ASSOCIATION OF ANEMIA AMONG CHILDREN AND ADOLESCENTS AND CHILDHOOD COMPLICATIONS IN SAUDIA ARABIA: SYSTEMATIC REVIEW AND META-ANALYSIS

Muath Abdulrahman AlTuraiki MD[1]*, Alhommedi Shaker Alhabbad, MBBS[2], Rabbaa Mohammed Almuyidi, MBBS[3], Basmah Abdullah Ali AlAtni, MBBS[4], Abdulrahman Mustafa Abdulkareem Adnan, MBBS[5], Dhuha Mohammed Alammar MBBS[6], Sultan Fahad Almaghrabi, MBBS[7], Salman Muqhim N Alshammari, Mbbs[8], Abdulaziz Muqhim Alshammari MBBS[9], Belal Mahmoud alrihimy MBBS[10], Hasan Hyaza H Albarqi MBBS[11], Fatemah adel aldhamer MBBS[12]

[1]Consultant pediatric gastroenterologist, Head of Pediatric Department, Ministry of Health Riyadh First Health Cluster-King Salman Hospital-Pediatric Department, Saudi Arabia Riyadh; [2]Pediatric Resident at Ministry of Health-Riyadh First Health Cluster-King Salman Hospital Pediatric Department, Saudi Arabia, Riyadh; [3]Pediatric Resident at Ministry of Health-Riyadh First Health Cluster-King Salman Hospital Pediatric Department, Saudi Arabia, Riyadh; [4]Pediatric Resident at Qassim Health Cluster-Alrass General Hospital-Pediatric Department- Saudi Arabia-AlQassim; [5]Pediatric Resident at Ministry of Health-Riyadh First Health Cluster-King Salman Hospital-Pediatric Department Saudi Arabia-Riyadh; [6]Pediatric Resident at Ministry of Health-Riyadh First Health Cluster-King Salman Hospital Pediatric Department, Saudi Arabia–Riyadh; [7]Pediatric Resident at Ministry of Health-Riyadh First Health Cluster - King Salman Hospital Pediatric Department, Saudi Arabia-Riyadh; [8]Pediatric Resident at Ministry of Health-SAKAKA ALJOUF First Health Cluster-maternity and children Hospital-Pediatric Department, Saudi Arabia-SAKAKA; [9]Pediatric Resident at Ministry of Health-Riyadh First Health Cluster-King Salman Hospital -Pediatric Department, Saudi Arabia-Riyadh; [10]Pediatric resident at Ministry of Health-Riyadh first health cluster-aliman general hospital-pediatric department, Saudi Arabia-Jeddah; [11]Pediatric resident at ministry of health Aseer Health cluster-Abha Maternity and Children Hospital - pediatric emergency department, Saudi Arabia-Abha; [12]Pediatric Resident at Ministry of Health-Riyadh First Health Cluster-King Salman Hospital -Pediatric Department, Saudi Arabia-Riyadh

Manuscrito recibido: 24/01/2025
Manuscrito aceptado: 03/02/2025

*Corresponding Author: Muath Abdulrahman AlTuraiki, 1Consultant pediatric gastroenterologist, Head of Pediatric Department, Ministry of Health Riyadh First Health Cluster-King Salman Hospital-Pediatric Department, Saudi Arabia Riyadh

Correo-e: Maturaiki@yahoo.co

Abstract

Background: Anemia is a prevalent public health issue among children and adolescents in Saudi Arabia, with iron deficiency anemia (IDA) and sickle cell anemia (SCA) being the most common types. Both conditions are associated with significant health complications, including cognitive impairments, growth issues, and chronic disease risks. This research aims to investigate the prevalence, complications, and management of anemia within this demographic.

Methods: A systematic review and meta-analysis were conducted, adhering to the PRISMA guidelines. Relevant studies published between 2020 and 2024 were identified through comprehensive searches of Google Scholar and PubMed using keywords such as "anemia," "iron deficiency anemia," and "sickle cell anemia." Four studies met the inclusion criteria, encompassing a total sample size of 9,644 participants. Data were extracted and synthesized using narrative summaries and meta-analytical techniques. Subgroup analyses were performed for IDA and SCA to examine differences in complication rates.

