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Review

Enhancing Health: Effective Interventions Addressing Iron-Deficiency Anaemia Among Adolescent Girls And Reproductive-Aged Women In India: A Comprehensive Systematic Review

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A B S T R A C T

The global prevalence of anaemia, primarily iron-deficiency anaemia (IDA), remains a significant public health concern, especially prevalent in low- and middle-income countries like India. This dissertation evaluates diverse intervention strategies targeting anaemia associated with iron deficiency among vulnerable populations in India, focusing on adolescent girls and reproductive-aged women. The study critically assesses the impact of educational interventions, directly observed oral iron supplementation, intravenous iron therapies, mobile phone call reminders, iron-supplement bars, dietary diversification and nutrition education initiatives. Key findings highlight the effectiveness of educational interventions in enhancing awareness and understanding of anaemia among pregnant women and adolescent girls. Studies suggest improvements in compliance and haemoglobin levels with directly observed oral iron supplementation, while also emphasizing challenges related to noncompliance. Intravenous iron sucrose interventions show promise, especially for severe anaemia, though efficacy in moderate cases requires further research. Innovative methods like mobile phone call reminders and iron-supplement bars demonstrate potential in enhancing compliance and improving iron levels among affected populations. Dietary diversification initiatives and nutrition education underscore the significance of behavioural changes for sustained improvements in dietary quality, essential in combating anaemia, particularly in rural settings. Recommendations emphasize the need for a comprehensive approach, including conducting accurate nationwide surveys using venous blood samples, implementing intermittent iron-folic acid regimens and advocating for innovative, multi-faceted interventions addressing iron deficiency and other micronutrient deficiencies. The importance of continuous research, community engagement and adaptive policy-making for effective anaemia management is highlighted. Implications of the findings suggest the integration of health and nutrition education into school programs, potential inclusion of intravenous iron sucrose in healthcare systems for severe anaemia and the need for accessible community-based workers for effective iron supplementation. While the studies reviewed offer diverse insights into combating anaemia, they highlight the need for tailored, multi-dimensional interventions, continual monitoring and a collaborative effort involving policymakers, healthcare professionals and communities to effectively address anaemia in India's diverse demographics.

Abbreviations

IDA: Iron-deficiency anaemia, WHO: World Health Organization; Hb: Haemoglobin; NIPI: National Iron Plus Initiative; IFA: Iron-folic acid; UNICEF: United Nations International Children's Emergency Fund; Global Nutrition Survey: A worldwide survey

assessing nutrition status; SDG: Sustainable Development Goals; NNACP: National Nutritional Anaemia Control Program; ACP: Anaemia Control Program; NNAPP: National Nutritional Anaemia Prophylaxis Program; PW: Pregnant Women; NFHS: National Family Health Survey; PRISMA: Preferred Reporting Items for Systematic Reviews; PICO: Patient/Population, Intervention, Comparison group, Outcome; MeSH: Medical Subject Headings; SEED Division: Science for Equity, Empowerment & Development Division; DOHBIT: Directly Observed Home-Based Daily Iron Therapy; ASHA: Accredited Social Health Activist; DFS: Double Fortified Salt; RCT-Randomised control trial.

1. Introduction

Iron-deficiency anaemia (IDA) remains a prevalent global health concern, affecting approximately one-third of the world's population[1]. This condition poses a significant public health challenge, notably among women of reproductive age, contributing to elevated maternal mortality rates, especially in low- and middle-income countries[2]. The World Health Organization (WHO) defines anaemia based on low haemoglobin (Hb) levels, specifically below 11.0 g/dL for pregnant women, below 12.0 g/dL for non-pregnant women and below 13.0 g/dL for men. Its impact is notably profound on children, adolescent girls and women of reproductive age, with pregnant women being particularly vulnerable. Factors such as parasitic infections, nutritional deficiencies and inflammatory conditions significantly contribute to the higher prevalence of anaemia in low- and middle-income nations[3]. The compounded effect of anaemia with other prevalent diseases leads to severe health crises, resulting in substantial physical and cognitive impairments[4].

India stands among regions grappling with a high prevalence of anaemia, affecting over 40% of menstruating adult women and adolescent girls, according to the World Health Organization's 2021 data. The 2016 Global Nutrition Survey highlighted India's anaemia struggle, ranking it 170th out of 180 countries concerning the prevalence of anaemia among females[5]. Despite initiatives like the National Iron Plus Initiative (NIPI), focusing primarily on iron-folic acid (IFA) supplementation as part of the anaemia control initiative, high levels of iron-deficiency anaemia persist in India, as highlighted by Kulkarni et al[1]. The UNICEF Data (2019) extensively covers proposals to extend nutrition targets to 2030, emphasizing the severe consequences of maternal and infant anaemia, including heightened risks like postpartum haemorrhage and increased maternal mortality, as well as adverse outcomes such as low birthweight and impaired child development. Acknowledging these implications, the UN Sustainable Development Goals (SDGs) integrated the objective of preventing and addressing anaemia by 2030 among females of childbearing age, representing an ambitious and forward-thinking goal.

Iron deficiency anaemia (IDA) holds paramount significance in public health due to its pervasive nature and impact on various population groups. This systematic review aims to assess the implications of IDA within this domain, focusing on the effectiveness of interventions. Globally, IDA disproportionately affects women of reproductive age and children, necessitating a comprehensive understanding of its multifaceted dimensions for targeted interventions, policy formulation and resource allocation. This study aims to evaluate the impact of intervention approaches specifically aimed at combating anaemia related to iron deficiency among reproductive-aged women and adolescent girls in India. Through a comprehensive analysis of existing literature and studies, this research seeks to illuminate the effectiveness, limitations and potential areas for improvement in intervention strategies addressing this specific health concern within the Indian demographic.

3. Background and Context: Literature Review

4. Background

The problem addressed in the study revolves around the effectiveness of intervention methods targeted at addressing IDA among women of reproductive age and adolescent girls in India. Anaemia, characterized by a decrease in red blood cells count, poses significant health risks to women, expectant mothers and adolescent girls, leading to maternal fatalities and health complications[6,7]. Iron-deficiency anaemia (IDA) particularly impacts preschool children and women of childbearing age, contributing to increased maternal health issues and mortality rates while ranking as the second most prominent cause of disability in the world[3]. Anaemia can lead to substantial impacts on both the mental and physical health, as well as the social and economic welfare of any woman[8]. Mawani et al. emphasizes that the prevalent symptoms of anaemia, notably weakness, fatigue and shortness of breath, have significant implications. These physical manifestations can lead to increased anxiety, depression and a noticeable decline in the overall quality of life for affected individuals, particularly women[9]. Consequently, these symptoms can severely impede daily activities and work performance. Several specific contextual factors contribute to the prevalence of anaemia associated with iron-deficiency in India. These include limited resources within families, inadequate knowledge and awareness, individual food preferences, improper cooking methods, dietary practices, worm infestations, non-adherence to iron-folic acid (IFA) supplementation and other deficiencies within the National Iron Plus Initiative (NIPI). Strengthening NIPI is essential to effectively tackle these challenges and combat IDA[1]. Oral iron supplementation serves as a preventive measure for controlling anaemia within the population. This led to the establishment of India's National Nutritional Anaemia Control Program (NNACP) in 1970, which aimed to distribute iron and folic acid (IFA) tablets to vulnerable groups through paramedical staff. Over time, policy changes within the NNACP evolved into the current National Iron Plus Initiative (NIPI), which involves decentralizing the distribution of IFA supplies to states based on their specific needs[10].

Kapil et al. highlights various challenges hindering the effective implementation of the anaemia control program[11]. These obstacles encompass the insufficient emphasis given by states due to anaemia's inconspicuous nature in comparison to more visible diseases, thus lowering its priority status. Additionally, there's a deficiency in counselling provided to beneficiaries or caregivers regarding the benefits and potential side effects of iron and folic acid (IFA) intake, resulting in subpar compliance. The process of setting up systems for procuring and distributing IFA supplements by state governments, previously sourced from the

Government of India, is currently underway. However, estimating the necessary IFA tablets per village remains a considerable challenge for medical officers. Furthermore, transportation issues persist, especially in delivering IFA supplements to remote rural and tribal areas. Challenges also arise in training health workers, Integrated Child Development Services staff and schoolteachers on the weekly IFA supplementation program for children aged 6-19 years.

4.2. Aim of the study

The purpose of the study is to investigate the effectiveness of intervention methods for managing anaemia associated with iron deficiency among reproductive-aged women and adolescent girls and in India. This study aims to address the persistent issue of anaemia prevalence among vulnerable populations in India, particularly in light of global estimates reported by the World Health Organization (WHO). According to WHO's global estimation in 2011, about 38.2% (equivalent to 32.4 million) of expectant mothers worldwide were affected by anaemia, while the prevalence among non-pregnant women was approximately 29%. These statistics highlight the substantial burden of anaemia faced by women, especially those in reproductive age groups, underscoring the urgency and importance of exploring effective intervention strategies to combat IDA in India[5].

4.3. Knowledge gap

The landscape of research on anaemia among adolescent girls and reproductive-aged women in India underscores a critical gap in comprehending the effectiveness of interventions, specifically targeting iron deficiency-associated anaemia. Despite the implementation of diverse interventions and programs by the Government of India, anaemia's prevalence has remained persistently high, with concerning upward trends noted between 2015-2016 and 2019-2021. This situation necessitates a comprehensive evaluation of intervention efficacy focusing on iron deficiency anaemia within these demographic groups. Existing studies have been geographically limited and insufficiently comprehensive, concentrated within specific regions. Consequently, this restricts the generalizability of findings, impeding the development of universally effective intervention strategies. A systematic review is imperative to consolidate and assess the diverse interventions across various geographical areas in India, determining their impact on iron deficiency-associated anaemia among these specific populations. The research should address the limitations of food-based and clinical strategies criticized for their prematurity and lack of sufficiency in addressing iron deficiency anaemia. Evaluation of these strategies, including food fortification programs, iron supplementation initiatives and clinical approaches, becomes urgent to reduce anaemia within targeted demographic groups.

