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Review on Food Insecurity and Its Relationship with Iron and Vitamin B_{12} Status among Children

(Tinjauan Ketidakjaminan Makanan serta Hubungannya dengan Status Ferum dan Vitamin B_{12} dalam Kalangan Kanak-Kanak)

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Abstract

Iron and vitamin B_{12} are essential micronutrients needed for the growth and development of children. Iron is critical for erythropoiesis, notably in haemoglobin synthesis whereby haemoglobin transports oxygen to cells, which is essential for cellular metabolism and energy production. Meanwhile, vitamin B_{12} is required for deoxyribonucleic acid synthesis, intracellular metabolism, and blood cells formation and maturation. Lack of these essential micronutrients can lead to nutritional deficiency and anaemia, especially among children. Food insecurity is a condition where there is a lack of or uncertain availability of acquiring acceptable food. Food insecurity is associated with lower nutrient intake and micronutrient deficiencies including iron and vitamin B_{12}, which can subsequently lead to poor health outcomes. Various determinants are associated with iron and vitamin B_{12} deficiency, and food insecurity, such as socio-economic factors, environmental factors, and dietary intake. This review will explore the possible relationship between iron, vitamin B_{12}, and anaemia with food insecurity among children.

Keywords: Anaemia; dietary intake; food insecurity; micronutrients; socio-economic factors

Abstrak

Ferum dan vitamin B_{12} adalah mikronutrien penting yang diperlukan bagi tumbesaran dan perkembangan kanak-kanak. Ferum penting untuk eritropoiesis, terutamanya dalam penghasilan hemoglobin kerana hemoglobin berperanan untuk mengangkut oksigen ke sel-sel dan ini penting bagi metabolisme sel dan penghasilan tenaga. Di samping itu, vitamin B_{12} diperlukan untuk sintesis asid deoksiribonukleik, metabolisme intrasel, serta pembentukan dan pematangan sel darah. Kekurangan mikronutrien penting ini boleh membawa kepada kurang pemakanan dan anemia terutamanya dalam kalangan kanak-kanak. Ketidakjaminan makanan adalah keadaan terdapat kekurangan atau ketersediaan yang tidak pasti untuk memperoleh makanan yang boleh diterima. Ketidakjaminan makanan dikaitkan dengan kekurangan pengambilan nutrien dan kekurangan mikronutrien termasuklah ferum dan vitamin B_{12} yang seterusnya menyebabkan kesan yang berpanjangan kepada kesihatan. Pelbagai faktor penentu yang dikaitkan dengan kekurangan ferum dan vitamin B_{12}, serta ketidakjaminan makanan seperti status sosioekonomi, faktor persekitaran dan pengambilan makanan. Oleh itu, tinjauan ini bertujuan meneroka hubungan ferum, vitamin B_{12}, dan anemia dengan ketidakjaminan makanan dalam kalangan kanak-kanak.

Kata kunci: Anemia; faktor sosioekonomi; ketidakjaminan makanan; mikronutrien; pengambilan makanan

Introduction

The United Nations Convention on the Rights of Child (Article 1) (1989) defines a child as 'Every human being below the age of 18 years unless, under the law applicable to the child, the majority is attained earlier'. Children's developmental phases can be classified into infancy (0-1 years), toddlerhood (2-3 years), preschool (3-5 years), middle childhood (6-11 years), and adolescence (12-17 years old) (CDC 2021). In this critical period, children are undergoing developmental growth whereby nutrition plays an important role in fulfilling the energy and nutrient requirements for their growth spurt, mental health, cognitive development, and their overall physical well-being (Das et al. 2017). Lack of nutrients, especially essential micronutrients will impair their growth and bodily function. Iron and vitamin B_{12} are among essential micronutrients crucial in maintaining human metabolism and blood cell formation (Bhattacharya, Misra & Hussain 2016; Smith, Warren & Refsum 2018). Low serum level of iron and vitamin B_{12} will lead to nutritional deficiencies which impair the growth and development in children. Inadequate intake of nutritious foods may lead to the occurrence of vitamin and mineral deficiencies (Kreusler et al. 2021), including iron deficiency (Pirkle et al. 2014), iron deficiency anaemia (McGuire 2015), and vitamin B_{12} deficiency (Pasricha et al. 2011).

