YOUNG NURSES JOURNAL OF RESEARCH| JULY – SEPTEMBER 2026 |VOLUME 01| ISSUE 03|PAGES 10 – 20 | ISSN: 3139-1362

Effectiveness of a Selected Nutritional Intervention Strategy to Improve Haemoglobin Levels and Reduce Anaemia Prevalence Among School-Going Girls in Lucknow: A Quasi-Experimental Study

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https://doi.org/10.53926/YNJR/0022 https://ynjr.in/

ABSTRACT

Background: *Iron deficiency anaemia (IDA) remains a major public health concern among adolescent girls in India, with national prevalence estimates ranging from 40% to 65.7%. School-going girls represent a particularly vulnerable subgroup owing to the heightened iron demands of pubertal growth, the onset of menstruation, and limited dietary diversity. Food-based interventions using locally available, iron-rich food combinations offer a feasible and culturally acceptable approach to address this persistent nutritional deficit.* ***Objectives:*** *This study aimed to: (1) assess the prevalence of anaemia among school-going girls aged 9–16 years in a selected government school in Lucknow; (2) evaluate the effectiveness of a structured nutritional intervention comprising rice flakes and soyabean chunks in improving haemoglobin levels; and (3) examine the association between haemoglobin levels and selected demographic variables.* ***Methods:*** *A quasi-experimental one-group pre-test/post-test design was employed. Forty girls aged 9–16 years with haemoglobin below 10 g/dL were enrolled from a selected school, Lucknow, using non-probability consecutive sampling. A daily nutritional supplement comprising 50 g rice flakes and 50 g soyabean chunks was administered for three consecutive weeks. Haemoglobin levels were measured before and after the intervention using Sahli's haemoglobinometer. Anaemia severity was classified according to National Cancer Institute (NCI) criteria. Data were analysed using paired t-test and chi-square (χ^2) test at the 0.05 level of significance.* ***Results:*** *Prior to intervention, no selected participant had normal haemoglobin; 22.5% had mild, 52.5% moderate, and 25.0% severe anaemia. After the three-week intervention, 50.0% of participants achieved healthy haemoglobin levels, 22.5% had mild anaemia, and 27.5% moderate anaemia; no cases of severe or life-threatening anaemia were recorded. Mean haemoglobin increased significantly from 8.27 g/dL to 10.46 g/dL, representing a mean gain of 2.19 g/dL ($t = 22.275$, $p < 0.001$). No statistically significant associations were observed between haemoglobin levels and the tested demographic variables.* ***Conclusion:*** *A three-week daily provision of rice flakes and soyabean chunks produced a statistically significant and clinically meaningful improvement in haemoglobin levels among anaemic school girls in Lucknow. These findings support the integration of low-cost, culturally acceptable, food-based strategies into school health programmes as a complement to existing national anaemia-control initiatives.*

Keywords: *Adolescent girls; anaemia; iron deficiency; haemoglobin; nutritional intervention; rice flakes; soyabean; school health*

INTRODUCTION

Anaemia is among the most prevalent nutritional disorders worldwide, affecting an estimated two billion individuals more than 30% of the global population according to the World Health Organization (WHO) [1]. The condition imposes a substantial and multidimensional burden on human health, social functioning, and economic productivity in both developed and developing nations, affecting approximately 24.8% of the total world population [2]. Within the adolescent age group (10–24 years), it is estimated that one in four individuals suffers from anaemia, with the highest prevalence rates observed in low- and middle-income countries (LMICs) [3]. The highest national-level prevalence has been documented in sub-Saharan African nations, including Zambia, Mali, and Burkina Faso, where age-standardised point prevalence rates exceed 40,000 per 100,000 population [3].

Iron deficiency is universally recognised as the single most common underlying cause of anaemia, responsible for the majority of cases globally [1]. Beyond its haematological consequences, iron is critical for neurological development, immune function, energy metabolism, and cognitive maturation. In adolescents, IDA is associated with impaired scholastic performance, reduced concentration and memory, short attention span, diminished physical stamina, and behavioural disturbances [4]. Epidemiological evidence suggests that anaemic adolescents may experience a five-to-ten-point reduction in intelligence quotient (IQ) compared with non-anaemic peers a deficit with profound long-term consequences for educational achievement and life opportunities [4].

Globally, the nutritional and public health consequences of adolescent anaemia extend beyond the individual. Adolescent girls who enter pregnancy with pre-existing IDA face elevated risks of adverse maternal and foetal outcomes, accounting for more than 20% of prenatal morbidity and 10% of maternal mortality in developing nations [5]. As the period spanning childhood and adolescence represents a sensitive developmental window for physiological and behavioural changes, the early detection and treatment of anaemia during this phase is of paramount importance.

India carries one of the highest absolute burdens of anaemia in the world. Over 50% of women in the reproductive age group are reported to be anaemic, and the burden begins accumulating in early adolescence [5]. The National Family Health Survey-4 (NFHS-4, 2015–16) documented that 54% of adolescent girls aged 15–19 years were anaemic, with state-level prevalence varying from 30% to 69% across different age groups [5]. Between NFHS-3 and NFHS-4, the national decline in anaemia prevalence among adolescent girls was only 2 percentage points, reflecting the limited impact of existing interventions [5].