Research indicates disparities in access to anaemia screening services, leading to underrepresentation or exclusion of certain socioeconomically disadvantaged or geographically remote populations. This inequity exacerbates the prevalence of undiagnosed anaemia, particularly in areas with limited healthcare infrastructure or in marginalized communities. Studies often overlook or inadequately explore the socio-cultural determinants contributing to anaemia in India. Factors such as dietary practices, cultural taboos, gender inequalities, traditional beliefs and perceptions regarding health and menstruation can significantly impact anaemia prevalence. Understanding these socio-cultural elements is crucial for designing effective interventions and screening programs tailored to diverse cultural contexts within India. Limited Longitudinal Studies tracking the effectiveness of anaemia screening programs and their impact on high-risk populations are sparse. Evaluating the sustained effectiveness of screening initiatives over time is crucial for identifying successful strategies and areas requiring improvement or modification.

Moreover, the research gap in intervention methods for iron deficiency-associated anaemia in India extends due to a lack of studies covering both non-pregnant and pregnant individuals within adolescent and reproductive-aged groups. Existing literature often segregates pregnant and non-pregnant cohorts, limiting a holistic understanding across critical life stages and complicating comparative analyses. Including both pregnant and non-pregnant females within the same age cohorts in intervention studies is crucial to comprehend varying impacts and prevalence rates, thereby facilitating tailored intervention approaches. Recent proposals emphasize the necessity of conducting nationwide surveys using venous blood samples to estimate anaemia burden and its determinants across age groups, providing a more accurate assessment. The research should critically analyse existing interventions such as food fortification and iron supplementation programs, clarifying appropriate dosages and potential harmful effects.

4.4. Justifications of the study

The World Health Organization (WHO) has indicated that roughly two billion people globally experience anaemia, with half of all anaemia cases attributed to iron deficiency anaemia (WHO,2011). In India, the prevalence of IDA remains high and the country heavily relies on iron-folic acid (IFA) supplementation through the National Iron Plus Initiative (NIPI) as part of the Anaemia Control Program (ACP)[1]. The WHO considers India as a region with a significant burden of anaemia, affecting more than 40% of menstruating adult women and adolescent girls[5]. Despite efforts made through the National Nutritional Anaemia Prophylaxis Program (NNAPP), the prevalence of anaemia has increased among pregnant women (PW), rising from 49.7% to 52.2%. Similarly, anaemia prevalence has also risen among women of reproductive age, increasing from 53.1% to 57.0% between the second and fifth rounds of the National Family Health Survey (NFHS)[6]. The occurrence of anaemia among adolescent females in India increased from 54.2% (99% CI: 53.6–54.8) to 58.9% (99% CI: 58.3–59.5) from 2015–16 to 2019–21. Among the 28 states in India, 21 experienced an increase in anaemia prevalence, though the extent of this increase varied among states. While Chhattisgarh, Assam and Tripura demonstrated a significant surge of 15 percentage points, Karnataka, Punjab, Telangana, Madhya Pradesh and Bihar reported a slight increase of less than 5 percentage points[12]. Prior research conducted in India has concentrated on the topic of anaemia among adolescent females; nonetheless, these studies have been constrained in their coverage, primarily centring on restricted geographical regions[8].

Given this concerning trend of increasing anaemia prevalence despite existing interventions, there is a crucial need to evaluate the effectiveness of intervention methods for managing anaemia associated with iron deficiency among adolescent girls and women of reproductive age in India. Understanding the limitations and shortcomings of current programs and exploring alternative or supplementary approaches could provide invaluable insights to address and mitigate the persistent challenge of anaemia in these vulnerable populations.

4.5. Research question

What is the effectiveness of intervention methods for anaemia associated with iron deficiency among adolescent girls and reproductive aged women in India?

4.6. Research objectives

Investigate the impact of diverse intervention approaches (including iron supplementation, dietary modifications and educational programs) on reducing iron deficiency-related anaemia prevalence among adolescent girls and reproductive-aged women in India.

Analyse the impact of different intervention methods in the targeted population.

5. Methodological Approach

5.1. Research question

This systematic review was focused on the following study question. What is the effectiveness of intervention methods for anaemia associated with iron deficiency among adolescent girls and reproductive aged women in India? This question targeted individuals encompassing both adolescent girls and women of reproductive age, spanning from 10 to 49 years old.

5.2. Study design

This study concentrates on examining original research literature while adhering to the guidelines established by the Preferred Reporting Items for Systematic Reviews (PRISMA).

5.3. Search strategy

The current study reviewed complete publications, including titles and abstracts, of observational epidemiological reviews and experimental studies (randomized control trials) focused on assessing intervention effectiveness for anaemia related to iron deficiency among adolescent girls and reproductive-aged women in India. Employing the "PICO (Patient/Population, Intervention, Comparison group, Outcome)" approach, the researcher filtered studies based on the topic, title and abstract, specifically targeting samples of adolescent girls and reproductive-aged women with iron deficiency anaemia from India (Patient/Population), Various methods aimed at addressing anaemia related to iron deficiency like iron supplementation, dietary changes to enhance iron intake, health education programs, medical treatments (Intervention), comparing against a control group or different intervention strategies (Comparison group) and the impact on their haemoglobin levels or anaemia status (Outcome). The fundamental question guiding this review is: What is the effectiveness of intervention methods for anaemia associated with iron deficiency among adolescent girls and reproductive aged women in India? Additionally, the study adheres to several recommendations outlined in the PRISMA statement for conducting a systematic review.

5.4. Databases

The study conducted an electronic search across several databases to fulfil the primary criteria of the cross-sectional systematic review. To gather data pertinent to the study's topic, the researcher accessed literature from diverse sources. Multiple databases such as EMBASE, Scopus, Science Direct, Cochrane Library, PubMed Central, EBSCOhost, Web of Science were utilized to retrieve science-related papers from journals.

Additionally, Google Scholar was employed to identify potential studies that might not have been included in the specified databases. This search methodology was guided by the PRISMA approach to ensure a comprehensive exploration of published articles.

5.5. Search terms and keywords

The researcher utilized a specific search strategy tailored for a particular platform, employing a combination of text words and Medical Subject Headings (MeSH) controlled terms, particularly geared toward databases like PubMed. The search terms encompassed phrases related to the effectiveness of interventions or treatments, specifically targeting anaemia associated with iron deficiency in adolescent girls, reproductive-aged women or females in India. Such as (effectiveness of intervention OR effectiveness of treatment OR effectiveness of preventive measures) AND (anaemia associated with iron deficiency OR iron deficiency anaemia) AND (adolescent girls OR reproductive aged women OR females) AND (India OR Indian).

5.6. Inclusion criteria

The researcher applied specific criteria for article inclusion, focusing on studies meeting particular standards: (1) The population under study included adolescent girls and reproductive-aged women ranging from 10 to 49 years old, hailing from India; (2) The studies examined the effectiveness of treatment methods or interventions for iron deficiency anaemia among this demographic; (3) Included studies had a control group for comparison purposes; (4) The emphasis was on interventions and treatment plans aimed at addressing iron deficiency anaemia among adolescent girls and reproductive-aged women in India from a parental perspective.

After removing duplicate studies, the researcher evaluated the remaining articles based on their titles and abstracts. Only studies with open access to the full text and adhering to the inclusion criteria were considered. Any discrepancies were resolved and studies not meeting the criteria were excluded.

Additionally, the researcher checked the reference lists of retrieved articles. Articles published between January 1, 2017 and 2023 were selected, specifically focusing on children and young adults. This timeframe aimed to match the current status and appropriate treatment approaches used by individuals, groups and governmental bodies to manage iron deficiency anaemia in adolescent girls and reproductive-aged women. Therefore, the researcher included non-randomised intervention studies and RCTs published between 2013 and 2023 in the mentioned databases, limited to English language publications.

5.7. Exclusion criteria

The study excluded research that focused on assessing the effectiveness of intervention methods for anaemia not related to iron deficiency among adolescent girls and reproductive-aged women in India. Additionally, studies conducted before 2013, those published in languages other than English and studies lacking statistical analysis were excluded. Articles addressing anaemia prevalence, incidence or iron deficiency anaemia outside the age group of 10-49 were also not considered. Reports that did not specifically address iron deficiency anaemia and those lacking intervention or treatment-related information were excluded. Furthermore, research conducted in regions other than India was not included in the study.

5.8. Data Collection

This research utilized a Microsoft Excel spreadsheet to classify included articles according to various criteria, such as the size of the sample, age and gender distribution within the studied population, effectiveness of interventions, location of the study, authors, demographic details of participants and publication year.

5.9. Data Extraction

The research gathered data from the current study, yielding a final selection of 12 studies through a data extraction form. Key extracted information included, among other details, author names, journal titles, publication dates (year), study locations (local settings), the specific target population (comprising sample size and age range), the assessment tools or methodology used to gather specific information and the study findings.