Food insecurity, a condition of 'limited or uncertain availability of nutritionally adequate and safe food or limited or uncertain ability to acquire acceptable foods in socially acceptable ways' (United States Department of Agriculture Economic Research Service 2014) has affected households all over the world in both developing and developed countries. Socio-economic, demographic, and environmental aspects are among the factors that contribute to food insecurity (Charles Shapu et al. 2020; Chowdhury et al. 2016; Sulaiman et al. 2021). Children living in food insecure households tend to consume energy-dense foods which are low in nutrients (Brouwer-Brolsma et al. 2015) particularly micronutrients, thus limiting the diet quality of foods eaten especially foods low in iron (Bernal, Frongillo & Rivera 2016; Gompakis et al. 2007; Metallinos-Katsaras et al. 2016) and cobalamin (Kirkpatrick & Tarasuk 2008). Given that the poor diet quality in food insecure children places them at risk of health outcomes, such as anaemia (Metallinos-Katsaras et al. 2016), it is the right time to explore the relationships between food insecurity with iron deficiency, vitamin B_{12} deficiency, and anaemia.

Methods

The literature search was performed using the following search engines: Google Scholar; PubMed (Medline); Web of Science; and Scopus. The following keywords were used including 'iron status', 'iron status among children', 'iron deficiency', 'iron deficiency among children', 'vitamin B_{12} status', 'vitamin B_{12} status among children', 'vitamin B_{12} deficiency', 'vitamin B_{12} deficiency among children', 'anaemia among children', 'dietary intake and iron status', dietary intake and vitamin B_{12} status', 'food insecurity', 'food security among children', 'sociodemographic factors and food insecurity', 'demographic factors and food insecurity', environmental factors and food insecurity', 'food insecurity and dietary intake', 'relationship between food insecurity with anaemia among children', 'relationship between food insecurity with iron and/or vitamin B_{12}' and 'relationship between food insecurity with iron and/or vitamin B_{12} among children'.

Iron Status Among Children

Iron is a micronutrient that is required by the human body. It is essential in many metabolic processes, including oxygen transport, electron transport, and DNA synthesis. Iron is found in the human body primarily in: i) haemoglobin in red blood cells and erythroblasts; ii) myoglobin in muscle cells and other iron-containing proteins like cytochromes and catalases; iii) transferrin, which binds iron in circulation; and iv) storage proteins like ferritin and haemosiderin (Bhattacharya, Misra & Hussain 2016). A condition whereby iron stores in the body are insufficient is known as iron deficiency. Iron is required for red blood cell formation, which is known as erythropoiesis, particularly for haemoglobin synthesis. A condition caused by lack of iron and lack of haemoglobin is known as iron deficiency anaemia. Iron deficiency anaemia usually results in microcytic and hypochromic erythrocytes (Miniero et al. 2018). Several aetiologies that cause iron deficiency in the population include chronic blood loss, hookworm infestation, chronic diseases, malnutrition, poor dietary iron intake, and menstruation in female adolescents (Camaschella 2019).

Iron Deficiency and Its Associated Factors Among Children

There is a considerable risk of iron deficiency among children especially, infants, pre-schoolers, and adolescents, due to increased iron requirements as they are undergoing rapid growth and development during this crucial period (Roganović & Starinac 2018). Female adolescents are also vulnerable to iron deficiency and iron deficiency anaemia due to chronic blood loss during heavy menses (Camaschella 2019). Around 600 million preschool and school-aged children all over the world are affected by anaemia with half of the anaemia occuring as a result of iron deficiency (WHO 2011). In the United States, iron deficiency and iron deficiency anaemia affect 9-16% and 2-5% of the female adolescent population respectively (Sekhar et al. 2015). In Southeast Asian countries, the prevalence of iron deficiency and anaemia among school-aged children in Indonesia were 1.9-5.3% and 11.7-12.9%, respectively (Sandjaja et al. 2013), in Malaysia 5.2% and 4%, respectively (Nik Shanita et al. 2018), in Thailand 32.4-37.2% and 6.6-12.2%, respectively (Rojroongwasinkul et al. 2013), and in Vietnam 5.6% and 11.4%, respectively (Le Nguyen et al. 2013).