Data from the Comprehensive National Nutrition Survey (CNNS, 2016–18) showed that 40% of Indian girls aged 10–19 years were anaemic, representing an estimated national burden of 72 million affected adolescents with Uttar Pradesh alone accounting for nearly twice the burden of any other state [6]. A systematic review and meta-analysis by Daniel et al. (2024) encompassing community-based studies from across India reported a pooled anaemia prevalence of 65.7% (95% CI: 59.3%–71.9%) among adolescent girls aged 10–19 years, underscoring the persistently high and largely unaddressed nature of this burden [7]. Iron deficiency emerged as the strongest independent predictor of anaemia (OR: 4.68), followed by haemoglobinopathies (OR: 2.81) and vitamin A deficiency (OR: 1.86) [6].

Population-based surveys have identified concurrent micronutrient deficiencies vitamin B12 (25.6%), iron (21.3%), and dimorphic anaemia (18.2%) as the predominant aetiologies of anaemia among Indian adolescents [5]. More than 15 Indian states report a prevalence exceeding 55% among socially disadvantaged groups, with tribal and rural populations disproportionately affected [5]. The sociodemographic determinants of anaemia including maternal illiteracy, low household income, vegetarian dietary practices, and restricted access to healthcare compound the challenge of prevention and control [8, 9].

In recognition of this public health crisis, the Government of India launched the Anemia Mukt Bharat (AMB) strategy in March 2018 under the POSHAN Abhiyan framework, targeting a 3% annual reduction in anaemia prevalence across all age groups between 2018 and 2022 [10]. Despite these policy efforts, a recent cross-sectional assessment by Kumari et al. (2025) documented a residual anaemia prevalence of 56% overall rising to 68% among girls in an AMB-implementing area, with low awareness and poor supplementation adherence identified as major implementation barriers [10].

Adolescence constitutes a period of uniquely elevated iron demand driven by the physiological imperatives of the pubertal growth spurt: rapid expansion of blood volume, increased erythrocyte mass, and accelerated accretion of lean body mass all substantially increase iron requirements above those of childhood [4]. In girls, the onset of menstruation typically occurring in mid-adolescence (10–15 years) introduces additional monthly iron losses that further intensify this demand [4]. When these heightened requirements coincide with an iron-poor diet, the risk of developing IDA is substantially amplified.

In India, the dietary patterns of adolescent girls from lower socioeconomic strata are frequently dominated by cereal staples, characterised by poor bioavailability of non-haem iron and high concentrations of absorption inhibitors such as phytates and oxalates [11]. Poor dietary knowledge constitutes a compounding barrier: surveys of rural Indian girls have demonstrated that fewer than 50% understood the relationship between diet and anaemia, and less than 5% identified menstrual blood loss as a contributing cause [4]. Among tribal adolescent populations in Gujarat, additional predictors including infrequent egg consumption and poor handwashing practices further contributed to anaemia risk [9]. These multifactorial determinants highlight the need for integrated nutritional education alongside food-based intervention strategies.

Uttar Pradesh, the most populous state of India, harbours the largest absolute national burden of adolescent anaemia, with an estimated caseload nearly double that of any other state [6]. District-level assessments indicate a prevalence of anaemia among school-going adolescent girls of 56.3% in Lucknow, with figures reaching 64.0% in certain sub-population strata [12]. These rates substantially exceed the WHO threshold of 40% that classifies a community-level burden as a severe public health problem, and they underscore an urgent need for targeted, school-based nutritional interventions in this region. Against this backdrop of disproportionately high local anaemia burden, the present study was designed to assess prevalence and evaluate the effectiveness of a simple, low-cost dietary intervention in this specific context.

Food-based strategies for IDA management incorporate both haem iron sources (meat, poultry, seafood) and non-haem iron sources (legumes, dark leafy vegetables, fortified cereals) [1]. Culturally acceptable plant-based options are particularly relevant in settings characterised by a predominantly vegetarian dietary culture. Among plant-derived foods, rice flakes (*poha*) are a recognised source of iron alongside vitamins B and C and dietary fibre, while soyabean-derived products provide a nutritional matrix encompassing iron, high-quality protein, calcium, zinc, copper, and magnesium nutrients that synergistically support haemoglobin synthesis and immune function [13]. The inclusion of vitamin C-containing foods and the use of sprouted or fermented grains and legumes are known to enhance non-haem iron absorption by reducing anti-nutritional phytate concentrations [13].

