in the study at 0, 3, 6, 9, and 12 months. Each test was conducted by the same investigator to minimize any inter observer variation. The levels were categorized under non-anemic, mildly anemic, moderately anemic and severely anemic based on the WHO

Classification for anemia according to age and severity [3]. Monthly records and WIFS compliance cards were maintained by school-teachers at 3, 6, 9, and 12 months to measure compliance. Educational sessions regarding dietary sources of iron and benefits of iron and folic acid supplementation were conducted in schools. There were some cases of non-compliance due to nausea, vomiting, diarrhea, stomach-ache, and giddiness. All students were given de-worming medicine twice in the year.

Quantitative data analysis was performed using SPSS where quantitative variables were measured as means and SD, and qualitative variables were measured as a percentage. A chi-square test was used to establish an association between variables. The correlation between variables and normality of data was established using t-test and ANOVA. A p-value of 0.05 was considered as significant with a 95% confidence interval. There was no financial burden on the parents or guardians of the students enrolled. Informed written consent was obtained before conducting the study and confidentiality was ensured.

3. Results

School going children in the age group 10-18 years from 12 government-funded senior secondary schools were enrolled in the study. A higher number was enrolled (1200 participants) to compensate for the loss at follow up. The effect of an intervention with weekly iron and folic acid supplementation was measured over one year. At the end of the study, data from 1100 students were analyzed (100 students lost at follow up). 550 male and 550 female students enrolled in the study. The mean age of students was 13.7 years for both males and females. 15.6% (n=172) of children had a parent with no education. 85.1% (n=936) fathers and 12.8% (n=141) mothers of the students enrolled were employed. 62.9% (n=692) students lived in nuclear family type and 76.2% (n=838) students belonged to a middle-class household (according to BG Prasad socioeconomic classification). 21.5% (n=236) students were underweight and 8.9% (n=98) were overweight with equal distribution between both genders.

Only 4.1% of students were found to be non-anemic. Mild, moderate, and severe anemia was prevalent in 15.2% (n=167), 70.3% (n=773), and 10.4% (n=114) students respectively. The prevalence of severe anemia based on age and gender at 0, 3, 6, 9, and 12 months are presented in Table 1.

Table 1: Prevalence of severe anemia during intervention at 0, 3, 6, 9, and 12 months according to age and gender

Prevalence of Severe Anemia (frequency)					
Age group	**0 month**	**3 months**	**6 months**	**9 months**	**12 months**
10-11 year	141	134	96	54	21
12-14 year	95	92	60	23	8
15-18 year	158	157	117	70	46
Gender					
Male	161	157	105	60	29
Female	233	226	168	87	46

Among the mothers of students who were anemic, 14.7% (n=162) mothers had no education and 58.6% (n=645) mothers had completed school up to the eighth standard. The association between the level of education of a mother and the prevalence of anemia was found to be statistically significant (p-value < 0.001). 83.5% and 14.3% of students who were anemic had unemployed mother and father respectively. The association between a mothers employment status and prevalence of anemia was found to be statistically significant (p-value < 0.001). However, the association between fathers' employment status and prevalence of anemia was not found to be statistically significant (p-value = 0.097). 60.7% (n=668) of anemic participants belonged to a nuclear family type, and 35.1% (n=386) of anemic participants belonged to a joint family type. However, the association between the prevalence of anemia and family type was not found to be statistically significant (p-value =0.238). 73.1% (n=804) and 17.6% (n=194) anemic students belonged to a middle and lower socio-economic category respectively. 74% of students complained of fatigue and 24% of students complained of loss of concentration. The presence of various signs and symptoms is presented in Fig. 2 and Fig. 3 respectively.