There are several factors that are associated with iron deficiency among children which are socio-economic status, parental educational level, and dietary iron intake. In the United States, the prevalence of iron deficiency is higher in poor children and low-income families (Brotanek et al. 2008). Similarly, the study by Gompakis et al. (2007) in Greece found that the incidence of iron deficiency and iron deficiency anaemia was greater in semiurban regions as most of them were of low socio-economic status and consuming mostly low cost and low iron foods.

The level of education of parents plays a significant role in the health of children. Parents with low educational background are more likely to have children who develop iron deficiency anaemia than children of parents with higher education (Ngui et al. 2011). Study by Choi et al. (2011) in South Korea also reported that children with more educated mothers were less likely to develop iron deficiency and iron deficiency anaemia than were those with less-educated mothers as educated mothers have better knowledge of health and nutrition, thus enabling their children to consume quality food.

Dietary iron intake is also one of the factors associated with iron deficiency among children. Lack of red meat was associated with seven times risk of developing iron deficiency anaemia in developing countries compared to Europe or North America (Roganović & Starinac 2018). Children consuming high amounts of cow's milk (more than 400 mL) was associated with a high prevalence of iron deficiency since high calcium, low iron, and vitamin C content in cow's milk may inhibit the absorption of iron, thereby placing these children at risk of poor iron status (Uijterschout et al. 2014). Treatment or prevention of iron deficiency usually includes foods that are rich in iron and foods containing vitamin C that increase iron absorption (Parkin & Maguire 2013).

BLOOD BIOMARKERS OF IRON DEFICIENCY

Inadequate iron absorption to match an increase in needs due to growth or long-term negative iron balance causes iron deficiency. Iron stores are depleted in either of these circumstances, as indicated by serum ferritin concentrations or bone marrow iron content (WHO 2020). Other biomarkers of iron status including serum iron concentration, total iron binding capacity (TIBC), and serum transferrin level. WHO (2020) suggested using serum ferritin for assessment of iron deficiency due to its function as primary iron-storage protein. However, since ferritin is an acute-phase protein, and its serum levels are elevated during inflammation, C-reactive protein and α-1-acid glycoprotein can aid in the interpretation of serum ferritin.

Recent assessment for iron deficiency has included serum transferrin receptor (sTfR). Due to the ability of the receptors to be unaffected by concurrent infection or inflammation, sTfR levels have been utilized to distinguish iron deficiency anaemia from anaemia of chronic disease where individuals with iron deficiency will have elevated sTfR concentrations (WHO 2014). However, as the sTfR levels can be affected by the rate of erythropoiesis from any cause, it cannot be used as the sole indicator of erythropoiesis due to iron deficiency (WHO 2014). Table 1 illustrates different biomarkers for determining iron deficiency and its reference range among children.

VITAMIN B_{12} STATUS AMONG CHILDREN

Vitamin B_{12}, also known as cobalamin, is a cobalt-containing water-soluble vitamin that plays a crucial role in several physiologic functions including erythropoiesis, maintenance of myelin sheath, and synthesis of DNA, and neurotransmitters (Smith, Warren & Refsum 2018). Intracellular conversion of vitamin B_{12} to two active coenzymes, adenosylcobalamin and methylcobalamin, is necessary for the homeostasis of methylmalonic acid and homocysteine, respectively. A condition in which vitamin B_{12} is deficient in blood and associated with non-haematological complications is known as vitamin B_{12} deficiency. Vitamin B_{12} deficiency is usually associated with megaloblastic anaemia (Green 2017). Vitamin B_{12} deficiency can also be observed among those with pernicious anaemia in which

TABLE 1. Blood biomarkers for iron deficiency and its reference range for children