5.10. Study Selection

Initially, the research identified 381 articles through electronic searches. After removing 36 duplicates and excluding 110 articles for various reasons, 235 unique studies remained. Upon reviewing titles and abstracts, 210 citations were excluded, leaving 25 records for further assessment. However, upon closer examination, 13 of these articles were found unsuitable for inclusion due to reasons such as not meeting specific criteria related to the topic, population, lacking outcome data, focusing on anaemia unrelated to iron deficiency, considering different populations or genders and not being peer-reviewed.
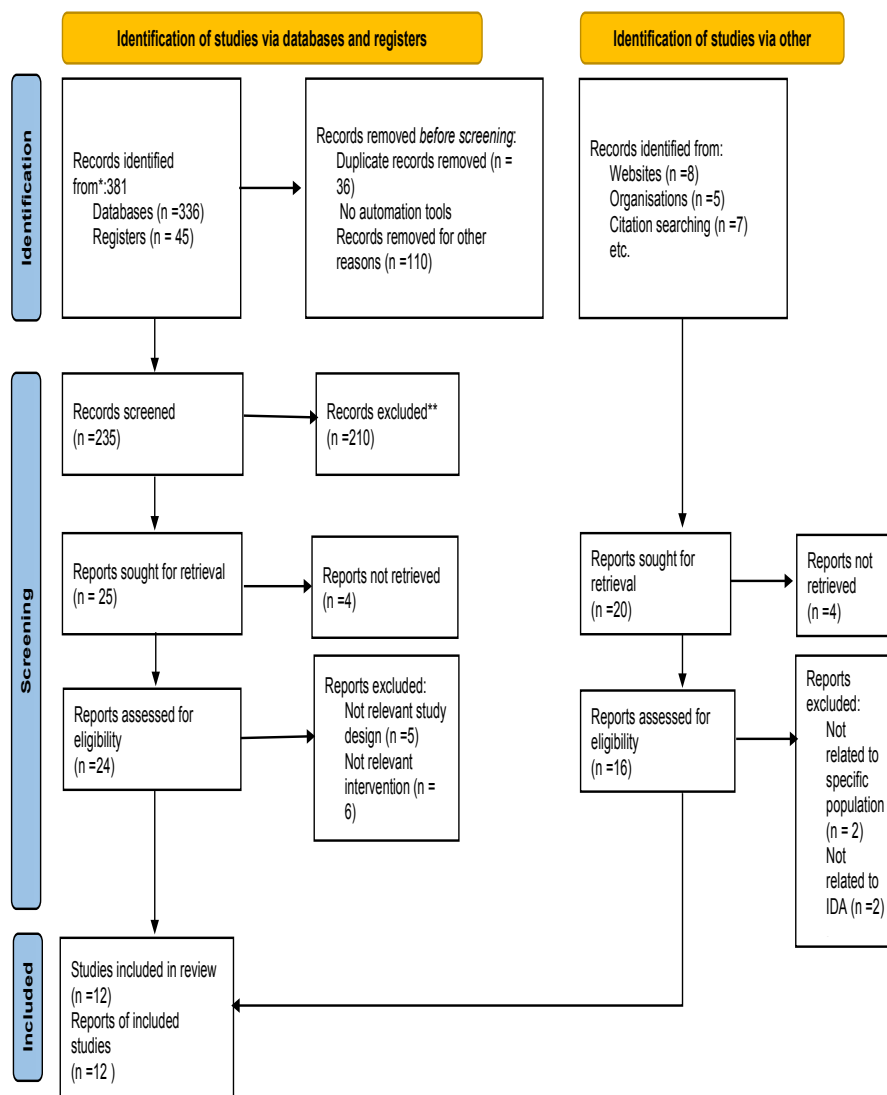
5.10.1. Prisma

Figure 1: Prisma 2020.

5.11. Methodological quality assessment

The researcher diligently examined complete articles, giving preference to top-tier research published in esteemed sources like academic journals and books. Materials without peer-review, such as technical reports and online presentations, were omitted. Only reports of outstanding quality with thorough citations were included in the review. Evaluation of the study's quality was performed using methodologies like PRISMA, CASP and ROBINS 1 within the systematic review.

The studies included in this compilation obtained financial support from various institutions and organizations. Gupta et al. were funded by the Indian Council of Medical Research in New Delhi[13]. Neogi et al. received backing from WHO, India[14]. Khanna et al. obtained support from the Postgraduate Institute of Medical Education and Research in Chandigarh, India[15]. Salam et al. were

funded by the National Institute for Health and Care Research[16]. Additionally, Rao et al. received support from the Science and Society Division, Department of Science and Technology in New Delhi[17]. Lastly, Bharti et al. secured a grant from the SEED Division (Science for Equity, Empowerment & Development), Department of Science & Technology, Ministry of Science & Technology in New Delhi, India[18].

5.12. Data analysis

This research utilized thematic analysis as its methodological approach to analyse and present the data. This process involved coding and assessing interconnected themes, specifically concentrating on recognizing repetitive patterns and themes evident within the dataset.

5.13. Ethics

Since this study involves a secondary analysis of already appropriately coded data, the researcher did not seek ethical review from the institutional review board. Nevertheless, prior consent was obtained from the institutional review board to conduct the present study.

6. Results

6.1. Study characteristics

This research involves 12 studies, selected using PRISMA **(Table 1)**, investigating interventions aimed at addressing iron deficiency anaemia among women of reproductive age and adolescent girls. Among these studies, seven were randomized controlled trials and five were non-randomized intervention studies. The study methodology followed the clinical question framework, utilizing the PICO format (Patient/ Problem, Intervention, Comparison, Outcome) from evidence-based medicine. This systematic review employed the PICO framework to assess the chosen studies, emphasizing high quality and minimizing bias. The analysis concentrated on four primary components: the participants involved in the studies, the interventions applied, comparisons made and the outcomes observed. The study sample encompassed the patient/population aspect, while tests and analyses pertained to the intervention segment. A summarized presentation of the study characteristics is provided in the table.

Table 1: Study Characteristics.

Author and Title of the journal	Design	Sample Type & Size	Data Collection/ Intervention	Tests & Analysis	Summary of Findings/ Outcomes
Ahamed et al. Effect of Directly Observed Oral Iron Supplementation During Pregnancy on Iron Status in a Rural Population in Haryana: A Randomized Controlled Trial[19]	community-based open labeled parallel block-randomized controlled trial	The study required various sample sizes: 200 pregnant women per group for anemia reduction, 30 per group for hemoglobin level increase and 90 per group for compliance differences. Inclusion criteria encompassed first-trimester pregnant women ready to stay at their current address until the completion of sixth month of pregnancy exclusion criteria involved severe anemia, malabsorption syndrome, psychiatric illness, recent severe bleeding or excessive iron supplement intake in the last month.	The data collection method involved selecting 40 ASHAs to oversee 10 pregnant women each, drawing blood samples for hemoglobin and serum ferritin measurements, storing and transporting samples for laboratory analysis, administering IFA tablets according to groups, monitoring compliance, recording noncompliance reasons and performing laboratory procedures for hemoglobin, serum ferritin and sTfR analysis at designated intervals.	SPSS for Windows 22.0, IBM	Supervised oral iron (IFA) supplementation enhances adherence to the regimen and positively impacts hemoglobin levels in pregnant women. Nevertheless, the intervention group did not exhibit a significantly greater improvement in serum ferritin levels or a reduction in the prevalence of IDA compared to the control group.
Bharti et al. A Community-Based Cluster Randomized Controlled Trial of "Directly Observed Home-Based Daily Iron Therapy" in Lowering Prevalence of Anemia in Rural Women and Adolescent Girls[18]	Community-based cluster randomized controlled trial	The trial was conducted in Block Sangrah, district Sirmour, Himachal Pradesh, India, from May 2010 to May 2011. It included anemic rural women (including various age groups and conditions) and adolescent girls aged 13 and older, totaling 32 clusters within 40 purposively selected hilly villages, while exclusion criteria involved certain medical conditions and ongoing iron supplementation beyond 4 weeks	Adolescent girls and anemic women were randomly assigned to receive either DOHBIT; n = supervised treatment in 16 villages involved 524 individuals, while unsupervised self-treatment at home involved 535 individuals across the same number of villages, each lasting for a period of 90 days. The study included a total of 1,059 participants (524 in the DOHBIT group and 535 in the self-treatment group). Exclusion criteria comprised active medical or psychiatric conditions, recent gastrointestinal bleeding or peptic ulcer diagnosis and ongoing iron supplementation beyond four weeks.	Stata software version IC/12.1 was used for conducting the various statistical analyses	The trial introduces an innovative approach to tackle anemia-related challenges in healthcare, particularly concerning low compliance, limited coverage and accessibility issues. While not revolutionary, it offers evidence-based and scalable strategies to improve iron therapy adherence and coverage, ultimately mitigating anemia in adolescent girls and rural women.

Gupta et al. Combating Iron Deficiency Anaemia among School Going Adolescent Girls in a Hilly State of North India: Effectiveness of Intermittent Versus Daily Administration of Iron Folic Acid Tablets[13]	Randomized controlled trial	In Shimla district, Himachal Pradesh, 1596 adolescent school girls were screened for anemia across nine schools, revealing 340 cases of mild to moderate anemia. After excluding nine participants who refused, 331 anemic girls aged 10-19 were enrolled. Using a lottery method, they were divided into three intervention groups: once-weekly (108 participants), bi-weekly (112 participants) and daily (111 participants).	The data collection and intervention methods involved the distribution of iron folic acid tablets, monitoring their consumption, recording any side effects reported by the participants and collecting blood samples for analysis at both the beginning and conclusion of the study	The analysis for this study was conducted utilizing Epi Info software designed for Windows (version 7, CDC, Atlanta, USA).	Occasional intake of IFA tablets produces comparable improvements in Hb and serum ferritin levels as daily consumption. Moreover, administering IFA tablets on a weekly basis is affected with fewer adverse effects compared to daily usage. As a solution to the adolescent health issue in India, it is advised that policymakers in the country consider adopting intermittent IFA regimens.
Kamalaja et al. Effectiveness of Health and Nutritional Education Intervention to Combat Anaemia Problem among Adolescent Girls[20]	Community based intervention study	300 adolescent girls between the ages of 13 and 17, attending regular school and residing in four villages within Moinabad mandal, Rajendranagar district, Telangana, India, were chosen due to having hemoglobin levels below 12 mg/100 ml. These girls were divided into two groups: a control group of 150 girls and an experimental group, which also comprised 150 girls.	A standardized schedule was created for gathering information. All 300 participants provided general details concerning their family type, family size, parents' occupation and educational status , meal schedules and dietary habits.		The research highlighted that rural adolescent girls lack essential health and nutrition knowledge due to multiple factors, necessitating educational interventions. Implementing health and nutrition education significantly improved awareness and knowledge levels, emphasizing its importance in enhancing nutritional status for future well-being.
Khanna et al. Impact of Community Based Nutrition Intervention in the Prevention and Control of Anaemia Among Reproductive Aged Women of India[15]	Community-based intervention study	The study involved three phases, including a six-month intervention period. At the outset, 600 women aged between 15 and 49, who were within the reproductive age range, were selected randomly for screening. Out of this initial pool, 443 women consented to take part. Women who were pregnant, exclusively breastfeeding or had a history of using prescription medications continuously for two weeks or longer during the study were excluded from participating.	The study conducted a household survey and collected data from 443 participants, assessing nutritional status through food recall and physical measurements. Biochemical analysis involving various biomarkers was performed on 153 participants initially and 141 at the study's end, recommending ferritin with mean corpuscular volume (MCV) as a superior indicator for detecting anemia compared to hemoglobin.	S.S, T. S	The intervention successfully improved women's anemia status, highlighting the necessity for continuous efforts to alleviate this issue. To achieve this, offering informative educational programs focusing on nutrition and implementing multicomponent interventions involving healthcare providers, families and addressing nutritional deficiencies are suggested for effective long-term solutions.
Mehta et al. Efficacy of iron-supplement bars to reduce anaemia in urban Indian women: a cluster-randomized controlled trial[21]	Cluster-randomized controlled trial	Recruited non-pregnant women aged 18-35 with hemoglobin concentrations below 12 g/dL for an intervention to test the efficacy of daily iron supplement bars. Out of 361 women attending anemia-education, screening and treating camps, 179 were eligible to participate in the controlled randomized trial (c-RCT).	The study employed clinical assessments, including blood tests and questionnaires, alongside biological sample collection, clustered data analysis and record keeping to assess the influence of iron-enriched snack bars in diminishing anemia among Indian women in the reproductive age bracket, a cluster-randomized controlled trial was conducted.	Linear Mixed Models (LMM), Generalized Estimating Equations (GEE)	The study found that daily consumption of iron-supplement bars significantly increased Hb and hematocrit levels in non-pregnant anemic women within 90 days, showing improvement as early as 15 days. Around 70.8% reached normal hemoglobin levels, 82.1% achieved normal hematocrit levels and no side effects were reported, indicating the bars as a practical solution for addressing iron deficiency in this group.