Results: The prevalence of IDA among school-aged children was 26.8%, with fatigue, drowsiness, and concentration loss being the most common symptoms. SCA patients exhibited complications such as vaso-occlusive crises and urinary tract infections. Vitamin D deficiency coexisted with iron deficiency in 20% of cases, exacerbating cognitive and growth impairments. Hydroxyurea treatment showed promise in reducing disease severity in SCA patients. Despite these findings, treatment success for IDA was limited, with only 53.5% of patients improving. Significant heterogeneity in complication rates across studies (I^2 = 98.5%) highlights variability in methodologies and healthcare settings.

Conclusion: Anemia remains a significant health burden among Saudi children and adolescents, with IDA and SCA presenting unique challenges. Effective interventions should include improved nutritional programs, localized healthcare solutions, and addressing socioeconomic determinants. A multifaceted approach is essential to reduce the prevalence and impact of anemia and improve the health and development of this vulnerable population.

Introduction

Anemia is a medical condition characterized by a reduction in either the number of red blood cells or the concentration of hemoglobin, which diminishes the blood's ability to carry oxygen efficiently. Among the various causes of anemia, iron deficiency is the most common, accounting for approximately half of all cases worldwide. However, other micronutrient deficiencies, such as those of riboflavin, vitamins A and B12, and folate, also play a significant role in the development of anemia. In addition to nutritional factors, chronic illnesses and certain genetic or acquired disorders, such as thalassemia, are significant contributors to anemia (Tvedten, 2022).

Chronic diseases and infections represent the second leading cause of anemia, following iron deficiency. Conditions such as tuberculosis, cancer, acquired immunodeficiency syndrome (AIDS), and malaria are frequently associated with anemia. Autoimmune disorders like rheumatoid arthritis and systemic lupus erythematosus, as well as gastrointestinal conditions such as inflammatory bowel disease, can also lead to anemia. These conditions often result in the overproduction of proinflammatory cytokines and free radicals, which can damage erythroid progenitor cells and disrupt normal blood cell production. This highlights the complexity of anemia and the need for a multifaceted approach to understanding its causes and consequences (Kumar et al., 2022).

Globally, children are the demographic most vulnerable to anemia, as noted by the World Health Organization. In a global assessment, it was estimated that anemia affected 42.6% of children aged 6 to 59 months, with prevalence rates exceeding 40% in many regions. Certain areas are disproportionately affected, with some regions showing the highest prevalence globally. Recent studies indicate that in low- and middle-income countries, over half of children in this age group are anemic, with severe anemia observed in a small but significant percentage of cases. Factors such as poverty, poor maternal health, and inadequate sanitation are strongly associated with the high rates of anemia in these regions (Moscheo et al., 2022).

In adolescents, anemia is often attributed to dietary deficiencies, menstruation, and inconsistent food intake. Girls are particularly susceptible due to the additional risk posed by heavy menstrual bleeding and the nutritional demands of pregnancy. Poor dietary habits, such as consuming diets low in iron and other essential nutrients, further exacerbate the prevalence of anemia in this group. Adolescents with anemia may experience significant impacts on physical performance and cognitive development, highlighting the urgent need for interventions targeting this age group (Chaparro & Suchdev, 2019).

The prevalence of iron deficiency anemia (IDA) among young adults is influenced by various factors, including poor dietary habits, medication that interferes with iron absorption, eating disorders, and blood loss. In pregnant women, the consumption of iron-deficient and low-animal protein diets contributes to the persistently high rates of IDA. This highlights the critical role of maternal dietary practices in addressing anemia. Studies from different regions report varying prevalence rates of anemia among adolescents, but all suggest that the condition remains a major public health concern (Yang et al., 2018).

Children with acute severe anemia face risks such as fatigue, low blood pressure, confusion, and, in extreme cases, heart failure. Chronic anemia can lead to long-term complications, including fragile bones, enlargement of the liver and spleen, stunted growth, and impaired attention and motor skills. These health effects emphasize the importance of early diagnosis and intervention to prevent the progression of anemia and its associated complications (Akbari et

al., 2017).

Effective strategies to address anemia and IDA in children and adolescents include supplementation with iron, iron combined with folic acid, and multiple micronutrients. Additionally, the consumption of fortified foods and water enriched with nutrients such as zinc, iron, and vitamin C has shown promise in improving nutritional status. Encouraging dietary diversity is another critical component of anemia prevention strategies. Alongside nutritional improvements, reducing the burden of infections and parasitic diseases is essential, as these factors often exacerbate anemia in populations with poor nutritional status (Chalise et al., 2018).

