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prevalence of Iron deficiency anemia among children aged 2–10 years in Ahmed Gasim Hospital 2022

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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

(وَلَقَدْ خَلَقْنَا الْإِنْسَانَ مِنْ سُلَالَةٍ مِنْ طِينٍ . ثُمَّ جَعَلْنَاهُ نُطْفَةً فِي قَرَارٍ مَكِينٍ . ثُمَّ خَلَقْنَا النُّطْفَةَ عَلَقَةً فَخَلَقْنَا الْعَلَقَةَ مُضْغَةً فَخَلَقْنَا الْمُضْغَةَ عِظَاماً فَكَسَوْنَا الْعِظَامَ لَحْماً ثُمَّ أَنْشَأْنَاهُ خَلْقاً آخَرَ فَتَبَارَكَ اللَّهُ أَحْسَنُ الْخَالِقِينَ)

صدق الله العظيم.

(المؤمنون آية 12-14)

Dedication

We dedicate our research work to our family and many friends. A special feeling of gratitude to our loving parents, whose words of encouragement and push for tenacity ring in our ear. To our family and many friends have never left my side and are very special.

Acknowledgments

First we wish to thank Allah for granting us the Confidence and Success to complete this study. We wish to thank our supervisor who were more than generous with their expertise and precious time. A special thanks to **Dr. ###,** our supervisor for his countless hours of reflecting, reading, encouraging, and most of all patience throughout the entire process.

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Abstract

Background: Iron deficiency anemia has remained one of the most severe and important nutritional deficiencies in the world today. It is a condition that affects 20-25% of the world's children. It impairs their cognitive development, affects their immune system and is associated with increased morbidity rates. Although iron deficiency anemia is largely preventable, there is a high rate of iron deficiency anemia among children in most developing countries resulting in recurrent blood transfusions and its associated complications. Limited information is available on factors associated with iron deficiency anemia among Sudanese children.

The objective of this study was to establish the prevalence and factors associated with Iron deficiency anemia among children aged 2 to 10 years seen at Ahmed Gasim Hospital located Khartoum at Sudan throughout the study period.

Methods: This was a cross-sectional study using the quantitative approach. A total of 129 children were selected randomly. Data was analyzed with SPSS. Categorical variables are presented as proportions and their associations determined by chi-square test with ($P<0.05$) as significant level and logistic regression.

Results: The result of the study revealed the prevalence of iron deficiency anemia was 22.4% among respondents. Prevalence of anemia was 32% with 73.5% of these cases having iron deficiency. No socio-demographic factor was associated with iron deficiency anemia. The factors found to be associated with iron deficiency anemia history of recent blood transfusion in past year. Children who consumed cow milk before six months were three times more likely to have iron deficiency anemia, but no statistical significance observed.

Conclusion: The prevalence of anemia and iron deficiency anemia is still higher among children from Sudan. Blood transfusion and cow milk consumption before six months increase the risk of iron deficiency anemia among children aged 2-10 years.

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List of Abbreviations

AAP	American Academy of Pediatrics
DHS	demographic and heath survey
ESRD	end-stage kidney disease
Hb	Hemoglobin
IDA	iron deficiency anemia
IRIDA	iron-refractory iron-deficient anemia
M.C.H.C	Mean Corpuscular Hemoglobin
M.C.V	Mean Corpuscular Volume
NSAIDS	Nonsteroidal anti-inflammatory drugs
R.D.W.	Red cell distribution Width corpuscular volume
SPSS	Statistical Package for Social Sciences
WHO	World Health Organization

Chapter One

Introduction, Rationale & Objectives

1. Introduction, Rationale & Objectives

1.1 Introduction

Anemia caused by iron deficiency, iron deficiency anemia, is the most important nutrition problem in the world. Despite the considerable economic and scientific development seen in the last decades regarding anemia, its global prevalence decreased only marginally. Estimates of the World Health Organization (WHO) indicate that 24.8% of the world population, that is, almost one-fourth of the population, is anemic. Iron-deficiency anemia is defined as a serum hemoglobin level below 11.0 g/dL. Early childhood is an age at risk of Iron deficiency anemia and its deleterious consequences. Children are more vulnerable to developing anemia because they are rapidly growing and liable to infection The highest prevalence are found in children younger than 5 years of age and pregnant women1. In developing countries, 47.4% of the children in the 0-4 years' age group are anemic [1]. Iron-deficiency anemia stems from an unbalance between the amount of bioavailable iron absorbed from food and the body's requirement. It represents the final manifestation of iron deficiency, characterized by small red blood cells because of inadequate hemoglobin, significant reduction in the body's iron reserves, and low hematocrit [2]. Iron is involved in many metabolic and oxidation reactions and is essential for mitosis. Once the deficiency during childhood sets in and remains for a long time, the health consequences are severe. The following changes have been observed: late psychomotor development, difficulties in language acquisition, significant loss of cognition, greater susceptibility to infections, fatigue, and irritability [3]. Iron deficiency anemia is a preventable condition and its control needs reliable data and continuous monitoring and evaluation process at the country level to establish a baseline, identify the barriers, develop sound interventions, and assess the progress [4]. However, in Sudan national level anemia prevalence survey is not frequently conducted. Available data on anemia in children is based on small-scale research, health services reports, and estimation. The most recently available nationally representative prevalence data on childhood anemia in Sudan, which was obtained via selected states' survey in 1995, revealed a prevalence of more than 80% [5]. So, measuring the population prevalence of anemia and its determinants in children will enable the country to update its figure as well as to have a reliable estimation and a better understanding of the problem. This study was conducted in Sudan to assess the level of iron deficiency anemia in children 2 years to less than 10 years of age and to identify its determinants.

1.2 Problem statement

Iron deficiency anemia is a problem of serious public health significance, given its impact on psychological and physical development, behavior, and work performance. It is the most prevalent nutritional problem in the world today, affecting more than 700 million persons and approximately 36.4 to 61.9% of under five children in sub-Saharan Africa are also affected. Simply stated, an iron deficiency occurs when an insufficient amount of iron is absorbed to meet the body's requirements. Measuring the population prevalence of anemia and its determinants in children will enable the country to update its figure as well as to have a reliable estimation and a better understanding of the problem.

1.3 Justification

Early childhood is an age at risk of Iron deficiency anemia and its deleterious consequences. Children are more vulnerable to developing anemia because they are rapidly growing and liable to infection. Moreover, micronutrients such as iron and folic acid are likely to be inadequate in children’s diets if parents are not well informed. Iron deficiency Anemia is not only one of the leading causes of childhood mortality and morbidity, it may also affect cognitive development and school performance. In Sudan, there is limited evidence on the prevalence and determinant of Iron deficiency anemia in children aged 2-7 years. However, in Sudan national level anemia prevalence survey is not frequently conducted. Available data on anemia in children is based on small-scale research, health services reports, and estimation. The most recently available nationally representative prevalence data on childhood anemia in Sudan, which was obtained via selected states’ survey in 1995, revealed a prevalence of more than 80%. This study was conducted in Sudan to assess the prevalence of anemia in children and to identify its determinants

1.4 Objectives

1.4.1 General Objective

- To assess the Prevalence of Iron deficiency anemia among children aged 2–10 years in Ahmed Gasim Hospital

1.4.2 Specific Objectives

- To assess general characteristic of children such as socio-demographic factors
- To describe family socio-demographic characteristics

Chapter Two

Literature Review

2. Literature Review

2.1 Iron-deficiency anemia

Iron-deficiency anemia is a more severe condition in which low levels of iron are associated with anemia and the presence of microcytic hypochromic red cells in the circulation, the relative number of which reflects the severity of the iron deficiency. Iron deficiency is the most common micronutrient deficiency worldwide and one of the most important public health problems, affecting approximately 25% of the world's population according to the World Health Organization (WHO). Iron deficiency is the most common in preschool children and women of childbearing age, particularly in regions of Asia and Africa with poor access to iron-rich foods [6]. There are lower rates of iron deficiency in developed countries such as the United States and other industrialized regions with healthy food rich in nutrients. However, the problem still exists and can have a great impact on mental and physical development, health maintenance, and the quality of life of affected children [7].