School-based nutritional interventions have demonstrated efficacy in improving haemoglobin concentrations and reducing anaemia prevalence. Singh et al. (2020) showed that weekly iron-folic acid supplementation combined with structured health education produced a 54.7-percentage-point reduction in anaemia prevalence among adolescent school girls over six months [14]. A quasi-experimental study by Mohapatra et al. (2023) demonstrated that micronutrient-fortified mid-day meals increased the odds of being non-anaemic by 1.93-fold among schoolchildren in Odisha [15]. Mahapatra et al. (2021) similarly reported significant haemoglobin improvements and reductions in anaemia prevalence following the provision of micronutrient-fortified rice to schoolchildren in Gujarat [16]. A systematic review and meta-analysis further confirmed that school feeding programmes significantly improve dietary iron intake, haemoglobin concentrations, and serum ferritin levels in children in developing countries [17].

Despite a growing evidence base for supplementation-based approaches, rigorous evidence evaluating the short-term effectiveness of locally available, culturally acceptable, and low-cost food-combination interventions on haemoglobin levels in school-going girls in urban Uttar Pradesh remains sparse. Food-based approaches offer distinct advantages of palatability, cultural acceptability, absence of pharmaceutical supply-chain dependency, and potential for integration into existing mid-day meal or school tiffin programmes. The Lucknow district, characterised by high anaemia prevalence and a large school-age population with limited healthcare access, constitutes an appropriate and strategically important site for such an investigation.

Nurses, as frontline healthcare professionals in school and community settings, are uniquely positioned to identify at-risk adolescents, deliver nutrition education, and facilitate the implementation of evidence-based dietary interventions. Evidence generated from such school-based studies can directly inform school nursing practice, health education curricula, and government nutrition policy. The present study was therefore designed to generate actionable evidence on the feasibility and impact of a specific, culturally grounded nutritional intervention strategy for adolescent anaemia.

Study Objectives

The present study was undertaken with the following objectives: to assess the prevalence of anaemia among school-going girls aged 9–16 years in a selected school in Lucknow; to evaluate the effectiveness of a selected nutritional intervention comprising rice flakes and soybean chunks in improving haemoglobin levels among school-going girls; and to determine the association between haemoglobin levels and selected demographic variables of the study participants.

MATERIALS AND METHODS

Research Design and Approach

A quantitative research approach was adopted. The study employed a quasi-experimental one-group pre-test/post-test design to evaluate the effectiveness of a structured nutritional intervention on haemoglobin levels. This design enabled systematic within-group comparison of haemoglobin measurements before and after the intervention, thus permitting objective evaluation of the intervention's impact over a defined period.

Study Setting

The study was conducted at a selected School, located in Lucknow, Uttar Pradesh, India. The institution had a total enrolment of 200 students, of whom 145 girls fell within the target age range of 9–16 years.

Study Population and Sample Size

The study population comprised school-going girls aged 9–16 years enrolled at the selected institution. A sample of 40 girls who fulfilled all inclusion criteria was recruited using non-probability consecutive sampling. **Inclusion criteria:** The study included adolescent girls aged between 9 and 16 years who were enrolled in the selected school and had a baseline haemoglobin level of less than 10 g/dL, as determined during the pre-intervention assessment. **Exclusion criteria:** The study excluded girls who were currently receiving iron or folic acid supplementation, those with known medical conditions or hormonal disorders, those whose family members were unwilling or uncooperative, and girls who declined to participate in the study.

Study Instrument

Data collection comprised two components:

Part A: Demographic Proforma: Sociodemographic information was collected for each participant, including age, number of children in the family, birth order, maternal and paternal educational level, monthly family income, family size, age at menarche, menstrual history, and dietary pattern.

Part B: Haemoglobin Measurement: Haemoglobin levels were assessed using Sahli's haemoglobinometer, a point-of-care photometric instrument widely used in resource-limited settings. The procedure involved aspirating 20 mm^3 of capillary blood obtained by sterile fingertip lancet puncture into a calibrated Sahli's pipette, releasing the blood into a haemometer tube pre-filled with 0.1 N hydrochloric acid (diluted 1:10), and stirring the mixture with a glass rod. Distilled water was added drop by drop until the resultant acid haematin colour matched the standard brown comparator. The reading was recorded in g/dL.

Anaemia severity was classified according to National Cancer Institute (NCI) criteria applicable to the 9–16 years age group (Table 1).

Table 1. *Classification of anaemia severity according to National Cancer Institute criteria (age group 9–16 years).*

Haemoglobin Level	***Classification***
≥11.0 g/dL	*Healthy (Normal)*
10.0 g/dL to lower limit of normal	*Mild Anaemia*
8.0–10.0 g/dL	*Moderate Anaemia*
6.5–7.9 g/dL	*Severe Anaemia*
<6.5 g/dL	*Life-Threatening*

Nutritional Intervention

The intervention consisted of the daily provision of 50 g rice flakes and 50 g soyabean chunks, prepared in the form of a nutritional ball, administered to each participant during the morning break (10:30 hours) from week 2 through week 4 of the data collection period (three consecutive weeks). Rice flakes (*poha*) were selected for their content of iron, vitamins B and C, and dietary fibre; soyabean chunks were selected for their complementary provision of iron, high-quality protein, calcium, zinc, copper, and magnesium nutrients synergistically supportive of haemoglobin synthesis and erythropoiesis [13].