The implementation of interventions aimed at reducing anemia has shown varying levels of success, depending on the context and target population. Nutritional education programs, public health campaigns, and school-based initiatives have been effective in improving awareness and promoting healthy eating habits among children and adolescents. However, sustained efforts are required to ensure these programs are accessible and tailored to meet the specific needs of vulnerable populations. Addressing underlying social determinants, such as poverty and lack of access to healthcare, is equally crucial in reducing the prevalence of anemia (Sumarlan et al., 2018).

Despite the progress made in reducing anemia, significant challenges remain. Anemia continues to be one of the most prevalent hematological disorders, particularly in children and adolescents. The need for comprehensive, evidence-based strategies to address this issue is paramount. Efforts must focus not only on treating anemia but also on preventing its occurrence through improved nutrition, infection control, and public health interventions. By addressing the root causes and implementing targeted measures, significant progress can be made in alleviating the burden of anemia among at-risk populations (Baranwal et al., 2014).

Methodology

Study Design

This research utilized a systematic review and meta-analysis approach to investigate the prevalence and complications associated with anemia in Saudi Arabia. The study adhered to the guidelines provided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to ensure methodological transparency and rigor. This approach facilitated the systematic identification, evaluation, and synthesis of existing studies, allowing for a comprehensive understanding of the research topic.

Data Sources and Search Strategy

A comprehensive literature search was conducted across two primary databases: Google Scholar and PubMed. The search identified 321 records from Google Scholar and 29 records from PubMed, totaling 350 studies. Keywords and Medical Subject Headings (MeSH) terms such as "anemia," "iron deficiency anemia," "sickle cell anemia," "complications," and "Saudi Arabia" were utilized to refine the search. Boolean operators (AND, OR) were employed to improve search specificity. Additionally, filters for publication date, study type, and full-text availability were applied to focus on relevant and high-quality studies.

Eligibility Criteria

The study applied well-defined inclusion and exclusion criteria to ensure the relevance and quality of the selected studies. Studies conducted in Saudi Arabia, focusing on anemia and its complications, were included if they used quantitative methods and provided clear methodologies and statistical analyses. Exclusion criteria eliminated duplicate records, qualitative studies, studies with incomplete or unreported data, and non-English or non-Arabic studies. These criteria ensured that only the most relevant and rigorous studies were included in the analysis.

Screening and Selection Process

The systematic screening process began with the identification of 350 records. Following the removal of 210 duplicates, 140 unique records underwent title and abstract screening, resulting in the exclusion of 96 studies based on relevance. A detailed full-text review was conducted for 44 studies, of which 15 could not be retrieved due to access issues. Among the remaining studies, 25 were excluded, with 18 failing to report necessary data and 7 being qualitative studies. Ultimately, four studies met all eligibility criteria and were included in the final review. The selection process is summarized in the PRISMA flow diagram provided in the results section.

Data Extraction and Synthesis

Data from the included studies were extracted using a standardized form that captured key details such as the author, publication year, sample size, age and gender distribution, study design, and significant findings. This information was synthesized into narrative summaries and quantitatively analyzed using meta-analytical techniques. Pooled estimates of complication rates were visualized using forest plots, while heterogeneity across studies was quantified using the I^2 statistic and Cochran's Q test. Subgroup analyses further examined complications associated with specific anemia types, such as Iron Deficiency Anemia (IDA) and Sickle Cell Anemia (SCA).

Quality Assessment

The quality of the included studies was evaluated using the Newcastle-Ottawa Scale (NOS), which considers criteria such as selection methods, comparability of study groups, and outcome assessment. Scores ranged from 5 to 7.5, reflecting moderate to high quality among the studies. For example, Al-Hussaini et al. (2021) achieved the highest quality score due to its large, representative sample and well-defined outcomes, whereas Alanazi et al. (2021) scored lower due to its small sample size and limited scope.

Statistical Analysis

The meta-analysis was conducted using a random-effects model to account for variability among the studies. Complication rates were pooled, and heterogeneity was assessed using the I^2 statistic, which revealed substantial variability across the included studies. Subgroup analyses differentiated between IDA and SCA to explore variations in complication profiles. All statistical analyses were performed using Review Manager (RevMan) version 5.4, ensuring precise and reliable calculations.