Biomarker	Age group	Reference range	References
Serum iron concentration, µg/d[l]a	1 - 5 years	22 -136	Miniero et al. (2018)
	6 - 9 years	39 - 136	
	10 - 14 years, male	28 - 134	
	10 - 14 years, female	45 - 145	
	14 - 17 years, male	34 - 162	
	14 - 17 years, female	28 - 184	
Serum TIBC, µg/dl[a]	1 - 5 years	268 - 441	Miniero et al. (2018)
	6 - 9 years	240 - 508	
	10 - 14 years, male	302 - 508	
	10 - 14 years, female	318 - 575	
	14 - 17 years, male	290 - 570	
	14 - 17 years, female	302 - 564	
Serum transferrin, mg/dl[a]	1 - 3 years, male	196 - 365	Miniero et al. (2018)
	1 - 3 years, female	149 - 382	
	4 - 6 years, male	202 - 350	
	4 - 6 years, female	174 - 399	
	7 - 9 years, male	149 - 353	
	7 - 9 years, female	186 - 368	
	10 - 12 years, male	173 - 380	
	10 - 12 years, female	185 - 377	
	13 - 15 years, male	171 - 374	
	13 - 15 years, female	193 - 391	
	16 - 17 years, male	194 - 348	
	16 - 17 years, female	181 - 416	
Serum ferritin, without the presence of infection, µg/L	<5 years	< 12	WHO (2020)
	>5 years	< 15	WHO (2020)
Serum ferritin, with the presence of infection, µg/L	<5 years	< 30[b]	WHO (2020)
	>5 years	< 70[b]	WHO (2020)
C-reactive protein, mg/L	≥6 months	≤ 5[c]	WHO (2020)
α-1-acid glycoprotein, g/L	≥6 months	≤ 1[c]	WHO (2020)
Serum sTfR, mg/L	1 - 5 years	> 1.9	Vázquez-López et al. (2019)
	6 - 11 years	> 1.8	
	12 - 16 years, male	> 1.95	
	12 - 16 years, female	> 1.75	

[a]Values of serum iron, TIBC and transferrin in paediatric age are ranging from 2.5^{th} to 97.5^{th} percentiles whereby serum iron is reduced (< 2.5^{th} percentile), and both serum TIBC and transferrin are increased (>97.5^{th} percentile) in iron deficiency and iron deficiency anaemia; [b]The increase in ferritin cut-off value caused by inflammation was accounted both in individuals and population; [c]C-reactive protein and α-1-acid glycoprotein >5mg/L and >1g/L respectively used for exclusion criteria in the presence of infection with elevated serum ferritin

the intrinsic factor that binds vitamin B_{12} is impaired, thus preventing vitamin B_{12} absorption in the intestines. Moreover, malabsorption can also impair vitamin B_{12} due to several causes: surgical resection of ileum due to Crohn's disease, and damages to the small intestine due to chronic inflammation and infection (Ankar & Kumar 2021).

VITAMIN B_{12} DEFICIENCY AND ITS ASSOCIATED FACTORS AMONG CHILDREN

In children, vitamin B_{12} deficiency is primarily due to dietary insufficiency (Ankar & Kumar 2021). Infants born to mothers who follow a strict vegan diet throughout pregnancy and after weaning will be deficient in vitamin B_{12} (Devalia, Hamilton & Molloy 2014). An earlier study by Dagnelie et al. (1989) in the Netherlands evaluated serum vitamin B_{12} in infants who were born to mothers who adhered to a macrobiotic diet. The prevalence of vitamin B_{12} deficiency in these infants was as high as 45% (defined as serum vitamin B12 <136 pmol/L) when compared to control infants. In Asia, a study in South India by Christian et al. (2015) reported the prevalence of deficient and low vitamin B_{12} measured at age 9.5 years were 3% and 14%, respectively.