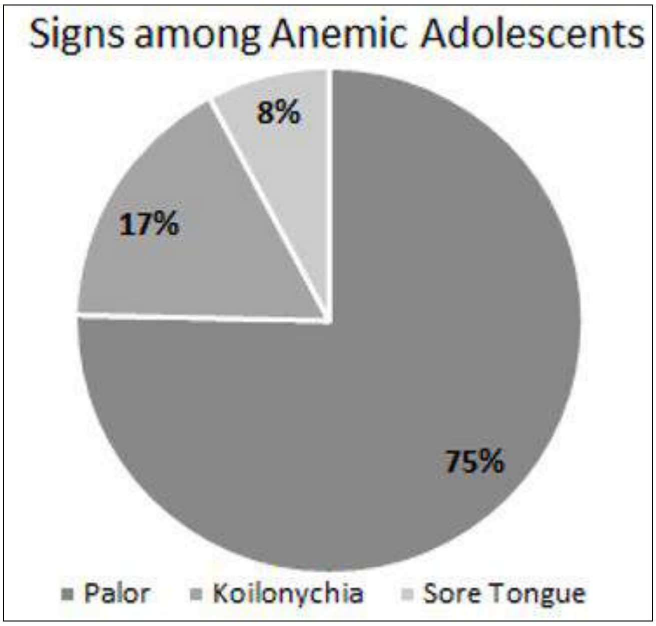

Fig 2: Distribution of signs among anemic adolescents

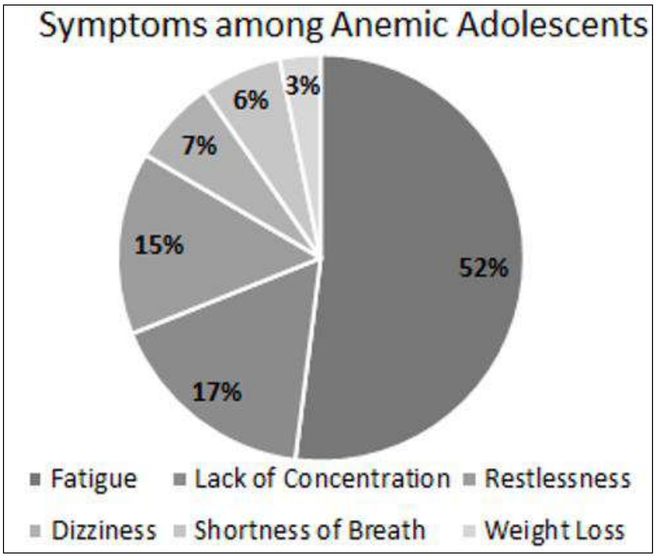

Fig 3: Distribution of symptoms among anemic adolescents

87.8% compliance for WIFS was observed at 3 months and increased to 95.2%, 96.9%, and 99.3% at 6, 9, and 12 months respectively post-intervention (health education sessions). 134 students were non-compliant with the main reasons documented as stomachache (66.4%; n=89) and vomiting (29.9%; n=40). 90.1% (n=496) of all females and 85.5% (n=4960 of all male students were compliant for iron and folic acid supplements. The association between gender and compliance for WIFS was found to be statistically significant (p-value =0.017). 90.6% (n=309) students between 12-14 years of age were compliant for WIFS followed by 89.8% (n=255) between 10-11 years and 84.6% (n=402) between 15-18 years of age. The association between age and compliance for WIFS was found to be statistically significant (p-value =0.018).

An overall improvement was noticed in the prevalence of iron deficiency anemia among students post-intervention. 95.8% (n=1054) of the students who were anemic pre-intervention reduced to 75% (n=825) post-intervention. The association between the overall prevalence of anemia before and after the intervention was found to be statistically significant. The mean level of hemoglobin was 9.69 g/dL and 9.4 g/dL in male and female students respectively at 0 months. The mean level of hemoglobin improved to 11.29 g/dL and 11.05 g/dL for male and female students respectively at the end of 12 months. Change in levels of hemoglobin post-intervention at 0, 3, 6, 9, and 12 months based on age, gender, and BMI are presented in Table 2. All students were aware of at least one dietary source of iron.

Table 2: Mean level of hemoglobin during intervention at 0, 3, 6, 9, and 12 months according to age, gender, and BMI