2.2 Clinical Features of Iron-deficiency anemia

Iron-deficiency anemia is chronic and frequently asymptomatic and thus may go completely undiagnosed. Weakness, fatigue, difficulty in concentrating, and poor work productivity are nonspecific symptoms ascribed to low delivery of oxygen to body tissues and decreased activity of iron-containing enzymes. The extent to which these non-hematologic effects of iron deficiency are manifested before anemia develops is variable. Signs of iron deficiency in tissue are subtle and may not respond to iron therapy. Iron deficiency has been reported to decrease cognitive performance and to delay mental and motor development in children but whether short-term treatment alters outcome is unclear [8]. Common signs and symptoms of IDA are: Difficulties with memory and concentration (cognitive), Fatigue, sluggishness, tiring easily, low energy level, Feeling mildly light-headed, Feeling unusually cold (Cardiovascular), Mild shortness of breath with exertion that goes away with rest (cardiopulmonary) and Pale conjunctiva, mucosa, or skin. Less common symptoms of iron deficiency include burning tongue (usually accompanied by zinc deficiency from malabsorption), restless leg syndrome, dyspnea in otherwise healthy adults, failure to thrive in babies and toddlers. Usually these are dominated by the symptoms coming from the primary cause of the IDA. Severe iron-deficiency anemia in pregnancy is associated with an increased risk of preterm labor, low neonatal weight, and increased newborn and maternal mortality. Iron deficiency may predispose a person to infections, precipitate heart failure, and cause restless leg syndrome [9]. In patients with heart failure, iron deficiency has a negative effect on the quality of life, irrespective of the presence of anemia. Iron deficiency can impact assessment of the diabetic state. Caution must be exercised in interpreting the results of HbA1c in patients of IDA and iron deficiency must be corrected before diagnosing diabetes and pre-diabetes solely on the basis of HbA1c criteria [10].

2.3 Prevalence of iron-deficiency anemia

Iron deficiency and iron-deficiency anemia (IDA) are common medical conditions seen worldwide [11]. The estimated prevalence of iron deficiency worldwide is twice as high as that of iron-deficiency anemia. IDA severely affects the lives of young children and premenopausal women (particularly those of low-income or in developed countries) [12]. In developing countries, iron deficiency and iron- deficiency anemia typically result from inadequate dietary intake and/or blood loss due to intestinal worm colonization, or both. In higher-income countries, certain eating habits such as vegetarian diet and chronic blood loss or malabsorption are the most common causes. Iron deficiency in developed countries is especially high in the elderly [11].

2.4 Etiology of iron-deficiency anemia

The most common causes of iron deficiency are summarized in Table 2.1.

Table 2.1 The most common causes of iron deficiency

Cause	Examples
Physiologic	
Increased demand	Infancy, rapid growth in adolescence, menstrual blood loss, pregnancy, blood donation
Dietary or environmental	Insufficient intake, resulting from poverty, malnutrition, diet (e.g., vegetarian, vegan, iron-poor)
Pathologic	*Decreased absorption*: gastrectomy, duodenal bypass, bariatric surgery, *Helicobacter pylori* infection, celiac sprue, atrophic gastritis, inflammatory bowel diseases (ulcerative colitis, Crohn's disease)

	Chronic blood loss: gastrointestinal tract, including esophagitis, erosive gastritis, peptic ulcer, diverticulitis, benign tumors, intestinal cancer, inflammatory bowel diseases, angiodysplasia, hemorrhoids, hookworm infestation, obscure source
	Genitourinary system: heavy menses, menorrhagia, intravascular hemolysis (paroxysmal nocturnal hemoglobinuria, autoimmune hemolytic anemia, march hemoglobinuria, damaged heart valves, microangiopathic hemolysis (TTP/HUS)
	Systemic bleeding: hemorrhagic telangiectasia, chronic schistosomiasis, Munchausen's syndrome (self-induced hemorrhages)
Drug-associated	Glucocorticoids, salicylates, NSAIDs, proton-pump inhibitors
Genetic	Iron-refractory iron-deficiency anemia (IRIDA)
Iron-restricted erythropoietic	Treatment with erythropoiesis-stimulating agents (ESA), anemia of chronic disease, chronic kidney disease

Poverty, malnutrition, and famine are the main causes for anemia from iron deficiency in developing countries, especially in children and pregnant women [12]. Cereal-based diet decreases iron bioavailability as they contain phytates that sequester iron into a poorly absorbable complex. Other common causes in developing countries include hookworm infections and schistosomiasis, which cause chronic blood loss [11]. Strict vegan and vegetarian diets, malabsorption, and chronic blood loss resulting from heavy menstrual losses are also well-known causes of iron- deficiency anemia. Chronic blood loss from the gastrointestinal tract, including occult blood, especially in male patients and elderly patients, may reveal the presence of benign lesions, angiodysplasia, or cancer. Obscure gastrointestinal blood loss, especially from the small bowel, may be seen by means of video-capsule endoscopy. This technique is increasingly used when conventional workups for iron-deficiency anemia is negative. Persons who donate blood regularly are also at risk for iron deficiency, and their iron levels should be monitored [13].

In rare forms of intravascular hemolysis as in in paroxysmal nocturnal hemoglobinuria, iron is lost in the urine, the iron deficiency then aggravating the hemolytic anemia. Anemia develops in endurance athletes, perhaps from some hemolysis, blood loss, and/or mild inflammation.

Nonsteroidal anti-inflammatory drugs (NSAIDS), anticoagulants more so than antiplatelet agents can aggravate blood loss. Proton-pump inhibitors (PPIs) by reducing acid secretion impair iron absorption (Table 2.1) [14].

Multiple causes may be operative in any given person. Low iron intake in the presence of intestinal infections with nematodes may result in severe anemia. Blood losses may combine with the anemia of inflammation [15]. In end-stage kidney disease (ESRD), iron-deficiency anemia results from dialyzer blood loss (average of 1–2 g elemental Fe per year), increased hepcidin from reduced hepcidin clearance and from inflammation, and PPIs and anticoagulant use. In elderly persons, the anemia correlates with advanced age and multiple related conditions, including iron deficiency inflammatory disorders, decreased levels of erythropoietin, and cancer. Obesity, now reaching epidemic proportions in Western societies, is associated with mild iron deficiency [16]. The processes include subclinical inflammation, increased hepcidin levels, and decreased iron absorption. In most cases, resistance to oral iron therapy is due to disorders of the gastrointestinal tract (Table 2.1). Partial or total gastrectomy or surgical procedures that bypasses the duodenum can produce such resistance. Bariatric surgery, such as laparoscopic Roux-en-Y gastric bypass, which is performed in obese patients is an emerging cause of iron deficiency (up to 45% of subjects) and anemia because the procedure effectively removes an active iron absorption site from the digestive process and increases gastric pH. Lifelong nutritional monitoring and iron supplementation are advisable [17].