Data Collection Procedure

Formal institutional permission was obtained from the Head of the school and concerned department prior to commencement of the study. Institutional ethical clearance was obtained from institutional ethical committee, Lucknow. Written informed consent was secured from each participant and, where applicable, from a parent or guardian. Participants were informed of their right to withdraw from the study at any point without consequence. Confidentiality of all personal and clinical data was strictly maintained throughout the study.

Data collection was conducted across four weeks. During week 1, the researcher visited the school daily at 09:30 hours, introduced herself to class teachers, and conducted haemoglobin screening. Girls with haemoglobin below 10 g/dL were consecutively enrolled until the target sample size was reached, with 15–20 girls screened per day in a designated room. From week 2 onwards, the nutritional intervention was administered daily under researcher supervision until the conclusion of week 4. At the end of week 4, post-intervention haemoglobin measurements were obtained using the same Sahli's haemoglobinometer procedure applied at baseline.

Statistical Analysis

Data were analysed using both descriptive and inferential statistical methods. Frequency distributions and percentages were computed for demographic variables and categorical haemoglobin classification data. Mean haemoglobin values before and after intervention were compared using a paired *t*-test. Associations between haemoglobin severity categories and demographic variables were examined using the chi-square (χ^2) test. A *p*-value of ≤ 0.05 was adopted as the threshold for statistical significance for all inferential tests.

RESULTS

Demographic Characteristics of Study Participants

The majority of participants (42.5%) were aged 13–14 years. Most came from families with three children (57.5%), and 62.5% were second-born daughters. Regarding maternal education, 45.0% of mothers had attained an intermediate level of schooling, with 20.0% being illiterate. Paternal education was distributed equally between intermediate and graduate levels (40.0% each). All participating families (100%) reported a monthly paternal income exceeding Rs. 5,000. Most families comprised 4–5 members (65.0%). The majority of girls (57.5%) had attained menarche between 13 and 16 years of age, while 25.0% had not yet reached menarche. Regular menstrual cycles were reported by 75.0% of participants. A predominantly vegetarian dietary pattern was followed by 77.5% of the sample.

Pre-Intervention Haemoglobin Levels

Table 2 presents the distribution of haemoglobin severity categories prior to the nutritional intervention.

Table 2. *Frequency and percentage distribution of participants according to haemoglobin level before nutritional intervention (n = 40).*

Haemoglobin Category	*Haemoglobin Range*	*Frequency (n)*	*Percentage (%)*
Healthy	*≥11.0 g/dL*	*0*	*0.0*
Mild Anaemia	*10.0 g/dL to lower limit of normal*	*9*	*22.5*
Moderate Anaemia	*8.0–10.0 g/dL*	*21*	*52.5*
Severe Anaemia	*6.5–7.9 g/dL*	*10*	*25.0*
Life-Threatening	*<6.5 g/dL*	*0*	*0.0*

Prior to the nutritional intervention, none of the participants from the selected 40 participants had normal haemoglobin levels. The majority (52.5%) exhibited moderate anaemia, 25.0% had severe anaemia, and 22.5% had mild anaemia. No cases of life-threatening haemoglobin levels were observed at baseline.

Post-Intervention Haemoglobin Levels

Table 3 presents the distribution of haemoglobin severity categories following the three-week nutritional intervention.

Table 3. Frequency and percentage distribution of participants according to haemoglobin level after nutritional intervention (n = 40).

Haemoglobin Category	*Haemoglobin Range*	*Frequency (n)*	*Percentage (%)*
Healthy	*≥11.0 g/dL*	*20*	*50.0*
Mild Anaemia	*10.0 g/dL to lower limit of normal*	*9*	*22.5*
Moderate Anaemia	*8.0–10.0 g/dL*	*11*	*27.5*
Severe Anaemia	*6.5–7.9 g/dL*	*0*	*0.0*
Life-Threatening	*<6.5 g/dL*	*0*	*0.0*

Following the three-week intervention, 50.0% of participants achieved healthy haemoglobin levels. The proportion with moderate anaemia declined from 52.5% to 27.5%, and no cases of severe or life-threatening anaemia were recorded post-intervention.

Comparison of Haemoglobin Levels Before and After Nutritional Intervention

Table 4provides a direct comparison of haemoglobin severity categories before and after the intervention.

Table 4. *Comparison of haemoglobin severity before and after nutritional intervention (n = 40).*

Haemoglobin Category	*Before Intervention n (%)*	*After Intervention n (%)*	*Change*
Healthy (≥11.0 g/dL)	*0 (0.0%)*	*20 (50.0%)*	*↑ 50.0 pp*
Mild Anaemia	*9 (22.5%)*	*9 (22.5%)*	*No change*
Moderate Anaemia	*21 (52.5%)*	*11 (27.5%)*	*↓ 25.0 pp*
Severe Anaemia	*10 (25.0%)*	*0 (0.0%)*	*↓ 25.0 pp*
Life-Threatening	*0 (0.0%)*	*0 (0.0%)*	*No change*

pp = percentage points.