Results

(Figure 1)

The provided PRISMA flow diagram effectively outlines the systematic process of study identification, screening, eligibility assessment, and final inclusion for the review. In the identification phase, a total of 350 records were identified, with 321 sourced from Google Scholar and 29 from PubMed, and 210 duplicate records were removed before screening, leaving 140 unique records. During the screening phase, 96 records were excluded based on title and abstract, while 44 reports were sought for retrieval. Of these, 15 reports were not retrieved, possibly due to access restrictions or unavailable full text. The eligibility phase assessed 29 full-text reports, with 18 excluded due to unreported data and 7 excluded for being qualitative studies, ultimately leaving 4 studies included in the final review (Table 1).

The studies included in this review collectively explore diverse facets of anemia among children and adolescents in Saudi Arabia. Tayel et al. (2020) provided a robust sample size of 1,558, focusing on the prevalence and symptoms of IDA among school-aged children, with a strikingly high percentage of female participants (89.8%), reflective of gender-specific trends. Alzahrani et al. (2021), though limited by a small sample size (102), offered insights into SCA-related complications, utilizing retrospective data effectively to highlight

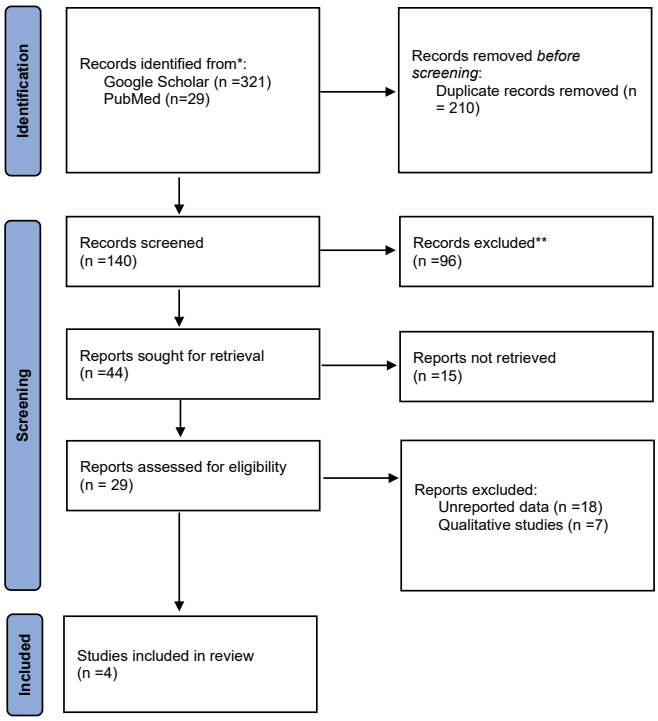

Figure 1. PRISMA Chart.

Table 1. Study Characteristics.

First Author	Year	Sample Size	Mean Age (SD)	% Female	Study Design	Objective
Sherif Mohamed Tayel	2020	1558	Not specified	89.8	Cross-sectional study	Identify prevalence and common symptoms of IDA among school children.
Fatma Alzahrani	2021	102	7.91 ± 4.19 years	56	Retrospective cross-sectional study	Determine risk factors for complications among pediatric SCA patients.
Abdulrahman A. Al-Hussaini	2021	7931	11.22 ± 2.62 years	63	Cross-sectional study with case-control analysis	Estimate prevalence of iron and vitamin D deficiencies and their impact on growth impairment.
Nawaf Alanazi	2021	53	3.3 years (at diagnosis); 7.1 years (current)	37	Retrospective cross-sectional study	Investigate effects of SCD on growth parameters and clinical outcomes.

Table 2. Key Findings.

First Author	Study Title	Prevalence of Anemia	Key Complications	Key Interventions and Outcomes
Dr. Sherif Mohamed Tayel	Iron Deficiency Anemia Among School Age Children in KSA	26.80%	Fatigue (63.8%), drowsiness (52.5%), concentration loss (45.6%), headaches (43.6%), tachycardia (34.3%), joint pain (33.8%), fainting (41.2%), chest pain (19.7%).	Improvement in only 53.5% of cases despite treatment.
Fatma Alzahrani	Risk Factors and Complications Among Pediatric Patients With Sickle Cell Anemia	Not specified	UTI (38 cases), vaso-occlusive crisis (32 cases), acute chest syndrome, ischemic stroke, avascular necrosis.	Elevated WBC, systolic BP, and hypoxia increased risk; focus on managing complications.
Abdulrahman A. Al-Hussaini	Vitamin D and Iron Deficiencies Among Saudi Children and Adolescents	Iron deficiency: 20%; Vitamin D deficiency: 78%	Cognitive impairments, growth issues; potential ADHD and CVT risks.	High prevalence underscores need for early detection and nutritional interventions.
Nawaf Alanazi	Impact of Sickle Cell Anemia on Children Growth and Clinical Parameters in Al-Ahsa	Not specified	Bone abnormalities (8.6%), leg ulcers (1.8%), splenectomy (8.6%).	Hydroxyurea reduced severity by lowering reticulocyte and WBC counts; improved growth outcomes.