Neogi et al. Safety and effectiveness of intravenous iron sucrose versus standard oral iron therapy in pregnant women with moderate-to-severe anaemia in India: a multicentre, open-label, phase 3, randomised, controlled trial[14]	A multicenter, open-label, phase 3, randomized, controlled trial	From January 31, 2014, to July 31, 2017, a total of 2018 pregnant women, aged 18 or above, at a gestational age between 20 to 32 weeks and having hemoglobin concentrations ranging from 5 to 8 g/dL or 5 to 9 g were included in the research. Among them, 999 were randomly designated to the intravenous iron sucrose group, while 1019 were allocated to the standard therapy group.	The study utilized a combination of quantitative and qualitative data collection methods. Quantitative methods involved screening based on specific criteria, random allocation of participants to intervention groups, clinical assessments of laboratory values, adherence monitoring, telephone follow-ups and documentation of adverse events. Qualitative data were gathered through semi-structured in-depth interviews (IDIs) carried out with educators and focus group discussions (FGDs). with students to explore perspectives, experiences and reactions regarding the educational intervention's effectiveness and challenges	Stata, version 15.1	In essence, intravenous iron sucrose emerges as a potentially safer option for managing severe anaemia during pregnancy, specifically between the 20th and 32nd weeks of gestation, particularly in cases where there is low compliance or an inability to tolerate oral iron therapy.
Nimbalkar et al. Impact of educational intervention regarding anaemia and its preventive measures among pregnant women: an interventional study[22]	Interventional study	One hundred pregnant women participated in the study after providing informed written consent. The initial assessment focused on the baseline knowledge of pregnant women concerning anemia and its precaution methods.	pre-designed, pre-tested and semi structured questionnaire		A single educational session led to a noteworthy enhancement in the understanding of anemia and its preventive measures among pregnant women. Regular educational interventions in outpatient departments are recommended to continually improve knowledge and encourage the adoption of healthy lifestyles, thereby preventing anemia and other micronutrient deficiencies during and after pregnancy
Rao et al. Dietary diversification for prevention of anaemia among women of childbearing age from rural India[17]	Intervention study	The study, covering 8,300 individuals, including 317 eligible non-pregnant women aged 15 to 35 from a subsistence farming community, residing in extended family setups with marginal land holdings, focuses on data from the first year.	The study employed quantitative methods such as blood sampling for hemoglobin levels and measurements of maternal characteristics while potentially integrating qualitative elements, such as observations or interviews, during a nutrition education intervention aimed at reducing anemia among rural non-pregnant women in India	SPSS	The study suggests that addressing the pervasive issue of anemia in rural India requires educational efforts aimed at altering understanding, mindsets and dietary habits within households. Additionally, it emphasizes the importance of nutrition education and social actions for sustainable improvements in diet quality among young rural mothers, suggesting strategies beyond technical solutions like fortification
Salam et al. Impact of a school-based nutrition educational intervention on knowledge related to iron deficiency anaemia in rural Karnataka, India: A mixed methods pre–post interventional study[16].	mixed-methods pre–post intervention study	Study involving 455 children, approximately 60% were aged 11-12, 56% of the children were females. These children were either in the sixth year (51.9%). or year 7 (48.1%). A total of 413 (90.8%) children took part in both pre-intervention and post-intervention tests. Seven teachers aged 30-45 participated in in-depth interviews.	Pretested Knowledge Assessment Questionnaire, Post-Intervention Testing, semi-structured interviews conducted in depth. Focus Group Discussions, Audio Recording and Note-Taking, Short Summary Preparation	The data analysis methods used in the study involved contributions from multiple authors, including DOCA, GK, BG, SSS, SG, AM, SR, BP, UC, JM, SP, PV, CK and AD.	The study showed the success of an interactive nutrition intervention for adolescents, boosting anemia knowledge, encouraging dietary changes and increasing iron and folic acid demand through interactive teaching

Sontakke et al. Effect of Mobile Phone Call Reminders With Standard Therapy Versus Standard Therapy Alone on Compliance with Iron Supplementation in Antenatal Women with Iron Deficiency Anaemia: A Randomized Controlled Trial[23]	Randomized controlled open-label trial	Study involving 253 pregnant women with IDA with Hb level 8-11 gm/dl between 13-28 weeks of gestation excluded 13 participants who did not respond to mobile phone call reminders for four consecutive days, resulting in a 5.13% attrition rate. The remaining participants were divided into a cohort of 120 women in the study group and an equivalent cohort of 120 women in the control group for further analysis.	The study employed a combination of clinical examinations, laboratory tests and questionnaires to collect data on the participants' demographics, health status and response to the interventions	SPSS Version 20.0, The Chi-square test	This research suggests that the incorporation of mobile phone call reminders alongside regular iron supplementation enhances adherence and raises hemoglobin levels during delivery in pregnant women experiencing iron deficiency anemia, as opposed to relying solely on standard therapy. Common challenges in compliance include daily tablet consumption, forgetfulness and side effects, which can be mitigated through patient education
Tigga and Debbarma A comparative study to evaluate oral iron and intravenous iron sucrose for treatment of anaemia in pregnancy in a poor socioeconomic region of Northeast India[24]	Randomized controlled trial (RCT)	The sample size for this study consisted of 100 consenting women with singleton pregnancies, a gestational age ranging from 18 to 28 weeks and diagnosed with iron-deficiency anemia, verified through a peripheral smear and Hb levels between 7 and 10.9 g/dL)	Clinical examinations and laboratory test	Unpaired t-test, Chi-square test	In the treatment of antenatal anemia, intravenous iron sucrose (IVIS) was determined to be more efficacious than oral iron therapy and no significant adverse drug reactions were observed

6.2. Critical appraisal tool

The research employed the Critical Appraisal Skills Programme (CASP) 2018 framework for both selecting articles and evaluating their quality. Specifically, it utilized the CASP Randomised Controlled Trial Standard Checklist, detailed in table 2, which consists of 11 questions designed to systematically guide the reader in assessing various aspects of a study. The checklist is structured into sections: Section A for quickly screening the study design's validity using the initial three questions, followed by Sections B, C and D for assessing methodological robustness and further appraisal if needed. Responses are categorized as 'Yes,' 'No,' or 'Can't tell,' with prompts under each question highlighting essential considerations. Additionally, space is provided for noting the reasons behind the answers. It's essential to note that CASP checklists are primarily intended for educational purposes in workshop settings and they do not recommend the use of a scoring system[25].

Table 2: CASP Randomized Controlled Trial Standard Checklist.

	Ahamed et al.[19]	Bharti et al.[18]	Gupta et al.[13]	Mehta et al.[21]	Neogi et al.[14]	Sontakke et al.[23]	Tigga and Debbarma[24]
Did the study address a clearly focused research question?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the assignment of participants to interventions randomised?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were all participants who entered the study accounted for at its conclusion?	Yes	Yes	Yes	Yes	No	Yes	Yes
Were the participants 'blind' to intervention they were given?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the investigators 'blind' to the intervention they were giving to participants?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the people assessing/analysing outcome/s 'blinded'?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the study groups similar at the start of the randomised controlled trial?	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Apart from the experimental intervention, did each study group receive the same level of care (that is, were they treated equally)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the effects of intervention reported comprehensively?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the precision of the estimate of the intervention or treatment effect reported?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Do the benefits of the experimental intervention outweigh the harms and costs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Can the results be applied to your local population/in your context?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Would the experimental intervention provide greater value to the people in your care than any of the existing interventions?	Yes	Yes	Yes	Yes	Yes	Yes	Yes

6.3. ROBINS-I tool for non-randomised interventional studies

Non-randomized studies hold a significant role in assessing healthcare interventions, yet they can be susceptible to biases that influence their outcomes. Therefore, understanding and evaluating their strengths and limitations are pivotal. ROBINS-I (Risk of Bias in Non-randomised Studies - of Interventions) serves as a new tool to gauge bias risk in estimating intervention effectiveness compared to other methods, especially in studies where randomization wasn't used in treatment allocation. Assessing responses to signalling questions lays the groundwork for domain-specific evaluations of bias probability, which in turn contributes to an overall bias determination for a particular outcome. The term "judgment" is essential here, emphasizing the need for reviewers to appraise both the bias extent within a specific domain and its comparative impact across different domains.

The levels of bias assessment classification include "Low risk," "Moderate risk," "Serious risk," and "Critical risk" of bias. This review incorporates 5 non-randomized intervention studies as presented by Sterne et al[26].

Table 3: ROBINS-I for non-randomised interventional studies.