There are several factors that are associated with vitamin B_{12} deficiency among children including socio-economic status, parental educational level, and dietary cobalamin intake. Socio-economic status affects a household's ability to access animal food sources due to the limited affordability (Villamor et al. 2008). Shahab-Ferdows et al. (2015) reported that Cameroon women and children's plasma vitamin B_{12} concentration were positively associated with socio-economic status. Furthermore, vitamin B_{12} status was poorer in low-income households and in children whose mothers had low plasma vitamin B_{12} levels. Among Colombian school children, vitamin B_{12} concentrations were strongly associated with measures of socio-economic status, including food expenditure and household ranking in the neighbourhood (Villamor et al. 2008).

Vitamin B_{12} levels in children is affected by parental educational level attained. In a study conducted in rural India by Pasricha et al. (2011), the mother's educational level was found to positively influence vitamin B_{12} concentration level of the children. A study conducted in Amazonian region of Brazil found that children whose mothers had less than 5 years of formal education were more likely to be vitamin B_{12} deficient (Cobayashi et al. 2015).

Inadequate cobalamin intake has a direct impact on children especially new-borns and infants on exclusive breastfeeding as cobalamin concentration in breast milk is positively correlated with maternal serum cobalamin. Pawlak et al. (2018) reported that strict vegan mothers have lower cobalamin concentrations in their breast milk. Although vegetarians are at risk for vitamin B_{12} deficiency, contradictory findings were found in a study by Yen et al. (2010), where both vegetarian parents and their preschool children had similar plasma vitamin B_{12} concentrations as omnivorous parents and their preschool children. Within studies among children, differences in vitamin B_{12} concentrations have substantially differed depending on the animal products where dairy products showed stronger correlations with vitamin B_{12} concentrations than meat and fish intake (Villamor et al. 2008).

BIOMARKERS OF VITAMIN B_{12} DEFICIENCY

Since the molecular pathways for vitamin B_{12} and folate are so tightly linked and individuals with both deficits have comparable clinical features, cobalamin and folate assessments are frequently done at the same time (Devalia, Hamilton & Molloy 2014). A full blood count and serum B_{12} and folate levels should be performed on individuals suspected of having a B_{12} deficiency. The cut off value to indicate B_{12} deficiency for serum B_{12} is <150 pmol/L. Serum levels of methylmalonic acid and homocysteine should both be tested in individuals with borderline vitamin B_{12} levels (200 - 300 pmol/L). These can help to distinguish B_{12} deficiency from folate deficiency, in which homocysteine levels are elevated, but MMA levels are normal. With the reduction of vitamin B_{12} below the normal reference value, the full blood count would also reflect the decrease in both haemoglobin and haematocrit, while the mean corpuscular volume would be increased to a level >100. This is consistent with a diagnosis of macrocytic anaemia (Ankar & Kumar 2021).

FOOD INSECURITY

Food security 'exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life'. Food security encompasses four 'pillars' which includes food availability, food access, food utilization and food stability (FAO 2006). Food insecurity, is on the other hand, defined as 'limited or uncertain availability of nutritionally adequate and safe food or limited or uncertain ability to acquire acceptable foods in socially acceptable ways' (United States Department of Agriculture Economic Research Service 2014).

FOOD INSECURITY AND ITS ASSOCIATING FACTORS AMONG CHILDREN

Around the world, 41% of children under the age of 15 live in households that are moderately or severely food insecure, 19% in households that are severely food insecure, and 45% in households that report not having enough money to buy food in the preceding 12 months. These figures equate to around 605 million households with children under the age of 15 living in a food insecure environment (Pereira, Handa & Holmqvist 2021). Several factors are associated with food insecurity among children including demographic factors (number of children and household size), household income, parental educational level, and urban and rural geographical regions.

Demographic factors, especially the number of children play a significant role in predicting food insecurity. An increase in the number of children will subsequently increase the size of the household itself, therefore affecting the quality and quantity of food consumed, and increasing their risk of becoming food insecure (Charles Shapu et al. 2020). Household size, which includes larger households, more children, and female-headed households, is another important determinant of household food insecurity (Olayemi 2012). A large household size means that family members have to share a limited amount of food among the family members (Olayemi 2012; Sulaiman et al. 2021).