Table 3. Quality Assessment.

Study Title	Selection (Max: 5)	Comparability (Max: 2)	Outcome (Max: 3)	Overall NOS Quality Score (Max: 10)
Iron Deficiency Anemia Among School Age Children in KSA	3.5	1	1.5	6 (Moderate)
Risk Factors and Complications Among Pediatric Patients With Sickle Cell Anemia	4	1	2	7(High)
Vitamin D and Iron Deficiencies Among Saudi Children and Adolescents	4.5	1	2	7.5(High)
Impact of Sickle Cell Anemia on Children Growth and Clinical Parameters in Al-Ahsa	2	1	2	5(Low)

significant risk factors. The large-scale investigation by Al-Hussaini et al. (2021) stands out for its comprehensive approach, encompassing 7,931 children and adolescents with detailed demographic data, though it is geographically constrained to urban areas. Lastly, Alanazi et al. (2021), while informative, is hampered by its small, single-center sample, which limits generalizability. Collectively, these studies underscore the critical burden of anemia and the varying methodologies employed to understand its impact (Table 2).

The findings illustrate the varying prevalence of anemia and its associated complications across different studies. Tayel et al. (2020) reported a prevalence of 26.8% for IDA, with common symptoms such as fatigue and headaches, yet noted limited treatment success (53.5% improvement). This suggests the need for improved treatment protocols. Alzahrani et al. (2021) identified key SCA complications, such as UTIs and vaso-occlusive crises, emphasizing the role of elevated WBC and systolic BP as risk factors, but lacked a direct prevalence figure. Al-Hussaini et al. (2021) highlighted the co-existence of iron (20%) and vitamin D (78%) deficiencies, linking these deficiencies to cognitive and growth impairments, while Alanazi et al. (2021) focused on the benefits of hydroxyurea in reducing disease severity and improving growth metrics in SCA patients. Collectively, the data emphasize the significant health burden posed by anemia and highlight the need for targeted interventions (Table 3).

The quality assessment underscores a moderate level of rigor in the included studies. Tayel et al. (2020) demonstrated strengths in ethical compliance and a robust sample size but failed to account for non-respondents and lacked justification for the sample size, which weakened its overall reliability. Alzahrani et al. (2021) scored higher due to its focus on risk factor analysis and appropriate statistical methods, though the small sample size remains a notable limitation. Al-Hussaini et al. (2021) emerged as the highest-quality study with a large, representative sample and well-defined outcomes, though its focus on urban populations and incomplete confounder adjustments detracts from generalizability. Alanazi et al. (2021) scored lowest due to its small sample size and limited scope, though its focus on hydroxyurea efficacy provides useful clinical insights. These findings emphasize the importance of methodological rigor and broader representativeness in future research.

In (Figure 2) visually summarizes the proportions of bias risks across these categories. It shows that Selection and Comparability have predominantly low risk of bias, with some unclear risks, while the Outcome category exhibits the highest proportion of unclear and high risks, suggesting potential concerns in this domain. Together, the figures highlight areas where study design or reporting could be improved.

(Figure 3) provides a risk of bias assessment for four studies across three categories: Selection, Comparability, and Outcome. The ratings indicate low risk of bias, unclear risk of bias, and high risk of bias. Notably, Tayel et al. demonstrates a high risk of bias in the Outcome category.