	Confounding	Selection of participants	Classification of intervention	Deviation of intended interventions	Missing data	Measurement of outcomes	Selection of reported results	Overall risk of bias
Kamalaja et al. (2018)[20]	Moderate	Low	Low	Low	Low	Moderate	Moderate	Moderate
Khanna et al. (2023)[15]	Moderate	Low	Low	Low	Low	Moderate	Low	Moderate
Nimbalkar et al. (2017)[22]	Moderate	Low	Low	Low	Low	Moderate	Moderate	Moderate
Rao et al. (2013)[17]	Moderate	Moderate	Low	Low	Low	Moderate	Moderate	Moderate
Salam et al. (2023)[16]	Moderate	Low	Low	Low	Low	Moderate	Moderate	Moderate

6.4. Key themes

THEME	SOURCE
Impact of Educational intervention among pregnant women	Nimbalkar et al[22]
Effect of Directly Observed Oral Iron Supplementation	Ahmed et al[19]
Oral iron and intravenous iron sucrose	Neogi et al. (2019), Tigga and Debbarma[14,2]4
Effect of Mobile Phone Call Reminders With Standard Therapy	Sontakke et al[23]
Efficacy of iron-supplement bars	Mehta et al[21]
Directly Observed Home-Based Daily Iron Therapy	Bharti et al[18]
Dietary diversification for prevention of anemia	Rao et al[17]
Impact of nutrition educational intervention	Salam et al, Kamalaja et al[16,20]
Effect of nutritional intervention	Khanna et al[15]
Effect of intermittent versus daily administration of Iron	Gupta et al[13]

6.4.1. Impact of educational intervention in pregnancy: The study by Nimbalkar et al. aimed to evaluate how an educational intervention impacted pregnant women's awareness of anaemia and its preventive measures[22]. Their findings indicated that a solitary educational session notably improved pregnant women's comprehension of anaemia and its prevention. This suggests that educational interventions are effective in enhancing awareness of anaemia among this group.

6.4.2. Effect of directly observed oral iron supplementation among pregnant women: The community-based RCT by Ahmed et al. aimed to evaluate the impact of supervised iron-folic acid (IFA) supplementation on anaemia prevalence, iron status improvement and adherence among pregnant women compared to a control group in rural Haryana[19]. The study, conducted across seventeen villages, observed that supervised oral iron supplementation led to enhanced adherence to the regimen and showed a positive effect on haemoglobin levels in pregnant women. However, despite these improvements, the intervention group did not exhibit a significantly greater enhancement in serum ferritin levels or a reduction in the prevalence of anaemia compared to the control group.

6.4.3. Oral Iron Versus Intravenous Iron Sucrose: Neogi et al. and Tigga and Debbarma conducted comparative research exploring treatments for anaemia among pregnant women, juxtaposing intravenous iron sucrose against oral iron therapy[14,24]. Neogi et al. executed an Open-label, multicentre phase 3, RCT aiming to assess the safety and efficacy of intravenous iron sucrose versus standard oral iron therapy for moderate-to-severe anaemia in pregnant women[14]. Their results suggested that intravenous iron sucrose might serve as a potentially safer substitute, particularly for severe anaemia between the 20-32 weeks of gestation, particularly in cases where there are adherence or tolerance issues with oral iron therapy. However, challenges in attaining the intended sample size and completely assessing the primary outcome impacted the findings' applicability.

On the other hand, Tigga and Debbarma concentrated on comparing the safety and effectiveness of oral iron versus intravenous iron sucrose treatments specifically for iron-deficiency anaemia in pregnant women residing in a socioeconomically disadvantaged area in Northeast India[24]. Their study indicated that intravenous iron sucrose was more efficacious in addressing antenatal anaemia compared to oral iron therapy, with no noteworthy adverse drug reactions observed. Nonetheless, this study was constrained by its relatively limited sample size and potential limitations in capturing long-term effects or differences between treatments beyond the 8-week follow-up period. Both studies suggest that intravenous iron sucrose may confer advantages in managing severe anaemia during pregnancy, particularly when faced with challenges linked to adherence or tolerance to oral iron therapy.

6.4.4. Effect of mobile phone call reminders with standard therapy: The research by Sontakke et al. explored the efficacy of mobile phone call reminders alongside standard therapy on compliance with iron supplementation among antenatal women diagnosed with iron deficiency anaemia[23]. The research underscores the positive impact of mobile phone call reminders as an adjunct to standard therapy in enhancing compliance and improving haemoglobin levels in pregnant women diagnosed with iron deficiency anaemia.

6.4.5. Efficacy of iron-supplement bars: The research conducted by Mehta et al. aimed to assess the efficacy of iron supplement bars in elevating Hb concentrations and haematocrit percentages in non-pregnant anaemic women of reproductive age in urban India with haemoglobin levels below 12 g/dL[21]. The study revealed that daily consumption of iron-supplement bars significantly increased haemoglobin and haematocrit levels in non-pregnant anaemic women within 90 days, showing noticeable improvement as early as 15 days. Despite starting with low iron stores, a considerable proportion of women in the intervention group achieved normal haemoglobin concentrations (70.8%) and haematocrit percentages (82.1%) without reported side effects. This suggests that iron-supplement bars could offer a practical and effective solution to address iron deficiency in this demographic.

6.4.6. Directly observed home-based daily iron therapy: Bharti et al. carried out a community-cantered cluster randomized controlled trial aimed at assessing the efficacy of "Directly Observed Home-Based Daily Iron Therapy" (DOHBIT) in decreasing the occurrence of anaemia[18]. The findings suggest that DOHBIT presents an innovative approach to address challenges related to anaemia in healthcare, particularly in improving compliance, coverage and accessibility issues. While not groundbreaking, this approach offers evidence-based and scalable strategies to enhance iron therapy adherence and coverage, ultimately mitigating anaemia among rural women and adolescent girls.

6.4.7. Dietary diversification for prevention of anaemia: Rao, et al. conducted research with the objective of assessing how dietary diversification, demonstrated through live presentations of iron-rich recipes, could enhance the dietary iron status of rural Indian women of childbearing age who were not pregnant[17]. Employing quantitative methods such as blood sampling for haemoglobin levels and measurements of maternal characteristics, alongside potential integration of qualitative elements during a nutrition education intervention, the study emphasized the need for education to modify attitudes, knowledge and household dietary regimen to address anaemia in rural India. It highlighted the significance of nutrition education and social actions for sustainable improvements in diet quality among young rural mothers, advocating for strategies beyond technical solutions like fortification.

6.4.8. Impact of nutrition educational intervention

Salam, et al. conducted research to assess the effects of a nutrition-focused educational program in schools on adolescents' understanding of iron deficiency anaemia in rural Karnataka, India[16]. The results revealed that the interactive nutrition intervention effectively increased adolescents' awareness of anaemia. It encouraged dietary modifications and increased the understanding of the importance of iron and folic acid through interactive teaching methods. However, the study had limitations, focusing mainly on knowledge rather than behavioural changes. It also faced constraints related to a short post-intervention duration due to the pandemic and a narrow grade-level focus.

Similarly, Kamalaja, et al. conducted a community-cantered intervention targeting health and nutrition education among adolescents aged 13-17 years[20]. The results showed a minor enhancement in haemoglobin levels after the intervention, although its impact was limited. However, there was a notable improvement in knowledge, attitude and practices related to preventing anaemia, suggesting that nutrition education initiatives have the potential to lower anaemia prevalence among adolescent girls.

6.4.9. Effect of nutritional intervention: Khanna et al. aimed to create a nutritional intervention to prevent and manage anaemia in women of reproductive age[15]. The sole mean ferritin level displayed noteworthy enhancement ($p < 0.001$). Additionally, a substantial reduction of approximately 15% in the prevalence of anaemia was evident post-intervention ($p = 0.027$).

6.4.10. Intermittent Versus Daily Administration of Iron Folic Acid Tablets: Gupta et al. conducted a study to assess the impact of various supervised schedules (weekly, bi-weekly and daily) of iron folic tablet intake among anaemic adolescent girls[13]. They observed no significant differences in haemoglobin and serum ferritin level changes across the three groups throughout the intervention period. However, the research concluded that in the Shimla hills of North India, intermittent administration of iron-folic acid tablets in schools proved to be a viable and efficient method for increasing haemoglobin and serum ferritin levels

among anaemic adolescent girls. Specifically, the bi-weekly schedule demonstrated greater effectiveness in enhancing haemoglobin levels and displayed fewer reported side effects in comparison to the daily regimen.

7. Discussion

7.1. Introduction

Anaemia represents a significant global public health issue, with approximately one-third of the world's population affected by this condition. The majority of anaemia cases manifest as iron-deficiency anaemia (IDA), primarily prevalent among individuals residing in low- and middle-income nations[3]. IDA has continued to remain high in India. It is possibly due to relying on only IFA supplementation through ACP that is National Iron Plus Initiative (NIPI)[1]. According to Rai et al, despite various initiatives by the Government of India, the persistent high prevalence of anaemia nationally and its escalating rates (between 2015–2016 and 2019–2021) raise significant concerns for India's public health system[27].

This dissertation seeks to comprehensively examine and evaluate the various intervention methods designed to tackle anaemia linked to iron deficiency in this vulnerable population within the Indian context. This study aims to explore the strengths and limitations of diverse intervention strategies.

7.2. Assessing the impact of intervention strategies

The complexity of IDA among adolescent girls and reproductive-aged women necessitates comprehensive strategies and interventions targeting prevention, management and treatment. A range of studies has concentrated on different intervention methods such as educational initiatives, supplement plans and dietary changes to tackle the prevalence of anaemia. Grasping the effects and efficacy of these interventions is pivotal in devising evidence-backed methods to address iron-deficiency anaemia.

7.2.1. Impact of educational intervention among pregnant women:
The studies by Nimbalkar et al. cantered on evaluating pregnant women's understanding of anaemia and its prevention both before and after an educational training session[22]. Their research unveiled a notable improvement in comprehending anaemia and its precautionary steps among pregnant women following a single educational session. Additionally, the researchers advocated for the consistent implementation of these educational interventions within outpatient departments. This approach aimed to enhance women's awareness, promote the adoption of healthy behaviours and prevent anaemia and other micronutrient deficiencies during and after pregnancy. Nimbalkar et al. also highlighted that a majority of mothers exhibited substantial awareness regarding the importance of adequate maternal nutrition before and during pregnancy[22].