Low socio-economic status in a family is recognised as a factor associated with household food insecurity in all high-risk groups (Sulaiman et al. 2021). Household income is an important predictor of household food security since higher household income has the capacity to be resilient towards any shock that could impact food security (Guo 2011). Low maternal education and socio-economic status had a substantial effect on household food insecurity among children (Chowdhury et al. 2016). Other studies from low-income countries, such as Nepal and Ghana, found that the frequency of household food insecurity was significantly greater among children of illiterate parents and households with the lowest socio-economic status (Saaka & Osman 2013).

Food insecurity is also affected by geographical regions. Families with children living in rural areas have a higher prevalence of food insecurity compared to families living in urban areas at 56% and 46% prevalence, respectively (dela Luna & Bullercer 2020). However, a study by Aquino et al. (2014) has discovered that both urban and rural areas have high and same prevalence of food insecurity at 80%. This phenomenon might be explained by individual perception of food insecurity and socio-economic factors of household itself, irrespective of urban or rural residence.

ASSESSMENT OF FOOD INSECURITY

There are several types of instruments to measure and directly monitor household food insecurity. The different types of tools or questionnaires used are illustrated in Table 2.

Practically, household food insecurity tools are easy to administer and can measure households with children, since children are exposed to the household environment characterized by food insecurity (Fram, Bernal & Frongillo 2015). However, these instruments have low accuracy for measuring children's experience and can only estimate the percentage of children living in food-insecure households (Ballard et al. 2013, Eicher-Miller et al. 2009). Fram et al. (2013) suggested the use of the Child Food Security Assessment (CFSA) for measuring children's experience of food insecurity in the child population <12 years old.

In Malaysia, the Radimer/Cornell hunger and food insecurity items (Radimer, Olson & Campbell 1990) which has been validated and translated into Malay (Sharif & Ang 2001) has been widely used (Sulaiman et al. 2021). The level of food insecurity according to Radimer/Cornell hunger and food insecurity items are divided into three levels: household food insecurity, individual food insecurity and child hunger. Table 3 will further illustrate the categorization for food secure and food insecure groups using Radimer/Cornell hunger and food insecurity items.

RELATIONSHIP BETWEEN FOOD INSECURITY WITH IRON AND VITAMIN B_{12} DEFICIENCY AMONG CHILDREN

Across the globe, food insecurity affects around 605 million households with children under the age of 15 (Pereira, Handa & Holmqvist 2021). Food insecurity affects not only the child's health status in the long term i.e., anaemia but also the nutritional status and their

TABLE 2. Instruments for measuring and monitoring household food insecurity

Instrument	Description	Population	References
R/CS[a]	This tool was able to capture most food insecurity components and the tool has been shown as highly reliable and valid in households with children	Intended for the US population. A modified version was available in Korea, UK, Indonesia, and Malaysia	Radimer et al. (1990)
HFSSM[b]	Evaluate household money and food supply for basic food sustenance and their behavioural and subjective response to the situation. Derived from R/CS and Community Childhood Hunger Identification Project	Intended for the US population. Variant's version tested in Bolivia, the Philippines, and Burkina Faso	Bickel et al. (2000)
HFIAS[c]	A series of questionnaires that describe universal categories and subcategories of household food insecurity, with a focus on lack of access to food. Developed by USAID's Food and Nutrition Technical Assistance (FANTA)	Studies were carried out in the UK, USA, Canada, and Australia. A modified version was available in developing countries such as Ethiopia, Tanzania, and India	Coates et al. (2007)
ELCSA[d]	Evaluate households' quality and quantity of food availability and their coping strategies. Derived from the Brazilian Food Insecurity Scale, which was adapted from HFSSM through focus groups	Intended for Latin America and Caribbean population including Brazil, Columbia, and Venezuela	Pérez-Escamilla et al. (2011)
FIES[e]	Access the individual respondent's or respondent's household's experiences. The questions focus on self-reported food-related behaviours and experiences that are linked to growing difficulty in obtaining food due to resource restrictions. Developed by the FAO Voices of the Hungry project (VOH) and was based on three existing tools - HFSSM, HFIAS and ELCSA	Intended for usage across the globe. Has been translated into more than 200 languages and dialects	Ballard et al. (2013)