The comparison demonstrates a substantial improvement in haemoglobin distribution post-intervention: the proportion achieving healthy haemoglobin increased by 50 percentage points, moderate anaemia declined by 25 percentage points, and severe anaemia was entirely eliminated.

Effectiveness of Nutritional Intervention: Paired t-Test Analysis

The statistical effectiveness of the nutritional intervention was assessed by comparing mean pre- and post-intervention haemoglobin values using a paired *t*-test (Table 5).

Table 5 *Effectiveness of nutritional intervention in terms of haemoglobin improvement (n = 40).*

Assessment Point	*Mean Haemoglobin (g/dL)*	*S.D.*	*Mean Difference (g/dL)*	*t -value*	*p-value*
Before Intervention	*8.27*	*0.759*	*2.19*	*22.275*	*<0.001*
After Intervention	*10.46*	*1.073*			

Mean haemoglobin increased from 8.27 g/dL at baseline to 10.46 g/dL after the three-week intervention, representing a mean gain of 2.19 g/dL. The paired *t*-test revealed a highly statistically significant difference ($t = 22.275$, $p < 0.001$), confirming that the nutritional intervention produced a substantial and statistically significant improvement in haemoglobin levels.

Association Between Haemoglobin Levels and Demographic Variables: Chi-Square Analysis

For all demographic variables, the calculated chi-square statistics were below the corresponding critical values at the 0.05 significance level. Accordingly, no statistically significant association was demonstrated between haemoglobin levels and father's education ($\chi^2 = 7.359$, df = 6, critical value = 12.592), family size ($\chi^2 = 1.661$, df = 2, critical value = 5.991), age at menarche ($\chi^2 = 5.301$, df = 4, critical value = 9.488), or dietary pattern ($\chi^2 = 1.522$, df = 2, critical value = 5.991).

DISCUSSION

Prevalence of Anaemia at Baseline

The findings of the present study reveal a high and clinically significant burden of anaemia among school-going girls in Lucknow: all 40 enrolled participants demonstrated haemoglobin levels below the normal threshold, with 52.5% exhibiting moderate anaemia and 25.0% severe anaemia at baseline. These figures are consistent with district-level evidence from northern India, where studies have documented anaemia prevalence rates of 56.3%–64.0% among school-going adolescent girls in Lucknow [12]. On a national scale, NFHS-4 data documented 54% anaemia prevalence among adolescent girls [5], while the meta-analytic estimate by Daniel et al. (2024) indicated a pooled prevalence of 65.7% affirming the persistently high and geographically widespread burden of this condition [7].

The concentration of study participants in the moderate and severe anaemia categories prior to intervention is consistent with the sociodemographic profile of government school populations in Lucknow. More than half of families in the sample (57.5%) had three children, and 20% of mothers were illiterate sociodemographic factors previously associated with heightened anaemia risk through dietary constraints, reduced healthcare-seeking behaviour, and limited nutritional awareness [8]. The predominantly vegetarian dietary pattern (77.5%) further supports the expectation of poor non-haem iron intake, given that plant-based diets are characterised by lower iron bioavailability compared with animal-source foods and frequently contain high concentrations of absorption-inhibiting phytates and oxalates [11]. These observations are corroborated by Subramanian et al. (2022), who found maternal educational level and vegetarian dietary practices among the significant correlates of anaemia in adolescent girls in rural Haryana [8].

The study findings align closely with those reported by Kamble et al. (2021) under the Anemia Mukt Bharat programme in Delhi, which documented moderate anaemia in 46.4% and severe anaemia in 4.3% of screened school girls [18]. Similarly, Kishore et al. (2020) reported a 67.4% anaemia prevalence in adolescent girls in semi-urban Uttarakhand, with vegetarian dietary patterns and low maternal education emerging as significant determinants [19]. These parallel reports from geographically disparate Indian settings reinforce the conclusion that the study population is broadly representative of vulnerable urban government school populations nationwide.

Effectiveness of the Nutritional Intervention

The primary finding of the study was a statistically highly significant improvement in haemoglobin levels following the three-week nutritional intervention ($t = 22.275$, $p < 0.001$). Mean haemoglobin rose from 8.27 g/dL to 10.46 g/dL, representing a mean gain of 2.19 g/dL, and the proportion of participants with healthy haemoglobin levels increased from 0% to 50%. Severe anaemia was entirely eliminated within three weeks.

The magnitude of this improvement is particularly noteworthy given the brevity of the intervention period. The findings suggest that consistent daily provision of a small, iron-dense, low-cost food supplement administered in a supervised school setting can produce measurable and clinically meaningful haematological change within three weeks. The combination of rice flakes and soyabean chunks was selected for its nutritional complementarity: rice flakes contribute non-haem iron alongside vitamin C (an established enhancer of non-haem iron absorption), while soyabean chunks provide iron in a protein-rich matrix alongside zinc and copper essential cofactors in erythropoiesis and haemoglobin synthesis [13]. High adherence, ensured through supervised consumption during the school break, likely contributed to the consistency of the observed response.