Conversely, the study conducted by Daba et al. suggested that most mothers displayed limited awareness concerning the significance of proper maternal nutrition both before and during pregnancy[28], particularly in terms of emphasizing a balanced diet. Similarly, Kever et al. identified, in their investigation of pregnant women's knowledge and attitudes toward dietary practices, that more than half of the subjects demonstrated a robust comprehension of dietary behaviours during pregnancy, despite the significant occurrence of illiteracy among those surveyed[29].

Wakwoya et al. yielded comparable findings to Nimbalkar et al, indicating that the intervention significantly elevated both the haemoglobin levels and the adoption of iron-rich diets among pregnant women through nutrition education and counselling[30,22]. Nonetheless, the study's confinement to a solitary college in Gandhinagar city limits the wider applicability of the outcomes.

7.2.2. Effect of directly observed oral iron supplementation among pregnant women:
Ahamed et al. conducted a study aiming to evaluate the impact of directly observed iron-folic acid (IFA) supplementation on anaemia prevalence, iron status improvement and compliance among pregnant women, comparing it to a control group. The research demonstrated that the group receiving weekly supervision exhibited enhanced adherence to IFA supplementation and showed improvements in blood haemoglobin levels[19]. However, despite the observed increase in compliance and better haemoglobin levels, the study did not find a significant reduction in anaemia prevalence compared to the control group that did not receive direct supervision for IFA intake. These findings suggest that although supervised IFA supplementation led to improved adherence and better haemoglobin levels, it did not result in a significant reduction in the prevalence of anaemia among pregnant women in rural areas.

The study's significance lies in its proposal of an alternative approach to enhance iron therapy adherence, specifically targeting pregnant women in rural settings. It underscores the effectiveness of direct supervision in improving compliance with IFA supplementation, an essential factor in addressing anaemia during pregnancy. Moreover, the study's highlighting of the potential use of Accredited Social Health Activists (ASHAs) for directly observing iron supplementation demonstrates the feasibility of involving community health workers in overseeing and ensuring compliance with iron-folic acid intake among pregnant women in rural regions.

In a similar study conducted in Myanmar by Charoenlarp et al[31], a comparable improvement in serum ferritin levels was reported following directly observed iron-folic acid (IFA) supplementation. Ahamed et al. identified noncompliance as a major obstacle in India's oral iron supplementation initiative[19]. They underscored the importance of involving community-based individuals to oversee the direct administration of iron supplements. Additionally, they proposed utilizing resources such as ASHA and Anganwadi workers, along with traditional birth attendants, nurses, community volunteers and school teachers, as potential contributors to ensure the direct monitoring of iron supplementation.

7.2.3. Oral iron versus intravenous iron sucrose:
Neogi et al. and Tigga and Debbarma independently investigated treatments for anaemia in pregnant women, specifically comparing intravenous iron sucrose against oral iron therapy in their respective studies[14,24].

Neogi et al. (2019) investigated the safety and effectiveness of intravenous iron sucrose in comparison to standard oral iron therapy for managing moderate-to-severe iron deficiency anaemia in pregnant women[14]. Their findings suggested that intravenous iron sucrose might be a preferable option for treating severe anaemia (haemoglobin concentration 5–7 g/dL) during pregnancy, particularly between 20–32 weeks of

gestation. Nevertheless, in instances of moderate anaemia, its consideration should primarily occur when there's poor adherence or intolerance to oral iron therapy.

On the contrary, in cases where women comply effectively with oral therapy, the use of intravenous iron sucrose might not offer extra advantages. The authors stressed the necessity for more extensive evidence to conclusively determine the clinical efficacy of intravenous iron sucrose when compared to standard therapy for treating anaemia during pregnancy. Nonetheless, a multicentre clinical trial, discontinued due to lack of efficacy, focusing on pregnant women with moderate to severe anaemia, failed to establish the superiority of intravenous iron sucrose over standard oral therapy in reducing adverse outcomes for both the mother and the foetus[14].

One of the main drawbacks of the Neogi et al. study by Neogi et al. was linked to the evaluation of the primary outcome. Due to the high volume of patients, we couldn't engage with women before their discharge from the study hospitals, necessitating reliance on retrospective analysis from medical records[14]. This situation improved gradually over time. Typically, in Indian culture, women stay at their maternal homes post-delivery for several weeks. Consequently, details such as haemoglobin levels couldn't be gathered prospectively. Nonetheless, information related to the primary outcome was later collected during follow-up hospital visits or through telephone interviews. On the other hand, a recent study conducted by Tigga and Debbarma, the investigation aimed to assess the efficacy of intravenous iron sucrose (IVIS) compared to oral iron in treating anaemia among expectant mothers attending a tertiary care centre in Northeast India[24]. The study findings revealed that parenteral iron therapy demonstrated superior tolerability and efficacy in correcting anaemia when compared to oral iron. Additionally, it resulted in a faster increase in haemoglobin levels and higher neonatal birth weight without any adverse effects. Tigga and Debbarma highlights parenteral iron as a more favourable option for administration to pregnant women, particularly in challenging hilly terrains of Northeast India, where limited access to healthcare services often leads to a significant number of expectant mothers arriving at hospitals with moderate-to-severe anaemia during later gestation, thereby reducing the available time for correction[24].

The impact of intravenous iron sucrose on enhancing haemoglobin concentration displays contradictory evidence. While a substantial amount of research indicates a noteworthy increase in haemoglobin levels (ranging from 2 g/dL to 3 g/dL) within 4–6 weeks after commencing therapy, this improvement has been observed with both intravenous and oral treatments as evidenced by studies conducted by Kochhar et al. and Kriplani et al.[32,33]. On the other hand, studies by Froessler et al and Neeru et al have demonstrated no significant elevation in haemoglobin levels with intravenous therapy[34,35].

7.2.4. Effect of mobile phone call reminders with standard therapy: Sontakke et al aimed to evaluate how mobile phone call reminders[23], when used alongside standard iron supplementation therapy, impacted compliance among pregnant women dealing with iron deficiency anaemia. Their findings suggested that employing mobile phone call reminders in addition to the standard therapy for iron supplementation enhanced compliance rates significantly. Moreover, this combined approach resulted in a notable increase in haemoglobin levels among antenatal

women diagnosed with iron deficiency anaemia. The use of reminder phone calls in this ongoing research significantly improved adherence in the study group compared to the control group. Several studies have shown similar improvements with various interventions[36,37], challenging the findings of Srivastava et al[38].

However, the study by Sontakke et al. encountered some limitations. A significant drawback of this method is that, the study had a reduced participant count due to COVID-19 lockdowns across different regions of the country[23]. Haemoglobin estimation might have been conducted more frequently to assess the quantitative increase in levels over the treatment period.

7.2.5. Efficacy of iron-supplement bars: In their research, Mehta et al. demonstrated that the daily intake of iron supplement bars resulted in a noteworthy rise in haemoglobin and haematocrit levels among nonpregnant anaemic women aged 18–35 within a 90-day period[21]. The increase in haemoglobin levels was evident as early as 15 days after the baseline, with 93.1% of women in the intervention group exhibiting favourable haemoglobin increases compared to 34.6% in the control group. Similarly, in a study focusing on double fortified salt (DFS) conducted by Vinodkumar et al[39], it was observed that the iron and iodine components within the DFS remained stable for a period of two years during storage. The research findings highlighted the efficacy of DFS in delivering bioavailable forms of both iron and iodine. The research findings highlighted the efficacy of DFS in delivering bioavailable forms of both iron and iodine. Mehta et al. emphasizes the complex nature of addressing iron deficiency anaemia (IDA), noting its social, political and health-related dimensions. They stress the importance of considering various factors when comparing outcomes and interpreting the effectiveness of their intervention. At the same time, the study conducted by Mehta et al[21]. encounters limitations associated with the intervention's design. Specifically, the research assessed a closely monitored intervention where the intake of iron-supplement bars was closely supervised and documented by study staff within the intervention group. In contrast, the control group did not receive a placebo and lacked regular interaction with study personnel.

7.2.6. Directly observed home-based daily iron therapy: The study conducted by Bharti et al. aimed to assess the effectiveness of DOHBIT in reducing the prevalence of anaemia[18]. Its primary objective involved evaluating the correction of anaemia after a 90-day regimen of daily iron therapy. Secondary objectives included examining the average rise in haemoglobin levels, the percentage of individuals achieving a ≥2 g/dL increase in haemoglobin, treatment adherence and the occurrence of side effects related to iron therapy.

The trial's outcomes indicated that directly supervised, home-based iron therapy was successful in reducing the prevalence of anaemia and improving haemoglobin levels compared to unsupervised self-treatment. This research, conducted in Indian communities focusing on adult women and adolescent girls, demonstrated promising outcomes in addressing anaemia, showing superior efficacy and enhanced adherence compared to the control group.

Similarly, Horjus et al. highlighted the effectiveness of school-supervised and closely monitored therapy in managing anaemia among adolescents[40]. Additionally, Hart et al. and Webb et al demonstrated[36,3] the advantages of supervised treatment

over self-management in effectively treating tuberculosis and hepatitis C infection[41,42].

However, Bharti et al. identified several limitations in their study, including the absence of blinded assessors for haemoglobin estimation, failure to explore alternative causes of nutritional anaemia, contamination in three comparison clusters and missing follow-up haemoglobin data in 9.41% of the study participants[18].

7.2.7. Dietary diversification for prevention of anaemia: Rao et al. evaluated the impact of an intervention aimed at altering dietary habits to prevent anaemia in rural India[17]. Their findings suggest that the widespread issue of anaemia in rural Indian communities, often rooted in ignorance, necessitates educational initiatives to transform attitudes, knowledge and household dietary practices. While technical approaches like fortification can address iron-deficiency anaemia on a broader scale, their study emphasizes the pivotal role of nutrition education in fostering behavioural changes that lead to sustained improvements in overall dietary quality. This presents a viable opportunity to achieve crucial health objectives. Additionally, endeavours to enhance nutritional awareness through activities such as kitchen gardening or organizing food exhibitions might also prove beneficial. Gonmei et al. state that in India, the most common type of anaemia arises from inadequate dietary iron intake and poor absorption, resulting in iron-deficiency anaemia. Rao et al. initiated their study by implementing a nutritional education strategy cantered on live demonstrations of iron-rich recipes as a form of social action[17]. In a similar study conducted by Beard[43], the public health strategy involving iron fortification of food has demonstrated efficacy in diminishing the prevalence of anaemia among women of reproductive age in the United States. Jones et al suggest that insufficient awareness regarding the causes and effects of nutritional deficiencies might impact food selection, even within economically disadvantaged populations[44].