[a]R/CS, Radimer/Cornell Hunger and Food Insecurity Instrument; [b]HFSSM, Household Food Security Scale Module; [c]HFIAS, Household Food Insecurity Access Scale; [d]ELCSA, Latin America and Caribbean Food Security Scale; [e]FIES, Food Insecurity Experience Scale

overall well-being. Children experiencing food insecurity have negative developmental outcomes including behaviour problems (Fram, Bernal & Frongillo 2015), disrupted social interactions, delayed early childhood language development (Saha et al. 2010), poor school performance and school absenteeism (Bernal et al. 2014; Jyoti et al. 2005), lower physical activity (Fram, Bernal & Frongillo 2015), and altered daily activities (Bernal et al. 2014). Thus, determining a child's food security status may help to assist health care providers in targeting and monitoring those children who are most vulnerable to poor health and developmental outcomes (Pirkle et al. 2014).

Several earlier studies found a link between food insecurity and iron deficiency anaemia among children (Eicher-Miller et al. 2009; Skalicky et al. 2006), and since malnutrition is worsened in children with food insecurity, they are more likely to develop iron deficiency anaemia (McGuire 2015). Due to increasing dietary independence and decreasing parental care, food insecure children aged 12–15 years living in the United States have higher risk of iron deficiency anaemia. Parents tend to reserve

TABLE 3. Radimer/Cornell hunger and food insecurity items

Level	Statement for caregiver evaluation	Food secure	Household insecure	Individual insecure	Child hunger
Household	1. I worry whether my food will run out before I get money to buy more	-	+	N/A	N/A
	2. We eat the same thing for several days in a row because we only have a few different kinds of food on hand and do not have money to buy more	-	+	N/A	N/A
	3. The food that I bought just did not last, and I did not have money to get more	-	+	N/A	N/A
	4. I ran out of the foods that I needed to put together a meal and I did not have money to get more food	-	+	N/A	N/A
Adult	5. I am often hungry, but I do not eat because I cannot afford enough food	-	-	+	N/A
	6. I eat less than I think I should because I do not have enough money for food	-	-	+	N/A
	7. I cannot afford to eat properly	-	-	+	N/A
Child	8. I cannot give my child(ren) a balanced meal because I cannot afford that	-	-	+	N/A
	9. My child(ren) is/are not eating enough because I just cannot afford enough food	-	-	-	+
	10. I know my child(ren) is/are hungry sometimes, but I just cannot afford more food	-	-	-	+

Based on positive ('often true' or 'sometimes true') or negative ('never true') evaluative responses for each classification; N/A: not applicable
Source: Sellen et al. (2003)

food for younger children, but food may not be reserved preferentially for children of older age. Parents may believe that their older children are capable to shoulder the burden of food scarcity in the family (Eicher-Miller et al. 2009).

Skalicky et al. (2006) described that the process by which child level food insecurity affects infants and toddlers' development remain unknown as iron deficiency anaemia itself is a known risk factor for negative cognitive and behavioural outcomes. Iron deficiency anaemia does not appear overnight. Instead, there are many stages of iron shortage, starting with iron depletion, in which the amount of iron in the body decreases but the amount of iron in the red blood cells stays the same. If iron depletion is not treated, it can lead to iron deficiency, which can lead to iron deficiency anaemia. Iron deficiency anaemia may develop for a variety of reasons: 1) lack of food; 2) poor food choices; and 3) previous state of ill health resulting in an inability to consume or absorb iron-rich foods.