The present findings are consistent with those of Choudhary and Gupta (2019), who reported significant improvements in haemoglobin levels following a nutritional intervention in moderately anaemic adolescent girls [20]. Tamilselvi et al. (2020) documented a significant haemoglobin rise after dietary intervention using iron-rich foods among adolescent girls in rural Tamil Nadu [21]. Bhuvaneswari et al. similarly reported haemoglobin improvement and favourable changes in biochemical parameters of iron status following an alternative nutritional intervention for IDA in adolescent girls [22]. At the programmatic level, the comparable findings from internationally diverse settings lend weight to the generalisability of food-based approaches as effective components of comprehensive anaemia control strategies.

The WIFS-based intervention evaluated by Singh et al. (2020) produced a 54.7-percentage-point reduction in anaemia prevalence in six months among adolescent girls receiving pharmacological supplementation combined with health education [14]. Whilst the present study did not employ pharmacological agents, a comparable and even more rapid categorical improvement was achieved through dietary means alone within three weeks, with a 50-percentage-point increase in the proportion attaining healthy haemoglobin status. This finding is clinically relevant because it demonstrates that food-based school interventions can rapidly shift the haemoglobin distribution of anaemic populations even without pharmaceutical supplementation — a particularly important consideration in settings where supply chains for iron tablets are unreliable or compliance is poor.

Evidence from Zhu et al. (2021), studying adolescents aged 10–14 years in rural western China, reinforced the association between inadequate dietary iron intake and elevated anaemia risk, contextualising the global relevance of dietary interventions for IDA in school-age populations [23]. In the Indian context, Habtegiorgis et al. (2022), in a systematic review of Ethiopian studies, found that inadequate dietary diversity and low meal frequency were the predominant modifiable determinants of anaemia in adolescent girls precisely the targets addressed by school-based food supplementation programmes [24].

Mechanisms Underlying Haemoglobin Improvement

The observed haematological improvements can be attributed to the combined nutritional effect of the intervention. Rice flakes contain approximately 2.5–3.0 mg of iron per 50 g serving, alongside ascorbic acid (vitamin C), which potently enhances non-haem iron absorption by reducing ferric iron to the more soluble ferrous form in the intestinal lumen [13]. Soyabean chunks complement this with additional iron, alongside high-quality plant protein essential for the synthesis of transferrin, ferritin, and haemoglobin itself. The co-provision of zinc and copper supports the enzymatic systems of erythropoiesis, and the high-protein matrix promotes iron storage and utilisation in haematopoietic tissues [13]. The absence of pharmacological supplementation in the study design confirms that the haemoglobin improvements observed were attributable entirely to the dietary composition of the intervention.

Demographic Correlates of Haemoglobin Levels

Chi-square analysis revealed no statistically significant associations between haemoglobin severity categories and any of the tested demographic variables including father's education ($\chi^2 = 7.359$, $p > 0.05$), family size ($\chi^2 = 1.661$, $p > 0.05$), age at menarche ($\chi^2 = 5.301$, $p > 0.05$), or dietary pattern ($\chi^2 = 1.522$, $p > 0.05$). These findings likely reflect the limited sample size and restricted distributional variability within the study population for example, all participants reported paternal income above Rs. 5,000 per month, precluding analysis of income-based differences. The demographic homogeneity of the sample reduces statistical power to detect associations of modest effect size.

This non-significant finding should not be interpreted as evidence that sociodemographic factors do not influence anaemia risk. Prior evidence from Subramanian et al. (2022) in Haryana and Thaker et al. (2023) in Gujarat consistently identified maternal education level, tribal or remote residence, and poor dietary diversity as significant independent predictors of anaemia in adolescent populations similar to those enrolled in this study [8, 9]. These associations may not have emerged in the present study due to sample homogeneity. Future research with larger, socio demographically diverse samples will be needed to delineate the specific demographic determinants of anaemia in this population.

A supportive parallel study by Kalaichelvi and Nalini (2020) assessed anaemia prevalence and nutritional intervention effectiveness in 60 school girls at Milaganoor using a similar one-group pre-test/post-test design. At baseline, 13.0% had mild, 60.0% moderate, and 26.67% severe anaemia. After intervention, severe anaemia declined to 10.0%, and the distribution shifted towards milder anaemia categories [25]. This pattern of improvement with reduction in severe anaemia and progressive redistribution towards milder categories and, ultimately, normal haemoglobin parallels the trajectory observed in the present study, although the current study achieved a substantially higher proportion (50.0%) reaching healthy haemoglobin status post-intervention. The comparative evidence reinforces the consistency of food-based nutritional interventions across different school populations and geographic settings in India.

Clinical and Public Health Significance

The results of this study carry substantial clinical and public health significance. A mean haemoglobin gain of 2.19 g/dL exceeds the haematological threshold typically associated with symptomatic relief and functional improvement in anaemic individuals, suggesting that participants likely experienced tangible improvements in physical stamina, concentration, and overall well-being following the intervention. At the population level, the complete elimination of severe anaemia which affected 25.0% of participants at baseline represents a highly meaningful reduction in the risk of serious adverse outcomes including profound cognitive impairment, susceptibility to infection, exercise intolerance, and, in older girls, future maternal morbidity.