Infection with Helicobacter pylori infection leads to decreased iron absorption (Table 2.1) as the microorganism competes with its human host for iron, reduces the bioavailability of vitamin C, and may lead to micro-erosions that cause bleeding. Since it is estimated that half the world’s population is infected with H. pylori, clinicians should be aware of the possibility of infection and provide treatment in order to eradicate this acquired source of iron-resistant iron-deficiency anemia. The prevalence of celiac disease and its atypical manifestations, which include iron-deficiency anemia, appear to be increasing worldwide [18]. Whether gluten allergy contributes to iron deficiency is unclear. The incidence among iron-replete participants for a positive anti-transglutaminase antibodies is negligible; however, gluten sensitivity by this antibody test was found in 2.5% of participants with iron deficiency and seemed to occur in Caucasians. In another study of a series of patients with iron-refractory iron-deficiency anemia, 5% of participants had gluten sensitivity. These findings suggest that gluten sensitivity may be associated with secondary iron-refractory iron-deficiency anemia. Similarly, autoimmune atrophic gastritis is another rare cause of iron-refractory iron-deficiency anemia, result- ing from an immune reaction against gastric parietal cells and intrinsic factor, should be considered as a possible albeit unlikely cause of iron-refractory microcytic anemia [19]. In patients with inflammatory bowel disease (IBD), anemia may be iron-resistant, but it is multifactorial from a combination of deficiencies in iron, folate, and vitamin B12, inflammation, and side effects from drug therapy. An uncommon but important entity with respect to our understanding of iron sensing by the liver is an entity known as iron-refractory iron-deficient anemia (IRIDA). It is a rare autosomal disorder characterized by the absence of a hematologic response (an increase of <1 g of hemoglobin) after 4–6 weeks of treatment with oral iron. IRIDA is caused by a mutation in TMPRSS6, the gene encoding transmembrane protease serine 6, also known as matriptase-2, which inhibits the signaling pathway that activates hepcidin. Loss-of-function mutations in TMPRSS6 have been reported in many families [20]. In these families, constitutively high production of hepcidin is noted. Hepcidin blocks the intestinal absorption of iron despite the presence of anemia. Anemia is variable, more severe in children, and unresponsive to treatment with oral iron. Microcytosis is striking, transferrin saturation is very low in the presence of normal or borderline-low ferritin levels and high hepcidin levels. The diagnosis ultimately requires sequencing of TMPRSS6. Although IRIDA represents <1% of the cases of iron-deficiency anemia seen in medical practice, knowledge of this condition is valuable to clinicians, since it clarifies how essential the suppression of hepcidin is to the body's response to pharmacologic iron. IRIDA points to the existence of genetic susceptibility to iron deficiency. Variants of TMPRSS6 have been associated with modulation of serum hepcidin levels in individual persons as well as variation in iron levels in population studies [21].

2.5 Screening recommendations for IDA

Routine screening for IDA should be obtained in children 6–24 months of age. Screening consists of reviewing risk factors during any possible occasion or visit (risk assessment), and laboratory testing (laboratory screening) at least once during the mentioned period. Screening is recommended at all times for all infants and children who have any risk factor (malnutrition, low birth weight, prematurity, signs and symptoms of IDA, or living in the area with high prevalence of iron deficiency).

2.5.1 Risk assessment

Review of risk factors in all children is recommended at 4, 15, 18, 24, and 30 months, at 3 years, and once yearly afterward. This is currently the most important and valuable screening tool, more useful than laboratory testing of hemoglobin. Risk assessment consists of focused dietary history. The most vulnerable groups are children with the history of prematurity or low birth weight, infants using low-iron formula, nonformula cow's milk, soy milk or goat's milk before 12 months of age, infants having less than two iron-rich meals daily after 6 months of age, preschool children drinking more than 600 ml milk per day, or having less than three iron-rich meals daily [22].

2.5.2 Laboratory screening

American Academy of Pediatrics (AAP) suggests laboratory testing as the screening tool for iron deficiency at 1 year of age. Universal laboratory screening is recommended for all children 9–12 months of age. Additional laboratory screening is recommended for children with risk factors for iron deficiency and IDA. There are two groups of children that should undertake additional laboratory screening: - children with high risk for iron deficiency repeated laboratory testing at 15–18 months of age or when some risk is identified; and - children with special health needs (chronic diseases, inflammatory disorders, restricted diets) repeated laboratory testing in the period of early childhood (2–5 years of age). Laboratory screening in most cases includes complete blood count, which includes hemoglobin, hematocrit, mean corpuscular volume (MCV), and red blood cell distribution width (RDW). The minimum laboratory screening is measurement of hemoglobin with the normal value greater than 11 g/dl. Laboratory testing of serum ferritin at the time of the first screening is the major diagnostic tool in children with risk factors for iron deficiency and IDA [22]. Ferritin levels should be always evaluated carefully because ferritin is nonspecifically elevated in a wide variety of inflammatory conditions. A C-reactive protein can help to validate the results of serum ferritin levels. Other screening measurements that can be taken into account as a different approach for iron deficiency include reticulocyte hemoglobin concentration and combination of soluble transferrin receptor and hemoglobin [23]. It is recommended by AAP to perform risk assessment once a year during the period of adolescence. Adolescents with risk factors (those with a history of IDA, low-iron diet, or girls with heavy menstrual bleeding) should have laboratory testing for anemia [24]. Considering different opinions on screening recommendations in adolescents, each physician should personally decide about the screening process based on the risk factors. Laboratory testing should be done every 5 years starting from age 13 in girls, and at least once during the rapid growth period in boys. Children with any risk factor (increased physical activity, special diets, obesity, malnutrition, chronic illnesses, and heavy menstrual bleeding in girls) should be monitored more frequently. There is some controversy on routine screening for iron deficiency in areas with low rates of iron deficiency and IDA (i.e., United States). Studies provide little evidence that routine screening or iron treatment improves child's growth and neurodevelopmental outcome. On the other hand, routine screening is recommended because of the important health benefits. Besides, a physician should not decide about screening program only based on symptoms and risk factors in a child. Those who favor screening for iron deficiency in the adolescent period list high prevalence of anemia in that population and adverse consequences of iron deficiency. The screening tests are generally minimally invasive (blood sample), and therapy for IDA is safe [25].

2.6 Prevention of iron-deficiency anemia

Many recommendations for prevention of iron deficiency and IDA have been published, and the most commonly used are those provided by WHO and AAP. Widely used approaches include iron-fortified foods in a diet, iron-rich formulas, introduction of cow's milk in a diet from 12 months of age, screening for iron deficiency, and iron prophylaxis in infants [22]. It is important to emphasize that only a fraction of dietary iron is absorbed from food, depending on bioavailability (dietary iron absorption). Human milk contains only 0.3–1.0 mg/l of iron, but the bioavailability of iron is 50%, while milk formulas contain 12 mg/l of iron with bioavailability of iron 4–6% only [26]. As mentioned above, dietary iron has two main forms: heme and nonheme iron. Plants and iron-fortified foods contain nonheme iron only, whereas meat, seafood, and poultry contain both heme and nonheme iron. Heme iron has higher bioavailability than nonheme iron. The bioavailability of iron is approximately 14–18% from mixed diets, and 5–12% from vegetarian diets. Daily iron requirements vary depending on age and gender. Requirements for iron are 0.6 mg/day in healthy infants and 0.8 mg/day in preadolescent children. Adult males need 1 mg/day of iron, and adult females need 1.5 mg/ day. The recommended dietary iron for healthy full-term infants (from birth to 12 months of age) is 1 mg/kg/day (maximum 15 mg); for premature infants 2–4 mg/kg/day (maximum 15 mg); for toddlers 1–3 years of age 7 mg/day; for children aged 4–8 years 10 mg/day; for children aged 9–13 years 8 mg/day; for adolescent boys aged 14–18 years 11 mg/day, and for adolescent girls aged 14–18 years 15 mg/day. Boys have increased requirements during pubertal growth because of expanding blood volume and increase in hemoglobin concentration. Increased requirements in girls during puberty are mostly due to menstrual blood loss, although the loss differs in various individuals. Besides, adolescent girls more often have a tendency to eat food that contains less iron and to avoid high iron-containing foods, contributing to iron deficiency [27].