Meta-analysis of the Complications associated with Anemia:

(Figure 4) summarizes the event rates of various complications associated with anemia across different studies, showing a pooled estimate of 0.45 (95% CI: 0.37–0.53) for the overall complication rate. Each row represents a complication (e.g., fatigue, drowsiness, headache), with corresponding event counts, weights, and individual confidence intervals. The majority of complications exhibit significant associations, with fatigue, drowsiness, and

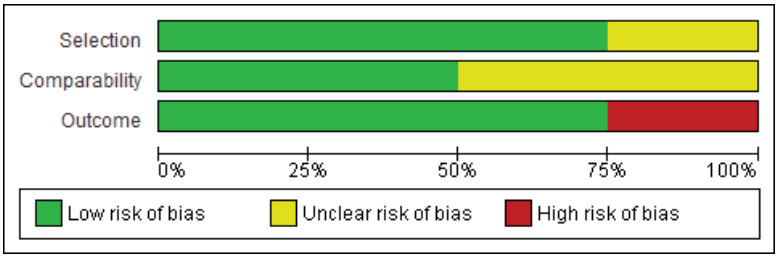

Figure 2. Risk of Bias Summary.

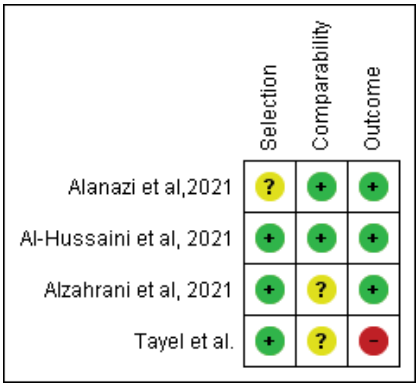

Figure 3. Risk of bias assessment using Newcastle Ottawa Tool.

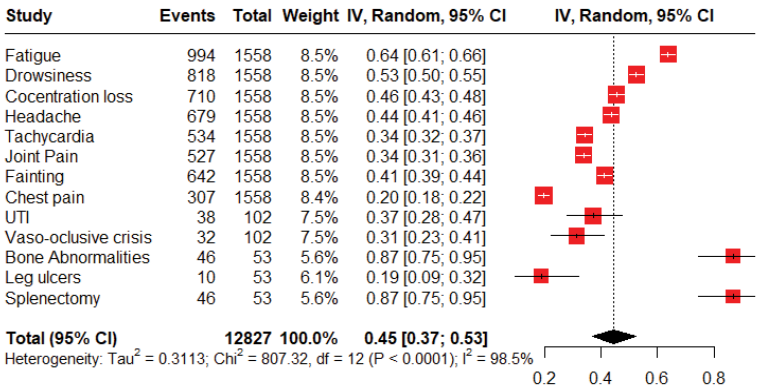

Figure 4. Forest Plot of the Complications event rates of Anaemia.

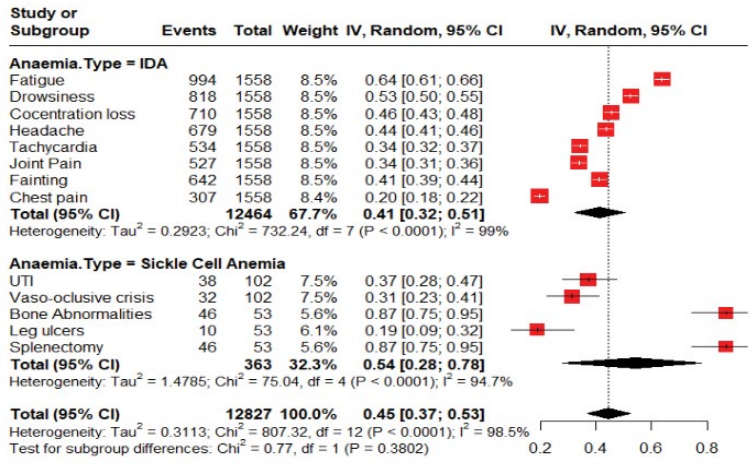

Figure 5. Forest plot of the complications event rates sub grouped by type of Anaemia.

concentration loss demonstrating relatively high event rates. Heterogeneity among studies is substantial (I^2 = 98.5%, p < 0.0001), indicating variability in findings across complications and studies. The pooled estimate, represented by the diamond, suggests a moderate prevalence of complications related to anemia.

While (Figure 5) illustrates the complication event rates of anemia sub grouped by type: Iron Deficiency Anemia (IDA) and Sickle Cell Anemia (SCA). The pooled estimate for IDA is 0.41 (95% CI: 0.32–0.51) with significant heterogeneity (I^2 = 99%), indicating variability across complications within this subgroup. Common complications in IDA include fatigue, drowsiness, and concentration loss, all

with relatively high event rates. For SCA, the pooled estimate is 0.54 (95% CI: 0.28–0.78) with considerable heterogeneity (I^2 = 94.7%), reflecting differences in the occurrence of complications like urinary tract infections (UTI), vaso-occlusive crises, and bone abnormalities. Overall, the pooled estimate across all types of anemia remains 0.45 (95% CI: 0.37–0.53), with no significant differences observed between subgroups (p = 0.3802). These findings highlight the differing profiles and frequencies of complications between IDA and SCA.