From a public health policy perspective, the study demonstrates the feasibility of a school-based, food-supply-driven approach to IDA control that can complement and reinforce the Anemia Mukt Bharat strategy. The low unit cost of rice flakes and soyabean both staple commodities accessible in virtually all Indian markets renders this intervention readily scalable across government school systems without significant infrastructure investment. The potential for integration into existing mid-day meal programmes administered under the National Food Security Act represents a particularly practical and cost-effective pathway for widespread implementation.

STRENGTHS

The study was conducted in a real-world government school setting under routine supervision, thereby enhancing its ecological validity and increasing the applicability of the findings to similar populations. The nutritional intervention, consisting of rice flakes and soybean chunks, was provided daily in a standardized and supervised manner, ensuring high participant adherence while minimizing variability in consumption. Haemoglobin levels were assessed using the validated Sahli's haemoglobinometer following a consistent and standardized protocol throughout the study, which ensured the reproducibility and reliability of the measurements. Furthermore, comprehensive descriptive and inferential statistical analyses facilitated both the characterization of anaemia prevalence and a robust evaluation of the intervention's effectiveness. Importantly, the intervention components rice flakes and soybean chunks are culturally acceptable, widely available, affordable, and well-suited for large-scale implementation within existing school nutrition programmes, thereby supporting the potential scalability and public health relevance of the findings.

LIMITATIONS

The study had several limitations that should be considered when interpreting the findings. First, the absence of a concurrent control group limits the ability to establish a definitive causal relationship between the nutritional intervention and the observed improvement in haemoglobin levels, as other factors such as regression to the mean, seasonal dietary changes, or concurrent school health activities may have contributed to the outcomes. Additionally, the intervention and follow-up period was limited to four weeks, preventing assessment of the long-term sustainability and durability of the observed haemoglobin improvements. The study included only 40 participants from a single government school in Lucknow, which restricts the generalisability of the findings to other geographical regions, rural settings, or private school populations. Although haemoglobin estimation was performed using Sahli's haemoglobinometer, a validated and commonly used instrument in resource-limited settings, it is less precise than automated haematology analysers. Furthermore, the absence of biochemical investigations such as serum ferritin, serum iron, and total iron-binding capacity limited the comprehensive assessment of iron stores and iron deficiency status. The inclusion criteria were restricted to adolescent girls with haemoglobin levels below 10 g/dL; therefore, the findings cannot be extrapolated to girls with borderline or normal haemoglobin levels for preventive purposes. Finally, the reliance on self-reported dietary intake and menstrual history may have introduced recall bias and social desirability bias, potentially affecting the accuracy of the collected information.

NURSING IMPLICATIONS

Nursing Practice: School health nurses are uniquely positioned to implement routine haemoglobin screening, facilitate the early identification of anaemia, and initiate timely, evidence-based nutritional interventions among school-age children. The findings of the present study highlight several important implications for nursing practice. School nurses should receive appropriate training on the significance and implementation of nutritional interventions for the prevention and management of iron deficiency anaemia (IDA) in school populations. They should also empower teachers to recognise the early clinical signs and symptoms of anaemia and to function as effective links between the school community and healthcare services, thereby promoting timely referral and management. Routine school health services should incorporate periodic monitoring and reinforcement of government initiatives, such as the Weekly Iron and Folic Acid Supplementation (WIFS) programme, to improve compliance and maximise programme effectiveness. In addition, structured nutritional interventions that include affordable, locally available, iron-rich foods should be integrated into school feeding and mid-day meal programmes to support sustainable improvements in nutritional status. School nurses should further conduct practical demonstrations on the preparation of inexpensive iron-rich meals and educate students and their families about appropriate food combinations that enhance non-haem iron absorption. Regular health education sessions should also be organised to promote awareness regarding balanced iron-rich diets, personal hygiene, periodic deworming, and the avoidance of barefoot walking, thereby contributing to the prevention and long-term control of iron deficiency anaemia among school children.

Nursing Education: The findings of the present study have important implications for nursing education. Undergraduate and postgraduate nursing curricula should incorporate dedicated, evidence-based content on the identification, assessment, prevention, and nutritional management of anaemia among adolescents. Nursing students should receive hands-on training in community-based anaemia screening using accessible point-of-care haemoglobin assessment tools to strengthen their clinical competence and confidence in early detection. Curriculum frameworks should also encourage student-led anaemia screening and health promotion activities in schools and community settings as an integral component of community health nursing clinical postings, thereby enhancing experiential learning while supporting public health initiatives. Furthermore, nursing faculty should ensure that teaching content remains aligned with the latest scientific evidence on dietary interventions for iron deficiency anaemia and national nutrition programmes, including the Anaemia Mukt Bharat (AMB) strategy, the Weekly Iron and Folic Acid Supplementation (WIFS) programme, and the POSHAN Abhiyan, enabling graduates to deliver evidence-based, community-oriented nursing care.