2.6.1 Recommendations for supplementation

Infants who are not breastfed, obtain sufficient amount of iron from iron-fortified formula. Breastfed infants should receive an additional source of iron (as iron supplement or complementary food) in these doses: - Full-term breastfed infants should receive an iron supplement from the age of 4 months (1 mg/kg/day, maximum 15 mg) until the infant has sufficient iron-rich complementary foods in a diet. - Premature breastfed infants should receive an iron supplement starting from the age of 2 weeks (2–4 mg/kg/day, maximum 15 mg) throughout the first year of life (as supplements or iron-fortified formula). Supplementation of iron is necessary to meet requirements in infants from populations with high rates of iron deficiency and IDA. In a prospective randomized trial of early versus late iron supplementation in low-birth-weight infants, infants who received early iron supplementation (started when feedings reached 100 ml/kg/day) had lower risk of infection and lower number of blood transfusions compared to infants who received late supplementation (started at 61 days of age) [28]. In a study from India that included breastfed infants at the age of 4–6 months, oral iron supplementation resulted in better growth, especially in infants who had anemia or were otherwise nutritionally deficient. Prevention of iron deficiency and IDA varies by geographical region, age group, and other conditions. In countries with high prevalence of IDA, comprehensive strategies and interventions for high-risk groups are implemented, in particular for young children, adolescent girls, women in reproductive age, and pregnant and breastfeeding women. In some regions, food fortification with iron, control of helminth infection, and control of malaria are effective approaches to prevent IDA [29].

2.6.2 Dietary recommendations

The optimal way to reach iron requirements is an improvement of food quality. In countries with low prevalence of iron deficiency, recommended dietary intake should assure expected iron requirements. Exclusive breastfeeding is recommended for the first 4–6 months of life. Preterm breastfed infants should receive an iron supplement from 2 weeks of age. Additional source of iron should be given to infants starting at 4 months of age, first as an iron supplement, followed by iron-fortified foods (two or more meals/day meet the expected requirements for iron). Partially breastfed and nonbreastfed infants should consume exclusively iron-fortified formulas [30]. Starting from the age of 6 months, infants should receive one feeding rich in vitamin C (green vegetables, fruits, and juices) daily. After 6 months of age, meat should be introduced in a diet. Heme iron (meat and fish) is more bioavailable than nonheme iron (vegetables and cereals). Combining heme foods with nonheme foods also increases the absorption of iron. Moreover, consumption of meat meets many requirements besides iron. Infants should not be given nonformula cow's milk until the age of 12 months. The higher concentration of calcium in cow's milk inhibits absorption of iron. Children aged 1–5 years should drink less than 600 ml of milk daily. Besides, they should take enough iron-containing foods to fulfill daily iron requirements. Children, who do not eat at least 2 or 3 iron-rich foods every day, may have inadequate iron intake and may need iron supplementation [31].

2.7 Iron deficiency anemia among children

Iron deficiency anemia is a major child health problem worldwide [32]. One-third of the world's population suffers from anemia, notably over half of the children in developing countries [1]. Iron deficiency is the main cause of childhood anemia; other causes include micronutrient deficiencies, haemoglobinopathies and infections such as malaria [33]. Children are more vulnerable to developing anemia because they are rapidly growing and liable to infection. Moreover, micronutrients such as iron and folic acid are likely to be inadequate in children's diets if parents are not well informed [34]. Anemia is not only one of the leading causes of childhood mortality and morbidity [35], it may also affect cognitive development and school performance [36] .

2.8 Previous studies

Iron deficiency anemia is the commonest nutritional disorder and affects a high percentage of people especially pre-school children and reproductive women in Arab Gulf countries despite the significant improvement in economic and health status. In developing countries having low-and middleincome, the prevalence of anemia among 6–59 month age children was >20% based on latest demographic and heath survey (DHS) report rounds between 2005–2018, and it is classified as severe public health problem [37]. The problem is alarming in Sub-Saharan African Countries such as Kenya 48.9% [38]; Mali 55.8% [39] and Tanzania 79.6% [40]. Lack of awareness among the mothers about the problem coupled with their low educational status [41], poor nutritional practices and unhealthy food habits [42], low iron bioavailability of the diet [43], decreased physical activities [44], malaria and parasitic infestations are additional factors associated with lower hemoglobin (Hgb) level in children [45]. Factors including family size, low socio-economic status, illiteracy and ignorance are associated with anemia among under five children. Infection with Hook worm and intestinal helminthes causes gastro-intestinal blood loss resulting in depletion of iron stores and consequently also impaired erythropoietin [7]. This leads to mal-absorption and inhibition of appetite, there by worsening micronutrient deficiency and children anemia [41]

Chapter Three

Methodology

3. Methodology

3.1 Study design

This study was cross sectional type of descriptive hospital-based study

3.2 Study duration

Data was collected from during period from Jun to Dec 2022.

3.3 Study area

The study was done in Ahmed Gasim peadiatrics hospital. It's the largest and busiest children hospital in Sudan. Established in 1957, the hospital is a 300 bed capacity hospital located in north Khartoum- Sudan.

3.4 Study population

All children admitted from the outpatient and emergency departments in Ahmed Gasim peadiatrics hospital

3.5 Sampling techniques

It was conducted by simple random sampling methods

3.6 Sample size

The sample size was calculated using the formula of Fisher., et al. (1998) formula was used to calculate the sample size:

$$N = (Z2 \times (p \times q))/e2$$

- n: sample size required by the study
- Z: the determined area under the normal curve by the desired confidence interval (for 95% confidence level z = 1.96).
- P: the proportion of the main attribute of the study (the expected prevalence of Iron deficiency anemia among children in Sudan (35%).
- q=1-p = 1 – 0.35= 0.65
- e=the desired precision (e=0.05)

Then the formula becomes as following:

$$\mathbf{n} = \frac{(\mathbf{1.96})\times(\mathbf{1.96})\times(\mathbf{0.65})\times(\mathbf{0.35})}{(\mathbf{0.05})\times(\mathbf{0.05})} = \frac{\mathbf{0.873964}}{\mathbf{0.0025}} = 129 \text{ study participants}$$

3.7 Inclusion criteria

- All children admitted from the outpatient and emergency departments who fell into this category were all included irrespective of chronic health conditions.

3.8 Exclusion criteria

Those children with incomplete information and absent caregivers however were excluded from the study.

3.9 Study variables

- Dependent variables: Prevalence of iron deficiency anemia Iron deficiency anemia among children aged 2–10 years
- Independent variables: general characteristic of children such as socio-demographic factors (age and gender), family socio-demographic characteristics such as (Marital status, Mother's educational level, Mother's employment status, Father's educational, and Father's employment status)

3.10 Data collection

Data was collected from respondents using structured interviewer administered questionnaires were constructed developed from questionnaire used in a previous study to obtain information on demographics, dietary lifestyle, and cultural, socio-economic, environmental and household conditions. Hard copies of the questionnaires, provided in English language, was distributed to study participants by research assistants. The purpose of the study was explained, and written consent obtained from the study participants. The participants had an opportunity to contact the research team for clarity on the questions in the questionnaire if the need arose.

3.11 Ethical Considerations

An approval from Institutional Ethics Committee, NAPTA College. The objective of the study was explained to all participants, and their consent was taken. Participants who fulfilled the above criteria were included in the study after taking consent. Approval and issuance of authorization verbal from the Ahmed Gasim was obtained. Moreover, a verbal consent form from caregiver was signed before data collection.