7.2.8 Impact of Nutrition Educational Intervention: The research carried out by Salam et al aimed to evaluate the impact of nutritional messages delivered in schools on adolescent understanding of anaemia and its prevention[16]. Post-intervention, there was a considerable upsurge in the proportion of children answering questions correctly, demonstrating an increase ranging from 7.3 to 49.0 percentage points across the tested questions. Moreover, there was a notable improvement in the average knowledge score among the participants. Interviews conducted with teachers and students revealed positive feedback regarding the intervention and educational resources. The study noted an evident boost in awareness levels, a favourable change in attitudes towards modifying dietary habits, increased interest in iron and folic acid supplements and enhanced sharing of acquired knowledge with both peers and families.

The intervention yielded significant positive outcomes, notably enhancing the understanding and knowledge base of the children involved. It resulted in a commendable increase in correct responses across the tested questions, reflecting a substantial improvement in their comprehension. The feedback gathered from teachers and students during interviews echoed a favourable reception of the intervention and its associated educational materials. This positive feedback corroborated the observed outcomes, indicating a notable surge in awareness levels, a shift towards more positive attitudes regarding dietary

changes, heightened interest in supplements like iron and folic acid and an enhanced inclination among participants to share their newly acquired knowledge with peers and families.

Before the intervention commenced, Salam et al noted that boys had a low level of understanding about anaemia[16], aligning with findings from various other studies such as Sarada and Thilak[45]. In contrast, as suggested by recent findings from Dubik et al and Bali and Alok[46,47], while there are no substantial gender differences observed in the administration of IFA supplementation within schools, the awareness of anaemia itself emerges as a motivating factor for the consumption of IFA tablets. Salam et al. (2023) highlight the collaborative development of educational resources and an execution strategy involving pertinent local stakeholders, such as teachers, health and nutrition experts, ensuring the program's acceptability and feasibility. Nevertheless, one drawback identified was the study's focus on evaluating changes in knowledge rather than addressing behavioural modifications[16].

Kamalaja et al executed an intervention study aiming at providing health and nutrition education to adolescents aged 13-17 years[20]. The study revealed modest yet discernible impacts of nutrition education on haemoglobin levels. Post-intervention, there was a slight increase in the number of participants within the experimental group showcasing normal or mild haemoglobin levels. In contrast, there was a decrease in those exhibiting severe or moderate levels compared to the pre-intervention phase. Moreover, all participants in the experimental group displayed an enhanced understanding of anaemia and its preventive measures. Their knowledge, attitude and practices scores witnessed a notable increase of 1%. These results echo findings from prior studies conducted by Sharma and Chawla and Upadhyay et al[48,49], which also noted significant improvements in nutritional knowledge among school girls following nutrition education sessions.

Furthermore, Kamalaja et al. inferred that reducing anaemia prevalence among adolescent girls requires comprehensive community and school-based nutrition education programs[20]. The study underscored a critical information gap among rural adolescent girls concerning health, food and nutrition. This knowledge deficit possibly arises from several factors, including limited purchasing power, inadequate access to nutritious food, prevalent misconceptions, social taboos and a lack of exposure to mainstream media platforms such as television, radio and newspapers that typically disseminate information on proper nutrition.

Overall, the study elucidated the positive impacts of nutrition education on adolescents' knowledge and haemoglobin levels, highlighting the importance of implementing comprehensive educational programs targeting health and nutrition among adolescent girls in rural areas. It also shed light on the existing gaps in nutritional awareness and access, emphasizing the need for holistic approaches to address these challenges effectively.

7.2.9. Effect of nutritional intervention: The study conducted by Khanna et al. aimed to develop and assess a nutritional intervention geared towards preventing and managing anaemia among women of reproductive age[15]. This intervention showcased positive enhancements in the anaemic status of these women, emphasizing the crucial role of continued intervention development to achieve sustainable effects in addressing the

burden of anaemia. The research advocated for the provision of relevant information and the implementation of well-designed interactive educational programs specifically tailored to improve the overall nutritional status of women during their reproductive years.

Khanna et al. emphasized the importance of employing the trans-theoretical model of behaviour[15], an approach that proved effective in reducing the prevalence of anaemia among women of reproductive age in India. This model focuses on behaviour change by targeting different stages of readiness, aligning interventions with individual motivations and addressing potential barriers to adopting healthier practices. The study recommends the utilization of diverse communication channels and household-level interactions as feasible strategies for implementing nutrition interventions on a larger scale.

The findings of this research highlight the significance of tailored and engaging educational programs in improving the nutritional status and reducing anaemia among women of reproductive age. Moreover, the study underscores the need for interventions that address various stages of behaviour change while considering individual motivations and potential obstacles to sustainably combat anaemia. It emphasizes the importance of accessible and multi-channel communication strategies for effective implementation, advocating for household-level interactions to maximize the reach and impact of nutrition interventions. Overall, these recommendations provide valuable insights for designing and executing comprehensive strategies to alleviate anaemia among women in their reproductive years.

7.2.10 Intermittent versus daily administration of iron folic acid tablets: Gupta et al. conducted a study to assess the effectiveness of supervised iron-folic tablet administration in schools for treating anaemia among adolescent girls[13]. Their investigation involved various administration schedules weekly, bi-weekly and daily and tracked changes in haemoglobin and serum ferritin levels during the intervention period. While the study noted similar rates of change in these levels across all three groups, the bi-weekly regimen showed a relatively more substantial increase in haemoglobin levels compared to both the once-weekly and daily regimens. Additionally, participants in the daily regimen reported a higher incidence of side effects compared to those in the intermittent regimen group.

Similarly, Kotecha et al. conducted a study among adolescent girls in India, following a methodology akin to that of Gupta et al[13]. Their findings supported the effectiveness of supervised weekly iron-folate supplementation in schools for reducing anaemia, supporting the conclusions drawn by Gupta et al[13]. Additionally, Horjus et al carried out a school-based investigation among adolescent girls in Mozambique and their results mirrored the efficacy of intermittent iron-folic acid tablets in elevating haemoglobin levels, aligning with the observations made in Gupta et al[40,13].

Conversely, a study conducted in Peru by Zavaleta et al reached a different conclusion, suggesting that a daily supplementation schedule was more effective than an intermittent regimen in enhancing haemoglobin values[50]. This contrasts with the findings of Gupta et al and other studies emphasizing the efficacy of intermittent iron-folic acid tablet administration[13].

The array of studies showcased here represents a concerted effort to address anaemia, particularly among vulnerable groups like pregnant women, adolescents and those in rural settings. Each research endeavour adopts varied methodologies and interventions aimed at enhancing iron levels and combating anaemia. Despite their divergent approaches and outcomes, they share a common objective of ameliorating iron status and reducing anaemia prevalence.

Several studies, including those by Ahamed et al, Bharti et al and Gupta et al[19,18,13], emphasize the importance of interventions involving directly observed supplementation, both at home and in school settings, showcasing improved adherence and promising results in enhancing haemoglobin levels among pregnant women and adolescent girls. Moreover, interventions involving directly observed oral iron supplementation demonstrated improved compliance and haemoglobin levels among pregnant women[19]. However, challenges related to noncompliance persist, emphasizing the importance of community involvement and employing resources like ASHA and Anganwadi workers for effective monitoring.

Educational interventions, as highlighted by Kamalaja et al, Nimbalkar et al and Rao et al[20,22,17], emerge as pivotal tools in increasing awareness and knowledge regarding anaemia prevention measures among adolescent girls and pregnant women. Nimbalkar et al highlighted a significant improvement in comprehension following educational sessions, emphasizing the importance of consistent implementation within healthcare settings[22]. However, contrasting findings by Daba et al and Kever et al from similar studies underscore the challenges in achieving consistent awareness levels among pregnant women regarding proper maternal nutrition and dietary practices[28,29]. While some studies observed substantial awareness, others identified limitations, indicating the need for tailored educational strategies.

Additionally, dietary diversification interventions, as explored by Rao et al[17], underscore the significance of education in modifying dietary practices, a crucial element in combating anaemia in rural settings. Novel supplementation methods, such as iron-supplement bars[21] and technological aids like mobile phone call reminders[23], demonstrate promise in enhancing compliance and improving iron levels among anaemic individuals, especially pregnant women. However, these interventions also face challenges related to study limitations and the need for continuous monitoring and supervision.

Moreover, community-based interventions integrating education, nutrition and healthcare support are shown to be effective in enhancing the anaemia status of reproductive-aged women.

In summary, these studies collectively illustrate the multifaceted nature of interventions required to address anaemia. They underscore the importance of tailored interventions encompassing education, innovative supplementation methods, technological support and community-based initiatives, all crucial in mitigating the burden of anaemia among diverse populations. This diverse range of interventions and methodologies showcased here emphasizes the need for a comprehensive, nuanced approach in combating anaemia in various contexts and demographic groups.

7.3. Recommendations

India stands out with the highest number of individuals affected by anaemia globally, as highlighted in studies by Rai

et al and Didzun et al[51,52]. The concerning trend of increasing anaemia prevalence from 2015–2016 to 2019–2021 has raised significant concern and garnered critical attention from international public health experts, donors and policymakers, as emphasized by Rai et al[27]. Notably, the Comprehensive National Nutrition Survey, conducted from 2016-2018, was the only survey assessing haemoglobin levels in children and adolescents aged 1-19 via venous blood samples, while other national surveys rely on capillary blood samples, which may lead to potentially inaccurate results. Rai et al recommend that the Indian government prioritizes a nationwide survey utilizing venous blood samples to accurately determine the prevalence of anaemia and its associated clinical factors across all age groups[27].