	Mean level of Hemoglobin									
Age group	**0 months**		**3 months**		**6 months**		**9 months**		**12 months**	
10-11 years	8.4	ANOVA	8.7	ANOVA	9.0	ANOVA	9.2	ANOVA	9.5	ANOVA
12-14 years	8.7	F=3.432	9.0	F=3.917	9.3	F=4.074	9.6	F=4.058	9.9	F=4.412
15-18 years	8.5	Sig <0.001	8.8	Sig <0.001	9.1	Sig <0.001	9.4	Sig <0.001	9.7	Sig<0.001
Gender										
Male	8.7	T-test	8.7	T-test	9.0	T-test	9.3	T-test	9.5	T-test
Female	8.3	t=3.518 Sig <0.001	9.0	t=-3.306 Sig <0.001	9.3	t=-3.644 Sig <0.001	9.6	t=-3.988 Sig <0.001	9.8	t=-4.038 Sig<0.001
BMI										
Underweight	8.6	ANOVA F=1.751 Sig =0.155	9.0	ANOVA F=2.76 Sig =0.041	9.2	ANOVA F=1.522 Sig =0.207	9.5	ANOVA F=1.606 Sig =0.186	9.7	ANOVA F=1.306 Sig=0.271
Normal	8.5		8.8		9.1		9.4		9.7	
Overweight	8.3		8.5		9.0		9.2		9.5	
Obese	8.1		8.5		9.4		9.6		9.9	

4. Discussion

Anemia is a global public health concern and affects both developing and developed nations with adverse health consequences. Globally, 1.62 billion people are affected and an estimated 36% population in developing nations is affected [11]. It poses a significant problem by affecting 305 million (25.4%) school children. Lack of awareness among parents (especially mothers) about the problem coupled with their low educational status, poor nutritional practices, unhealthy food habits, low iron bioavailability in the diet, infections, etc. are some factors associated with lower hemoglobin levels in children. Anemia reduces physical work capacity and cognitive function and has adverse effects on the learning and academic performance of young children decrease in the level of hemoglobin which in turn reduces the availability of oxygen to the tissues, and affects the cardiac output. Also, changes in levels of iron content in the neurological functioning have a direct impact on cognition.

Several programs have been launched in the past in India to tackle this problem. National Nutritional Anemia Prophylaxis program was initiated in 1970 with a focus on iron supplementation for pregnant and lactating females and children below 5 years of age. In 1991, this program was renamed as National Child Survival and Safe Motherhood Programme and the beneficiaries for iron supplementation were increased. National Nutrition Policy was adopted in 1993 to address under nutrition and malnutrition.

In developing nations, poverty, bureaucracy, operational inefficiency, and geopolitical realities have limited the efforts towards anemia prevention and reduction. Anemia is a severe public health problem in Nyando District, Kenya. Malaria and iron deficiency are strongly associated with anemia, non-malarial inflammation, and stunting [12]. In Srilanka, 47.8% of females children of ages 12-18 years were reported to have an iron deficiency [13]. According to the Nepal Demographic and Health Survey 2006, 48% of children below five years of age were anemic [14]. In another study in Eastern Nepal, 65.6% of adolescents (10-19 years) were anemic [15]. The prevalence of iron deficiency anemia among school children of rural Kazakhstan was reported to be 13% [16]. In Arab countries of the Persian Gulf, the prevalence of iron deficiency anemia among schoolchildren has been reported within a range of 12.6 to 50% [17]. A prevalence of 12.5% was reported in Turkey [18]. In the Philippines, anemia affects almost 70% of infants, 30% of preschool children and 40% of school children and pregnant women [19]. The government of the Philippines institutionalized food fortification; however, compliance and delivering fortified products to remote areas and vulnerable populations imposed a challenge [20]. Studies from Ethiopia also showed that the prevalence of anemia among schoolchildren ranges from 5.8%-37.6% [21, 22]. The Government of Ethiopia launched the National Nutrition Program (NNP) in 2013 with a focus on child and adolescent health [23]. Several strategies and initiatives have been implemented to ensure adequate access to micro-nutrients and provide comprehensive and routine nutritional assessment and counseling services for adolescents at school and health centers. The Ministry of Education implemented a strategy for School Health and Nutrition (SHN) to improve access to better health and nutrition services in government and private schools.

In Canada, approximately 5% of children from one to five years of age suffer from iron-deficiency anemia compared with 40% to 50% of children in non-industrialized countries [24]. Health Canada recommends exclusive breastfeeding for the first six months of life for healthy term infants as breast milk is the best food for optimal growth [25]. The 'Sprinkles' concept in Canada is based on home fortification of complementary food items and homemade foods with an appropriate level of micronutrients for infants and young children [26]. Sprinkles are microencapsulated iron and other micronutrients packed in a single-serve packet and serve as a combination of fortification and supplementation. Countries implementing or planning Sprinkles programs include Mongolia, Indonesia, Pakistan, Bangladesh, Bolivia, and Haiti. The prevalence of anemia in school children in Mexico, Colombia, and the United States was 11.6%, 4.2%, and 3.6% which are similar to previously published data from the ENSAUT 2006 (National Health and Nutrition Survey, Mexico), NHANES 2004-2006 (National Health and Nutrition Examination Survey, U.S.) and the ENSIN 2010 (Encuesta Nacional de la Situaci ón Nutricional, Colombia) [27-29]. Also, reports from countries such as the United States, Israel, and Canada have shown that overweight and obese children have a higher prevalence of iron deficiency than normal-weight children and intakes of other micronutrients such as folate, vitamin D, calcium, magnesium, and vitamin E are sub-optimal among obese children [30].