3.12 Data analysis

The collected data was analyzed by using the Statistical Package for Social Sciences (SPSS) for displaying frequency, mean and percentage. Descriptive statistics and correlation analysis was used to detect the association

Chapter Four

Results

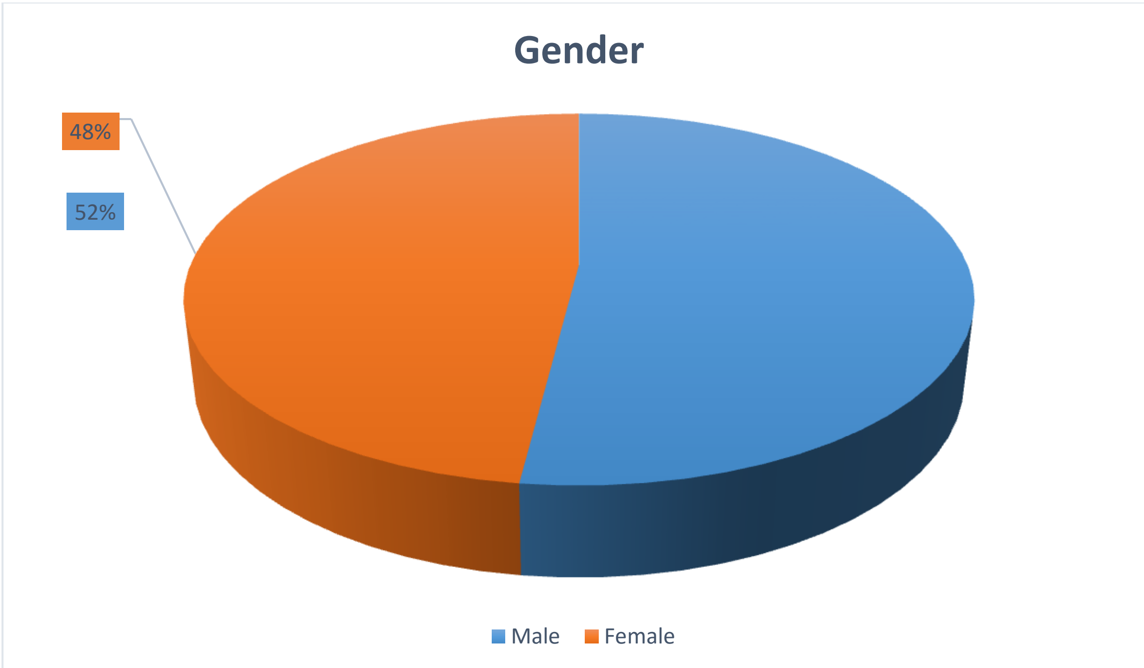

Figure 4.1 Distribution of Gender among Sudanese children (N=129)

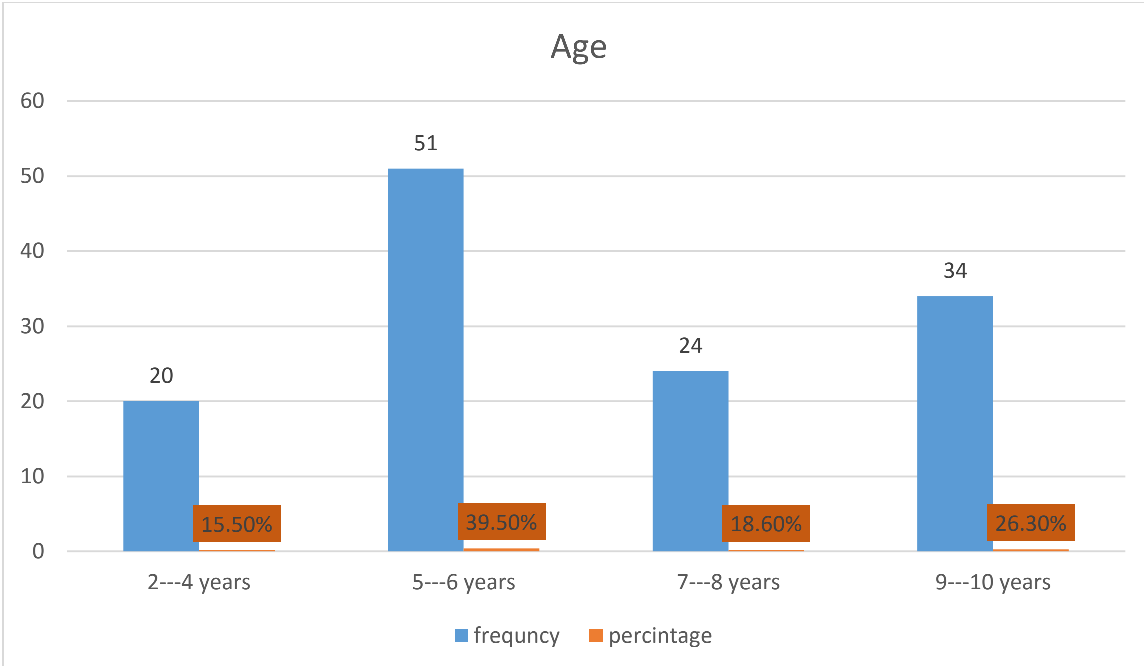

Figure 4.2 Distribution of Age among Sudanese children (N=129)

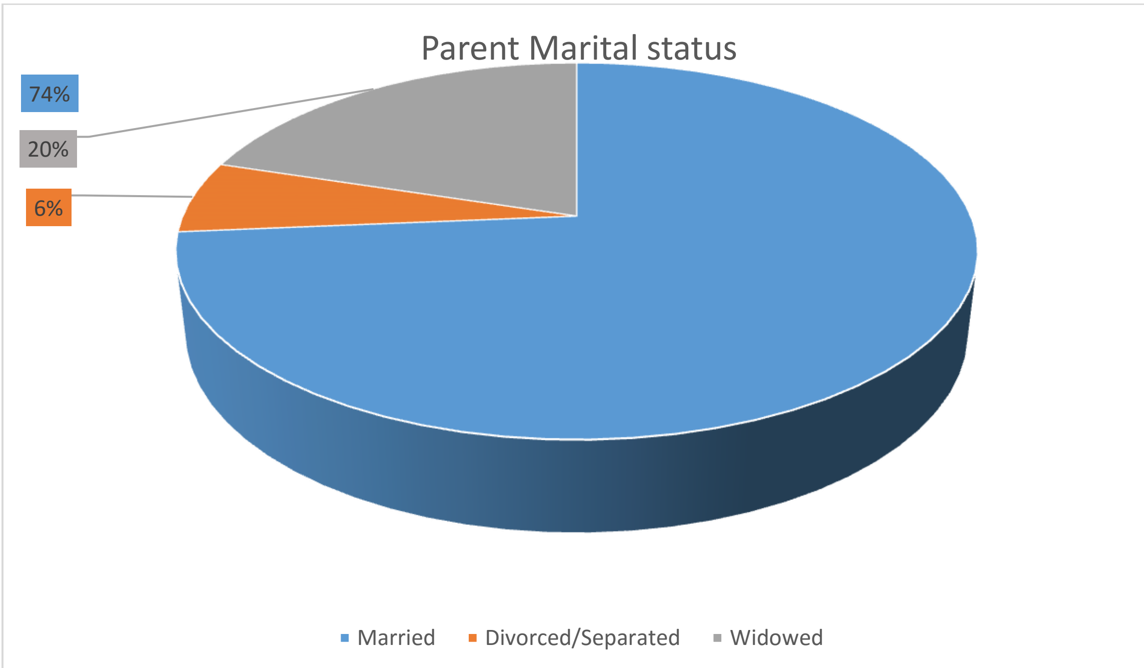

Figure 4.3 Distribution of Parent Marital status (N=129)