A study by Gupta et al. found that intermittent iron folic acid tablet intake had similar efficacy in raising haemoglobin and serum ferritin levels compared to daily administration[13], with fewer side effects when taken weekly. Consequently, they recommended policymakers in India adopt intermittent regimens to address adolescent health challenges related to iron supplementation.

Similarly, Rai et al. emphasizes the urgent requirement for substantial research to comprehend both the enduring advantages and potential adverse effects of iron supplementation programs[27]. They also suggest exercising caution in introducing new anaemia control programs due to the ongoing review by the WHO regarding the haemoglobin threshold used to define anaemia. Khanna et al recommend offering women comprehensive information and well-designed interactive educational initiatives[15], especially those enhancing the nutritional well-being of reproductive-aged women. They propose future intervention strategies should focus on addressing iron deficiency, deficiencies in other micronutrients like B12 and folic acid and potential risk factors. They also recommend multi-faceted interventions involving healthcare provider training, overcoming systemic barriers and engaging family members to encourage adherence to weekly iron-folic acid supplements and dietary modifications. According to Rao et al, there is a clear need not just for operational research to enhance the current iron supplementation program but also for innovative strategies aimed at improving the overall health and nutritional well-being of young rural mothers in India[17].

7.3.1. Future recommendations for policy makers: Addressing anaemia requires a multifaceted approach that spans healthcare, education, agriculture, community engagement, policy adaptation and ongoing research. A comprehensive strategy aims not only to identify and treat anaemia but also to prevent its occurrence by addressing root causes and promoting sustainable solutions.

- Revamping the guidelines for iron supplementation within the National Iron Plus Initiative (NIPI) is crucial, grounded on a comprehensive review of global scientific data. Potential adjustments in dosage, frequency and duration hold the potential to notably amplify the program's effectiveness while mitigating adverse effects, particularly among pregnant women.

- Prioritizing interpersonal counselling sessions to bolster compliance with Iron and Folic Acid (IFA) tablet consumption is a pivotal step.

- Augmenting budgetary allocations and training state-level officers in meticulous planning and budget allocation would ensure sufficient resources for the NIPI, thereby facilitating streamlined program execution.

- Initiating regular mass deworming in regions with heightened prevalence of anaemia among children under five is essential. Additionally, reinforcing malaria control efforts in areas prone to malaria assumes significant importance, given its substantial contribution to anaemia cases.

- Expanding the scope of NIPI to encompass interventions for various causes of anaemia, such as haemoglobinopathies and vitamin deficiencies, promises a comprehensive approach towards combating anaemia.

- Extending IFA administration to children aged 5-10 years across most states and tailoring IFA tablet provisions based on the severity of anaemia for pregnant women are measures poised to augment program efficacy.

- Robust monitoring and supervision mechanisms constitute a cornerstone for effective execution. Enhancing supervision and monitoring at all administrative tiers and refining performance reporting mechanisms to accurately portray program achievements are pivotal. Documenting compliance issues in weekly IFA administration within schools and providing guidance to caregivers on appropriate infant and young child feeding practices are additional measures that would fortify the program's efficacy.

- Integrating anaemia screenings into routine medical services is pivotal for early detection and intervention. This involves incorporating screenings within antenatal care and school health programs, ensuring accessibility even in remote and rural areas where healthcare access may be limited. By identifying anaemia early, interventions can be initiated promptly, preventing its escalation and associated health complications.

- Educational initiatives play a crucial role in raising awareness about the importance of a well-balanced diet rich in iron and essential nutrients. Targeting vulnerable groups like women of reproductive age, adolescents and expectant mothers is essential. Inclusivity in educational campaigns ensures that diverse demographics understand the significance of dietary variety and nutrient-rich foods in preventing anaemia.

- Innovative strategies such as fortified food initiatives and enhancing crop nutrient content are pivotal. Collaboration with food industries and agriculture sectors is necessary to develop sustainable solutions. Fortified foods and nutrient-enhanced crops can significantly contribute to addressing nutritional deficiencies, especially in communities where access to diverse diets is limited.

- Empowering communities through engagement with local leaders and healthcare providers fosters a sense of ownership over health. By involving the community in anaemia prevention efforts, behavioural changes towards healthier lifestyles can be encouraged, leading to long-term positive impacts.

- Continuously reviewing and adapting national policies related to anaemia management is crucial. These policies should reflect evolving research and WHO guidelines to ensure that interventions align with the most current scientific findings. Flexibility in policies enables the implementation of effective and evidence-based interventions.

- Encouraging ongoing research into alternative

supplementation methods, treatment approaches and socio-economic factors contributing to anaemia is essential. This research drives innovation in delivery mechanisms, aiming to enhance adherence and effectiveness of interventions, ultimately improving outcomes.

- Collaborative efforts involving policymakers, healthcare professionals and local communities are paramount. Prioritizing adaptability and continual learning ensure that interventions remain effective and relevant. This collaborative approach fosters a commitment to evolving strategies for impactful intervention and sustained progress in combating anaemia on a broader scale.

7.3.2. Implications: The landscape of addressing anaemia in India encompasses diverse intervention strategies that have garnered attention from various research studies. Kamalaja et al.'s research outcomes propose that the continuous provision of health and nutrition education, integrated within school and governmental nutritional initiatives, holds promise in long-term anaemia risk reduction through diversified dietary practices.

On the other hand, Neogi et al advocate for the potential integration of intravenous iron sucrose as an alternative treatment for severe anaemia in pregnant women within India's national healthcare program and similar healthcare settings[14]. They highlight that practitioners currently employ intravenous iron sucrose across public and private sectors for various anaemia types without a standardized protocol. Hence, incorporating this intervention into health programs would not significantly deviate from existing practices. However, ensuring its restricted usage among suitable candidates via a scientific protocol could pose initial challenges. Nonetheless, with governmental backing, assured drug availability and adequate training facilities, integrating this method within the present healthcare systems and resources remains feasible. The research by Salam et al demonstrates the effectiveness of an education intervention utilizing diverse teaching methods by school teachers to enhance awareness and attitudes regarding anaemia and its prevention among adolescents[16]. They suggest that implementing such interventions within the national curriculum and expanding its scope could potentially contribute to enhancing the nutritional status of adolescents. Ahamed et al note the crucial requirement for extending directly observed iron supplementation, emphasizing the need for available community-based personnel to supervise this initiative[19]. The study underscores the presence of two key groups of community-based workers, namely ASHA and Anganwadi workers, accessible across every village in India. Additionally, the authors propose alternative choices like school teachers, traditional birth attendants, community volunteers and nurses as viable options to ensure the successful execution of directly observed iron supplementation.

7.4. Limitations

The limitations of this systematic review encompass several facets that may impact the comprehensiveness and reliability of its findings. Firstly, the review's scope and inclusion criteria might restrict the breadth of interventions considered, potentially overlooking valuable studies or alternative approaches outside the predefined criteria. Additionally, publication bias could influence the selection of studies, favouring those published in prominent journals and databases while neglecting equally relevant insights from lesser-known sources. The variability in study designs, methodologies and quality across the included studies poses a challenge in synthesizing and comparing their findings, potentially affecting the review's credibility and the robustness of its conclusions. Moreover, potential geographical and cultural biases might limit the generalizability of findings to broader populations, as the review might primarily focus on specific regions or cultural contexts. Language restrictions and limited access to certain studies could introduce language and access bias, leading to the exclusion of valuable research published in languages other than English or from less accessible sources.

Addressing these limitations requires a multifaceted approach. Expanding inclusion criteria to encompass a wider range of interventions, study designs and languages could enhance the review's breadth and inclusivity. Rigorous assessment of study quality and a balanced consideration of diverse perspectives from various geographical regions and cultural contexts could mitigate biases and improve the review's applicability to different populations. Additionally, efforts to access unpublished data, ongoing trials and grey literature would contribute to a more comprehensive analysis, reducing the risk of overlooking valuable insights that might not be present in published sources. Lastly, meticulous synthesis and interpretation of findings, along with transparent reporting of limitations, are crucial for maintaining the review's credibility and providing nuanced conclusions.

8. Conclusion

The prevalence of iron-deficiency anaemia (IDA) in India poses a significant public health challenge, especially among vulnerable groups like pregnant women, adolescents and rural populations. Various intervention strategies have been explored to combat this issue, including educational programs, supplementation plans, dietary modifications and innovative approaches. These interventions aim to increase awareness, improve compliance and elevate iron levels among affected individuals. Educational initiatives have proven instrumental in enhancing knowledge about anaemia prevention, particularly among pregnant women and adolescent girls. However, contrasting outcomes across studies emphasize the need for tailored and consistent educational strategies to address anaemia effectively. Supplementation strategies, such as directly observed oral iron supplementation, have shown promise in improving compliance and haemoglobin levels. Yet, challenges related to noncompliance highlight the importance of community involvement and effective monitoring through healthcare workers or volunteers. Dietary diversification programs stress the significance of education in modifying dietary practices, especially in rural areas. Additionally, innovative methods like iron-supplement bars and technological aids like mobile phone call reminders demonstrate potential in enhancing compliance and improving iron levels among anaemia-affected individuals. Despite the promising aspects of these interventions, each study reveals limitations and challenges concerning study design, participant adherence, cultural factors and scalability. The diversity of findings emphasizes the need for context-specific, adaptable and evidence-based approaches to address anaemia effectively.

In conclusion, addressing iron-deficiency anaemia in India requires a comprehensive, multi-faceted strategy integrating educational initiatives, targeted supplementation, dietary modifications and innovative technologies. Success

relies on tailored interventions, continuous monitoring, community engagement and integrating these strategies into existing healthcare systems. Collaborative efforts involving policymakers, healthcare providers, community leaders and researchers are crucial to developing sustainable and impactful interventions. Furthermore, ongoing research, evaluation and adaptation of interventions are essential to refine strategies and ensure their effectiveness in combating anaemia and enhancing the health of affected individuals.

8. Acknowledgement

8. Declaration

I certify that this dissertation complies with the regulations of Manchester Metropolitan University. With the exception of specific citations, the content is original and no part of this work has been used for any other academic purpose or degree. Furthermore, this dissertation has not been submitted to any other educational institution in the UK or elsewhere for assessment.

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