Our study was limited in certain aspects: Firstly, additional laboratory variables such as level of methylmalonic acid and homocysteine could have altered the presentation of iron and vitamin B-12 deficiency. Secondly, though high levels of lead in the bloodstream have been reported to be a cause of anemia, we did not measure that among our study population. Despite presenting with these limitations, we were able to demonstrate a high prevalence of anemia among adolescents from rural areas of the state of Haryana, find a correlation between variables directly or indirectly causing iron deficiency anemia, the effectiveness of WIFS program under RKSK, and the importance of education and awareness among the public.

5. Recommendations

Poverty is one of the leading causes of Iron deficiency anemia. The problem has emerged as a global public health concern as it is seen among populations in both developing and developed nations. The strategies to prevent the disorder need collaboration among multiple sectors such as agriculture, health, industry, education, community, and local organizations. Some of the methods to achieve this include diet modification including fortified food, diet diversification, increased consumption of bio-available iron, additional supplements, education, and awareness among masses. Firstly, dietary changes can be made at several levels such as meal modification and diversification, increase ingestion of bio-available iron, and additional supplements. The strategies need to be integrated into the primary health care system. An example of collaboration among sectors can be learned from national programs in India where the adolescent health programs focus on building adolescent-friendly health centers, peer education programs, menstrual hygiene schemes, management of childhood illness, deworming (including routine anthelminthic control measures), etc. A major focus is laid on strategies and programs to increase awareness and knowledge among health care providers and the public related to the health risks associated with iron deficiency anemia. Food fortification programs need to be established widely as it is an effective method to provide an adequate amount of iron through diet. Again, this would need collaborative efforts from Government, producers, marketing, and consumers to reach the remote areas as well. The legislation surrounding fortification of food needs to be regulated to avoid adultery and establish adequate food control and quality assurance systems.

Second, merely providing iron and folic acid supplement in schools or health care centers will not solve the problem, rather motivating the target population to be compliant is vital. Community members including parents (especially mothers), neighbors, health workers, etc. need to be informed and educated about the benefits and side-effects of iron and folic acid supplementation for adolescents and pregnant women. Educational sessions, informative brochures, and videos should be provided in schools and colleges for both students and parents. Religious leaders, volunteer health workers, school teachers, and social workers can reinforce the message through active involvement in the community. Third, another strategy is to provide education and awareness regarding dietary sources of iron, benefits of supplements, maintaining hygiene, preventing infection, etc. Some dietary items which are a rich source of iron include green leafy vegetables, fruits, lentils, jaggery, nuts, etc. The recommended dietary allowance (RDA) for iron is 8 mg/d during age 9-13 and 11 mg/d and 15mg/d for male and females between age group 14-18 years [31].

6. Conclusion

This study revealed a very high prevalence of iron-deficiency anemia among adolescents irrespective of gender. Lack of timely intervention could worsen the problem and lead to adverse health consequences. WIFS has proven to be an effective strategy to address this concern; however, education, awareness, and compliance are must to produce maximum effect. Our results have shown that levels of hemoglobin have improved after compliance with WIFS. The overarching goal of this study is to guide policy planning to better identify and design strategies to help prevent and treat iron-deficiency anemia. These include dietary diversification of food items, increasing bioavailable iron in the diet, fortified food for full-term infants and children, and additional supplements.

7. Implication & Contribution

Iron-deficiency anemia is a global public health concern. This is the first study to show WIFS as an effective intervention to address this concern. Education and compliance are must to produce maximum effect. Lack of timely intervention could worsen the problem and lead to adverse health consequences among adolescents.

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There was no financial burden on the parents or guardians of the students enrolled.

Informed written consent was obtained before conducting the study and confidentiality was ensured.

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