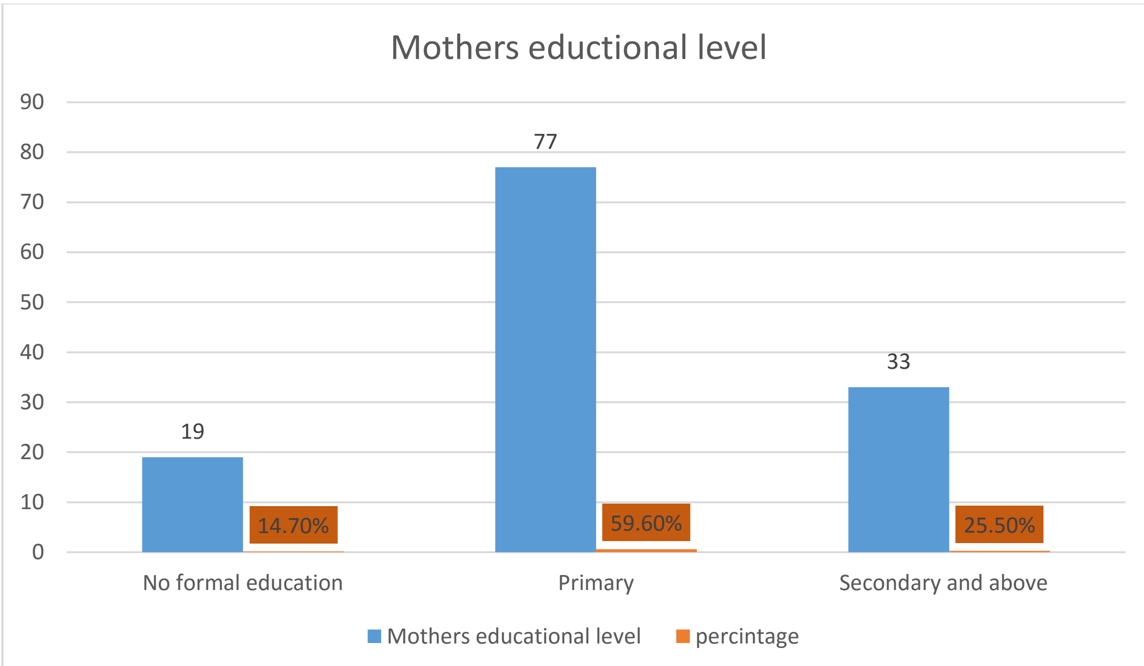

Figure 4.4 Distribution of Mother's educational level (N=129)

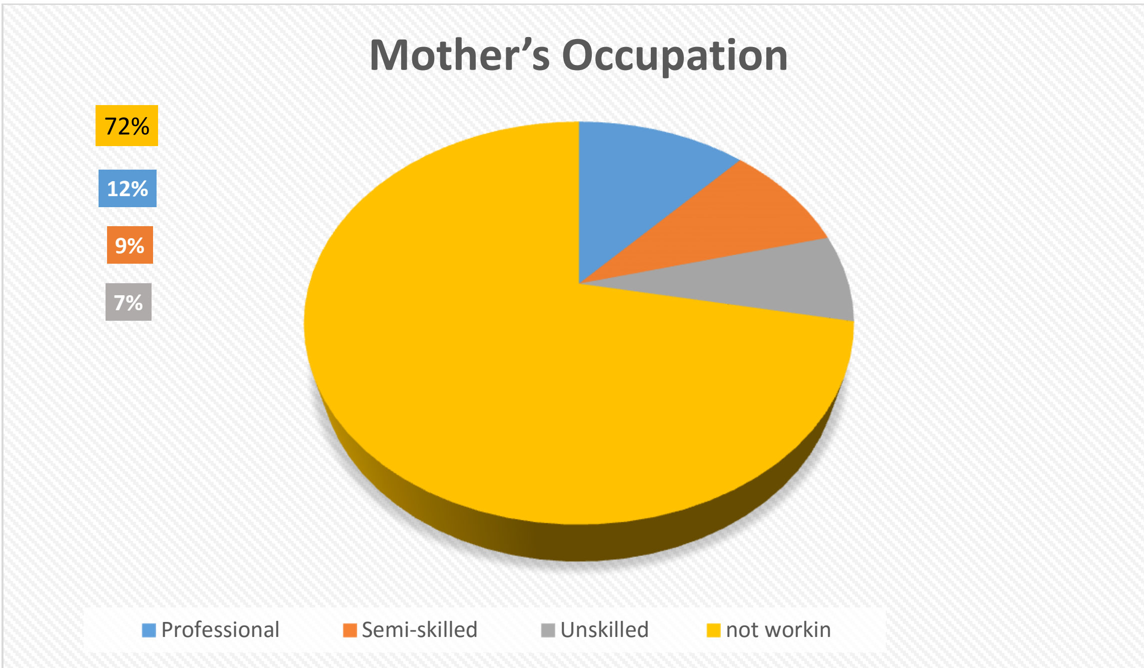

Figure 4.5 Distribution of Mother's occupation (N=129)

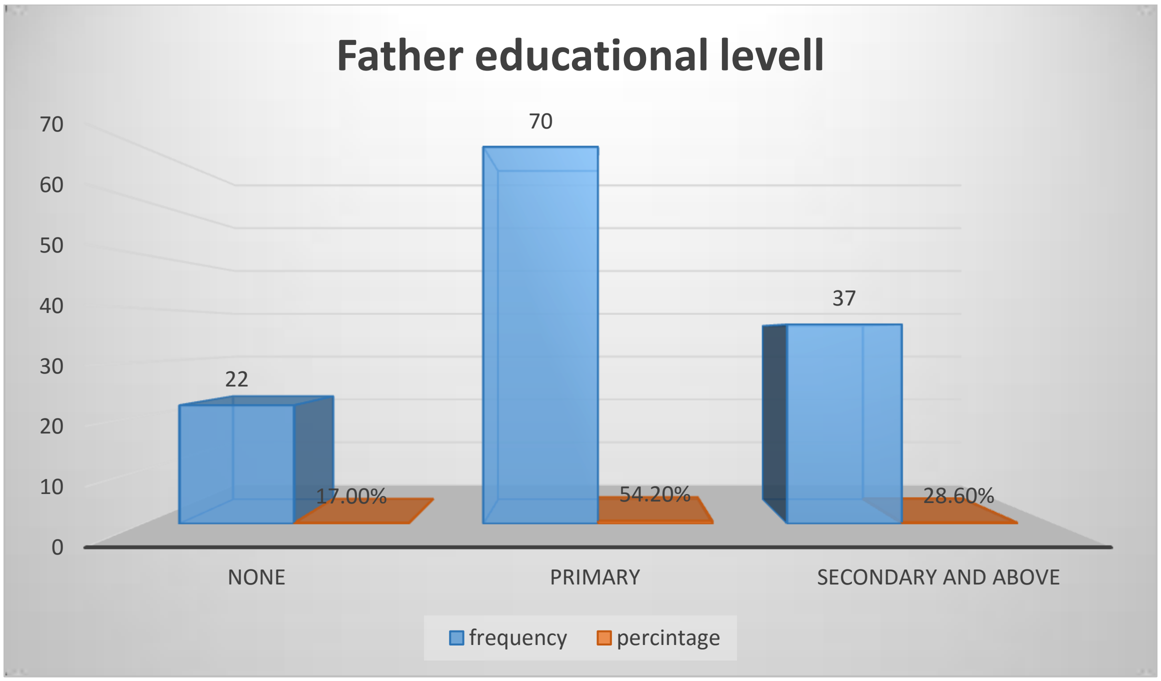

Figure 4.6 Distribution of Father's educational level (N=129)