Nursing Administration: The findings of this study have significant implications for nursing administration. Nurse administrators should organise regular staff development and continuing education programmes to strengthen nurses' knowledge and skills in the nutritional management of anaemia and the implementation of school health nursing protocols. Administrative policies should support the integration of routine haemoglobin screening into annual and periodic school health visits to facilitate early identification and timely management of anaemia. The systematic distribution of iron and folic acid tablets at six-monthly intervals should be institutionalised as a key component of school nursing services in accordance with national health guidelines. Nurse administrators should also collaborate with government health and nutrition departments to organise and strengthen anaemia control camps, community nutrition education programmes, and school-based health promotion events. Furthermore, comprehensive in-service training covering the aetiology, risk factors, assessment, dietary management, pharmacological treatment, and preventive strategies for anaemia should be made available to nursing personnel across all levels of healthcare, ensuring the delivery of evidence-based and coordinated anaemia prevention and control services.

Nursing Research: The present study highlights several important directions for future nursing research. Future investigations should evaluate the long-term effectiveness of food-based interventions for iron deficiency anaemia (IDA) using well-designed randomised controlled trials with adequate sample sizes and appropriate control groups to strengthen the evidence base. Research should also be conducted across diverse populations and settings, including rural areas, tribal communities, and private schools, to improve the generalisability of findings and facilitate comparisons across geographical and socio-economic contexts. In addition, mixed-methods studies exploring cooking practices, food selection behaviours, dietary habits, and cultural factors influencing iron intake would provide a more comprehensive understanding of barriers and facilitators to effective nutritional interventions, thereby informing culturally appropriate nursing strategies. Finally, research outcomes should be widely disseminated through peer-reviewed nursing journals, national and international scientific conferences, and policy briefs to promote the translation of evidence into clinical practice, school health programmes, and public health policy, ultimately contributing to improved prevention and management of iron deficiency anaemia.

RECOMMENDATIONS

Future research should include larger, geographically diverse samples to improve the generalisability of findings at the state and national levels. Well-designed two-arm randomised controlled trials comparing the effectiveness of food-based nutritional interventions with standard pharmacological supplementation, such as iron and folic acid tablets, should be undertaken using matched control groups to generate stronger evidence for clinical and public health practice. Government schools should regularly organise health camps that integrate haemoglobin screening with structured nutritional education to enhance awareness of iron deficiency anaemia and encourage the adoption of iron-rich dietary practices among adolescent girls and their families. Comparative studies involving government and private school populations are also recommended to examine socioeconomic differences in anaemia prevalence and responsiveness to nutritional interventions. In addition, longitudinal studies should be conducted to evaluate the long-term sustainability of haemoglobin improvements and determine the need for booster or maintenance nutritional strategies. Future investigations should incorporate biochemical markers of iron status, including serum ferritin, serum iron, and total iron-binding capacity, alongside haemoglobin estimation to provide a more comprehensive assessment of iron stores and intervention effectiveness. Furthermore, the food-based nutritional intervention evaluated in the present study should be piloted for integration into existing school mid-day meal programmes under the National Food Security Act to assess its feasibility, acceptability, cost-effectiveness, and scalability within the existing school nutrition infrastructure.

CONCLUSION

Iron deficiency anaemia constitutes a significant, persistent, and entirely preventable public health challenge among school-going adolescent girls in Lucknow, with all enrolled participants demonstrating haemoglobin levels below the normal threshold prior to intervention. The three-week daily provision of rice flakes (50 g) and soyabean chunks (50 g) produced a statistically significant and clinically meaningful improvement in haemoglobin levels, with mean haemoglobin rising from 8.27 g/dL to 10.46 g/dL (mean difference = 2.19 g/dL; $t = 22.275$, $p < 0.001$), 50.0% of participants achieving normal haemoglobin, and severe anaemia entirely eliminated post-intervention.

These findings affirm that a simple, low-cost, culturally acceptable, food-based daily supplement can produce rapid and substantial haematological improvement in anaemic school-age girls within the school setting. The vicious intergenerational cycle of anaemia — wherein an anaemic girl becomes an anaemic adolescent, then an anaemic mother, perpetuating nutritional deficiency across generations can be disrupted through timely, targeted nutritional intervention at the school level. School health nurses, educators, and administrators must collectively champion the routine integration of haemoglobin screening, evidence-based dietary education, and food-based supplementation into national school health and nutrition programmes. In conjunction with the sustained implementation of government initiatives such as the Anemia Mukt Bharat strategy and the WIFS scheme, community-level food-based approaches represent an indispensable, complementary pillar in the national effort to eliminate adolescent anaemia.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

FUNDING

This study received no external funding.

ACKNOWLEDGEMENTS

The authors express sincere gratitude to the school authority, teaching staff, and administrative personnel of selected school, for their cooperation and institutional support. The author thank all participating girls and their families for their willingness to contribute to this study.

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