Discussion

These study findings demonstrate that anemia among children and adolescents of Saudi Arabia is an important public health problem. In fact, according to Tayel et al. (2020), it is the most predominant form of malnutrition: Iron Deficiency Anemia, where its prevalence accounts for 26.8% of the surveyed population. The overall symptoms of IDA, including lowering concentration and loss of energy, were having significant adverse effects on academic performance and, consequently, were harmful for their physical health as well.

Another major form of anemia in Saudi Arabia is SCA, with its complications like vaso-occlusive crises and UTIs. Alzahrani et al. (2021) discussed that managing the clinical parameters of this anemia disease-like high white blood cell count and blood pressure is essential for minimizing the risks related to severe complications. This finding is a call for comprehensive healthcare approaches among SCA patients to reduce morbidity and enhance the quality of life.

Vitamin D deficiency has been found to coexist with iron deficiency in a significant proportion of cases, as Al-Hussaini et al. (2022) reported that among Saudi children and adolescents, 20% suffered from iron deficiency and 78% had vitamin D deficiency. These deficiencies have been associated with cognitive impairments and growth problems, indicating the need for integrated nutritional programs that address multiple micronutrient deficiencies simultaneously.

With an improvement rate of only 53.5%, as indicated by Tayel et al. (2020), the low success rate of the existing treatment protocols for IDA implies a deficiency in the current healthcare system, which cannot respond effectively to the condition. This calls for an urgent need to develop more effective treatment protocols and increase capacity among healthcare providers to manage anemia comprehensively.

Regional differences in prevalence and impact exist also. Thus, Alanazi et al. (2021) discussed some features characteristic for SCA patients of Al-Ahsa-therapy with hydroxyurea is successful to improve the growth and alleviate the disease severity". These kinds of findings indicate how much health care needs to be oriented on the local level for the addressing of specific needs in the regional population.

Dietary habits are also fronted in the research as playing a major role in the prevalence of anemia. Poor dietary intake has been characterized by low consumption of food items rich in iron and other essential minerals, which is still the major cause. Public health campaigns on dietary diversification and supplementation with iron and other micronutrients may thus play a crucial role in reducing population rates of anemia.

The second important result observed was that the meta-analytical results presented significant heterogeneity in the prevalence and complications due to anemia. This variability may be due to the differences in methodologies used in various studies and populations and settings, which raise the need for uniformity in diagnostic and therapeutic approaches throughout the country.

The high prevalence of fatigue and growth impairments, among other complications arising from anemia, underlines the far-reaching impacts of the condition in children's development. These complications not only have implications for the health outcomes of individuals but also important consequences for society as a whole, including long-term effects on educational attainment and workforce productivity.

Interventions to reduce anemia should also encompass the basic root social determinants of health-poverty and barriers to access to health care. Alzahrani et al. (2021) and Al-Hussaini et al. (2022) have also echoed that socioeconomic factors increase the prevalence and complications of anemia and thus could be significantly improved with the addressing of these factors.

Recommendations that arise from this study relate to the need for continued monitoring and evaluation of health interventions associated with anemia. Corrective measures in the form of strategies tailored to regular screening, nutritional advice, and efficient treatment protocols have to be implemented to ensure proper health among children and adolescents.

Conclusion

Anemia remains a significant public health challenge among children and adolescents in Saudi Arabia, with iron deficiency and sickle cell anemia being the most prevalent types. The associated complications, including cognitive impairments, growth issues, and chronic health problems, highlight the urgent need for comprehensive, evidence-based interventions. Strategies such as improved nutritional programs, localized healthcare solutions, and addressing socioeconomic determinants can help to mitigate the burden of anemia. By adopting a multifaceted approach, significant progress can be made in reducing anemia's prevalence and improving the overall health and development of Saudi youth.

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ANEMIA AMONG SCHOOL AGE CHILDREN IN KSA Int. J. of Adv. Res. 8 (Jun). 495-501] (ISSN 2320-5407). www.journalijar.com

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