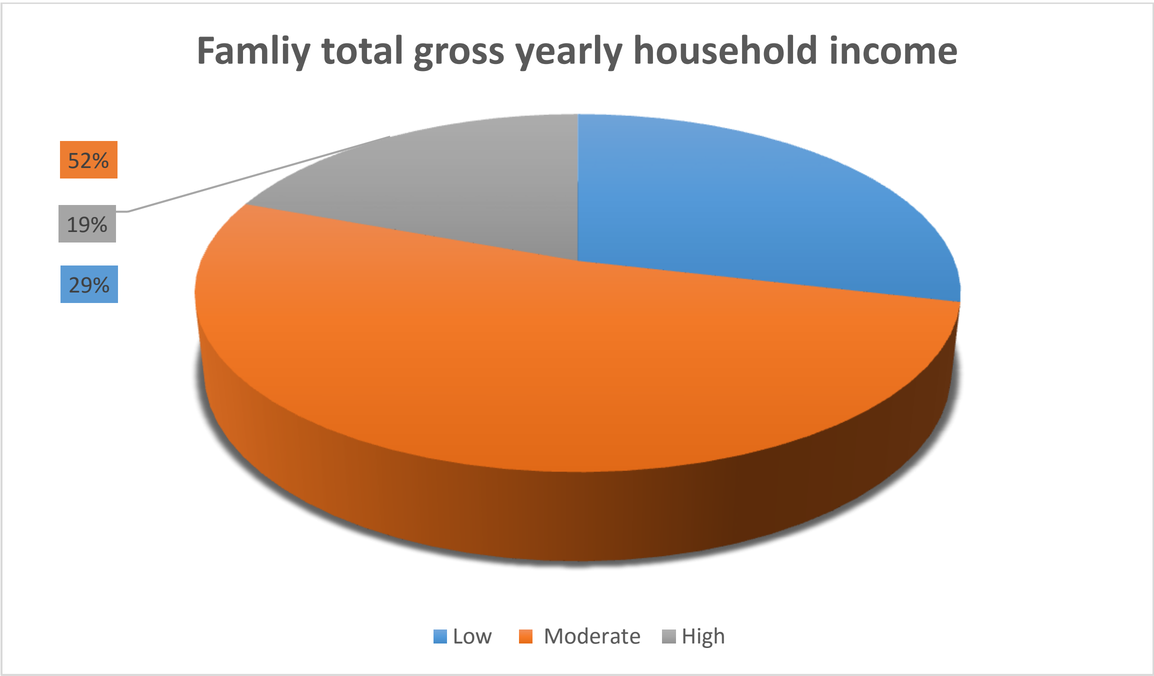

Figure 4.7 Distribution of Family total gross yearly household income (N=129)

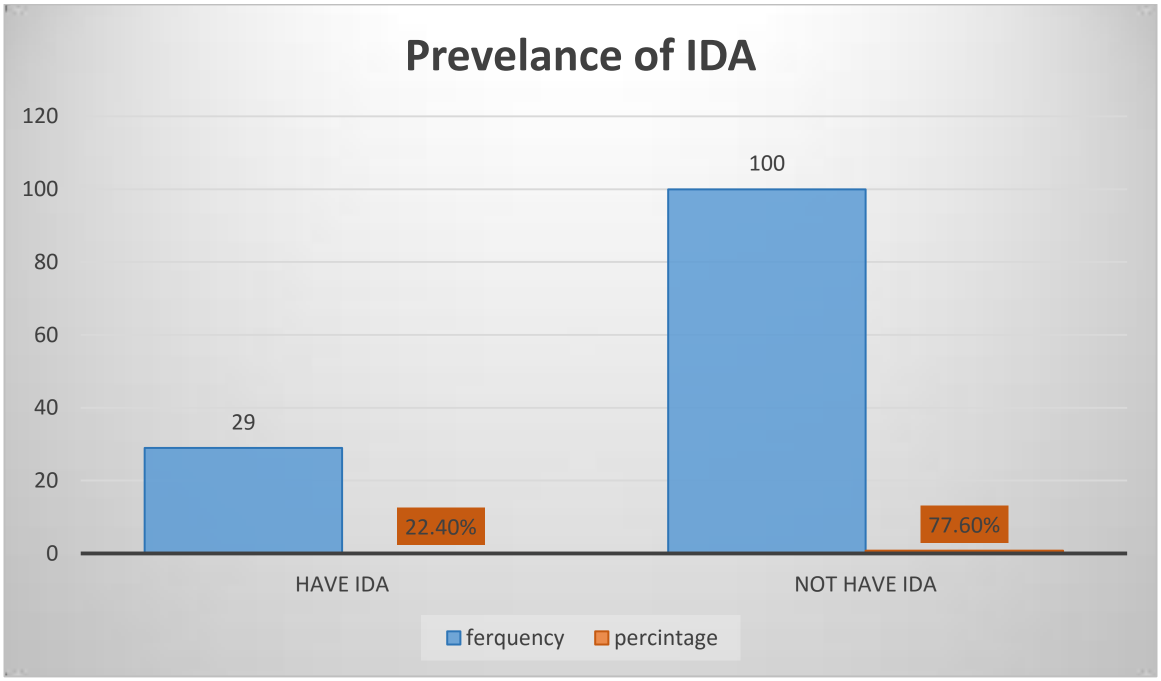

Figure 4.8 illustrates the prevalence of iron deficiency anemia among Sudanese children (N=129)

Table 4.1 Relationship between children, family socio-demographic characteristics with iron deficiency anemia.

Variables	Presence of IDA	P value

		Yes (%)	No (%)	
Gender	Male	12 (41%)	55 (100%)	0.597
	Female	17 (58.6%)	45 (45%)	
Age Years	2-4 years	11 (37.9%)	9 (9%)	0.923
	5-6 years	7 (24.1%)	44 (44%)	
	7-8 years	5 (17.2%)	19 (19%)	
	9-10 years	6 (4.6%)	28 (28%)	
Parent Marital status	Married	17 (58.6%)	78 (78%)	0.333
	Divorced/Separated	3 (10.3%)	5 (5%)	
	Widowed	9 (31.0%)	17 (17%)	
Mother's educational level	None	3 (10.3%)	16 (16%)	0.413
	Primary	21 (74.2%)	56 (56%)	
	Secondary and above	6 (20.6%)	27 (27%)	
Mother's Occupation	Professional	5 (3.8%)	10 (10%)	0.293
	Semi-skilled	1 (0.7%)	11 (11%)	
	Unskilled	0 (0%)	9 (9%)	
	not workin	23 (79.3%)	70 (70%)	
Father's educational level	None	2 (6.8%)	20 (20%)	0.817
	Primary	18 (62.0%)	52 (52%)	
	Secondary and above	9 (31.0%)	28 (28%)	
Family total gross yearly household income	Low	8 (27.5%)	29 (29%)	0.253
	Moderate	16 (55.1%)	51 (51%)	
	High	5 (17.2%)	20 (20%)	
Total		29 (100%)	100 (100%)	

Table 4.2: Dietary factors associated with iron deficiency anemia.

Variables		N%	Presence of IDA		P value
			Yes (%)	No (%)	
History of pica consumption during pregnancy	Yes	32 (24.8%)	11 (37.9%)	21 (21%)	0.029
	No	97 (75.2%)	18 (62.1%)	79 (79%)	
History of cow	Yes	15 (11.6%)	8 (27.5%)	7(7.0%)	0.015

milk consumption before 6 months	No	114 (88.3%)	21 (72.4%)	93(93%)	
Food frequency patterns of the households	Milk	19 (14.7%)	6 (20.6%)	13 (13%)	0.043
	Meat	6(4.6%)	2(6.8%)	4 (4%)	
	Fresh vegetables	6(4.6%)	3 (10.3%)	3 (3.0%)	
	cooked vegetables	95 (73.6%)	17(58.6%)	78 (78%)	
	Fruits	3 (2.3%)	1(3.4%)	2 (2.0%)	

Table 4.3: Relationship of morbidity and environment factors with iron deficiency anemia.

Variables		N%	Presence of IDA		P value
			Yes (%)	No (%)	
Immunization status	Partial	106 (82.1%)	23 (79.3%)	83 (83%)	0.447
	Full	23 (17.8%)	6 (20.6%)	17 (17%)	
Malaria infection	Yes	45 (34.8%)	13 (44.8%)	32 (32%)	0.076
	No	84 (65.1%)	16 (55.2%)	68 (68%)	
Parasite infection	Intestinal/urogenital parasite	13 (10.1%)	5 (17.2%)	8 (8%)	0.18
	A. Lumbricoides	10 (7.7%)	3 (10.3%)	7 (7%)	
	G. lamblia	18 13.9%)	4 (13.7%)	14 (14%)	
	S. haematobium	9 (6.9%)	4 (13.7%0	5 (5%)	
	No	79 (61.2%)	13 (44.8%)	66 (66%)	
Diarrheal disease (in last 2 weeks)	Yes	60 (46.5%)	20 (68.9%)	40 (40%)	0.029
	No	69 (53.4%)	9 (31.0%)	60 (60%)	
Blood transfusion (past year)	Yes	14 (10.8%)	7 (24.1%)	7 (7%)	0.007
	No	115 (89.1 %)	22 (75.8%)	93 (93%)	
Source of water for drinking or/for bath	Unsafe (river, lagoon)	112 (86.8%)	19 (65.5%)	93 (93%)	0.040
	Safe (piped, fountain)	17 (13.2%0	10 (34.4%0	7 (7%)	

Chapter Five

Discussion, conclusion & Recommendations

5. Discussion, conclusion & Recommendations

5.1 Discussion

This study has highlighted the prevalence and factors associated with iron deficiency anemia among children aged 2 to 10 years seen in Ahmed Gasim hospital, Sudan. The findings of this study serve as a contribution towards the scarce baseline data on prevalence of iron deficiency anemia among children below 10 years in Sudan. The prevalence of anemia in this study was 22.4% which is lower compared to the results provided in the 2014/2015 Rwanda Demographic Health Survey which estimates prevalence of anemia of 37% among children. Compared to the prevalence of anemia observed in this study, the higher prevalence (66.6%) was reported among Ethiopian children [46] and a prevalence of 58.8% was observed among Ugandan Children [47]. In our study, 70.7% of children with anemia are seen to have iron deficiency, which is much higher compared to a study conducted in Rwanda where anemia in children in the southern highlands of Rwanda was said to be frequent, and one in four anemic children had iron deficiency [48]. The prevalence of iron deficiency anemia observed in this study (22.4%) is much higher compared to what reported by other study conducted in Northern and Southern province of Rwanda [49]. The reduced prevalence of anemia observed in this study when compared to other previous study conducted in in Africa could be explained by public health interventions such as deworming of children and malaria diagnosis and treatment that have played a huge role in curbing the problem of anemia in children in Sudan like most other developing countries. Increased proportion of children with anemia having iron deficiency can be explained by a large number of children having poor dietary iron intake in this study. Also serum ferritin measurement which is widely used in previous study as a marker for iron status was not used in this study, its value may be limited by its role as an acute-phase reactant as it is known to be elevated in both infections and inflammations; also, another important factor to consider is its cost in a developing country like Sudan.

Demographic and socio-economic status of the family showed no association with iron deficiency anemia. Even though previous studies done in another countries have demonstrated associations between anemia and other indicators of poor socioeconomic conditions in Africa [50, 51]. This inconstant result could be related to the study setting, where many previous studies were conducted in community settings while our study was conducted in hospital settings. In our study, we tested the association between iron deficiency anemia and socio-demographic characteristics, while in other studies assessed the association between anemia and socio-demographic characteristics, this could also explain our findings.

In our study, we found that children who consumed cow milk consumption before six months were likely to have iron deficiency anemia. This is similar to another study done in Tanzania

[52] which showed drinking of cow milk as a significant predictor of anemia [AOR = 2.5; (CI = 1.1 - 5.2)]. This can be explained by poor iron absorption in cow milk. Cow's milk has decreased iron density and bioavailability, excess protein and minerals, notably calcium, and therefore it interferes in the absorption of iron from other feeds. Cow milk is also linked to small intestinal hemorrhage in young children. Also, Vitamin C has been recognized to enhance the absorption of iron. Cow's milk contains little vitamin C and pasteurization reduces that amount significantly. We further found that children who have the history of blood transfusion had increased risk of iron deficiency anemia. With respect to this, blood transfusion provides a solution to the acute problem and not necessarily the underlying problem. Iron deficiency if present will persist without iron supplementation to correct the lack and supplement the child's needs. It is important to find out why the child is anemic and treat the cause as well as the symptoms.

5.2 limitation of study

In addition to strengths, limitations to this study exist. The study only included a limited number of children seen in a hospital and cannot be interpreted to be a generalized finding to a larger context without caution. Also, in diagnosing iron deficiency, Serum ferritin estimation could have increased the accuracy of its diagnosis.

5.3 Conclusion

This study yielded important information about the prevalence of iron deficiency anemia, and the various factors associated with its prevalence. It has helped in assessing the prevalence of anemia in this age group. Based on these findings, demographic and socioeconomic status showed no direct association with iron deficiency anemia. The study concludes that iron deficiency remains a very important cause of anemia in children in this age group. It emphasizes the need for iron supplementation in children who have recently had blood transfusion on account of severe anemia.

5.4 Recommendations

On the basis of the findings in this study, the following recommendations have been made:

The role of the Government and Ministry of Health cannot be overemphasized with implementation of policies that promote exclusive breastfeeding for first 6 months, and proper nutrition. This could be achieved through continuous information dissemination about iron rich foods and iron absorption by the human body, the improvement of environmental conditions and the application of reliable, easy to use and cheap methods for Hb estimation and possibly serum ferritin levels. Iron supplements should also be made affordable and easily accessible

Further studies in iron deficiency in adolescents will be vital as few studies have assessed iron deficiency in older children.

Chapter Six

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6.2 Questionnaire

NAPTA College

Faculty of medicine

Questionnaire

Part 1: Socio-demographic characteristics of respondents

Child Age: …………… Years

Child Gender:

Male ☐ Female ☐

Number of persons/household

<2 ☐ 2-5 ☐ >5 ☐

Parent Marital status

Married ☐ Divorced/Separated ☐ Widowed ☐

Mother's educational level

None ☐ Primary ☐ Secondary ☐ University ☐

Mother's Occupation

Professional ☐ Semi-skilled ☐ Unskilled ☐ Full-time carergiver/not workin ☐

Father's educational level

None ☐ Primary ☐ Secondary ☐ University ☐

Father's Occupation

Professional ☐ Semi-skilled ☐ Unskilled ☐ Full-time carergiver/not workin ☐

Famliy total gross yeatly houdehold income

Low ☐ Moderate ☐ High ☐

Part 2: Dietary factors assessed for IDA

History of pica consumption during pregnancy

Yes ☐ No ☐

History of cow milk consumption before 6 months

Yes ☐ No ☐

Food frequency patterns of the households

Milk ☐ Meat ☐ Fresh vegetables ☐ cooked vegetables ☐
Fruits ☐

Part 3: Morbidity and environmental factors associated with iron deficiency anemia

Immunization status

Partial ☐ Full ☐

Malaria infection

Yes ☐ No ☐

Parasite infection

Intestinal/urogenital parasite ☐ A. Lumbricoides ☐
G. lamblia ☐ S. haematobium ☐

Diarrheal disease (in last 2 weeks)

Yes ☐ No ☐

Blood transfusion (past year)

Yes ☐ No ☐

Source of water for drinking or/for bath

Unsafe (river, lagoon) ☐ Safe (piped, fountain) ☐

Part 4: Prevalence of iron deficiency anemia among children

Mild anemia Hemoglobin (Hb) levels of < 10g/dl) ☐

Moderate anemia Hemoglobin (Hb) levels of 7 - 9 g/dl ☐

Severe anemia Hemoglobin (Hb) levels of < 7 g/dl ☐