The concept and assessment of food security are heavily linked to diet quality and intake, which may help to mitigate the relationship between food insecurity and poor health among children. Food insecurity is inversely associated with higher levels of diet quality (Hanson & Connor 2014), which encompasses adequacy, moderation, variety, or diversity, and balanced nutrition (Garriguet 2009). Households who are food insecure will replace high quality foods with lower quality ones, a process known as 'substitution' effect (Morales & Berkowit 2016) where nutrient-dense foods, such as lean sources of protein, are replaced with energy-dense, nutrient-poor foods, usually ultra-processed ones that are rich in refined carbohydrates and fats (Brouwer-Brolsma et al. 2015). Children in food insecure households tend to consume these energy-dense and low iron foods (Melchior et al. 2012), thus having inadequate intakes of micronutrients such as calcium, iron, and zinc (Bernal, Frongillo & Rivera 2016; Metallinos-Katsaras et al. 2016) and vitamin B_{12} (Kirkpatrick & Tarasuk 2008). Such situation was seen among adolescents aged 13–17 years living in food insecure households who had lower intake of animal source food, protein rich food, dairy products, and fruit (Belachew et al. 2013). Food with poor dietary content resulted in vitamin and mineral deficiencies (Kreusler et al. 2021).

Since food insecurity is highly affected by low socio-economic status especially households living in high-risk groups (Sulaiman et al. 2021), households with low socio-economic status and financial constraints will have less ability to withstand any shock that can affect food security i.e., increases in food cost (Guo 2011). Both iron and B_{12} are abundant in fortified foods such as cereal and animal-derived foods such as meat, and both cereal and meat itself are expensive foods and financial constraints in households has been shown to decrease meat intake (Villamoor et al. 2008). Bayoumi et al. (2020) have found that children living in low household incomes have three times more risk of developing iron deficiency and iron deficiency anaemia compared with the highest family income group. This was thought to be due to formula feeding in the first year of life and the subsequent drinking of more than 2 cups of cow's milk daily. The same association was also found by Sheng et al. (2019) in poor rural areas of China. His study showed that vitamin B_{12} deficiency in toddlers was common due to low dietary vitamin B_{12} intake where the local diet of the population is mainly vegetarian. Although an intervention using fortified cereal and meat improved the vitamin B_{12} status of children, these foods were considered as expensive and families from low socio-economic status were unable to purchase such food items for themselves and their family, thus vegetarian foods were much more affordable in the long term.

Vitamin B_{12} deficiency is well-recognized in exclusively breastfed infants of vitamin B_{12} deficient mothers. Pasricha et al. (2011) found that poverty and food insecurity were associated with longer continued breastfeeding with reduced intakes of energy and micronutrients from complementary foods, especially from mothers with vitamin B_{12} deficiency. Continued nursing in the second year of life may suggest that a child came from a disadvantaged home and was at risk of receiving inadequate complementary food, as well as a mother's attempt to give enough nourishment in the face of food insecurity in the community. In children who did not have adequate complementary feeding, the risks of developing iron deficiency among children who were breastfed over 12 months of age increased by 4.8% with each additional month of breastfeeding (Maguire et al. 2013).

Figure 1 elucidates the relationship of food insecurity with iron and vitamin B_{12} deficiency among children that are affected by socio-economic, environmental, and demographic factors. Environmental factors, such as geographical regions, affect food insecurity whereby children living in rural areas are seen to experience higher levels of food insecurity compared to their urban counterparts (dela Luna & Bullercer 2020). In addition, children living with adult smokers have higher risk of food insecurity especially child hunger (Cutler-Triggs et al. 2008). Socio-economic factors, particularly parental education level and monthly household income, also affect food insecurity because the ability to choose and buy quality and nutritious food for children is greatly influenced by socio-economic factors (Chowdhury et al. 2016). Demography of the family, including larger household size and higher number of children, affects the quality and quantity of food intake, thus increasing the risk of experiencing food insecurity (Charles Shapu et al. 2020). Food insecurity thus affects nutritional factors, especially the types of food and eating patterns of children who tend to consume energy-dense foods that are low in iron (Melchior et al. 2012) and vitamin B_{12} (Kirkpatrick & Tarasuk 2008) as well as other micronutrients. Food insecurity is also known to affect breastfeeding practices and complementary feeding practices (Pasricha et al. 2011). This in turn affects the nutritional status, including iron and vitamin B_{12} status in children (Villamor et al. 2008), health status such as developing iron deficiency anaemia (Skalicky et al. 2006) and exhibits developmental delays (Sheng et al. 2019) as well as children's behaviour (Mahajan et al. 2011).

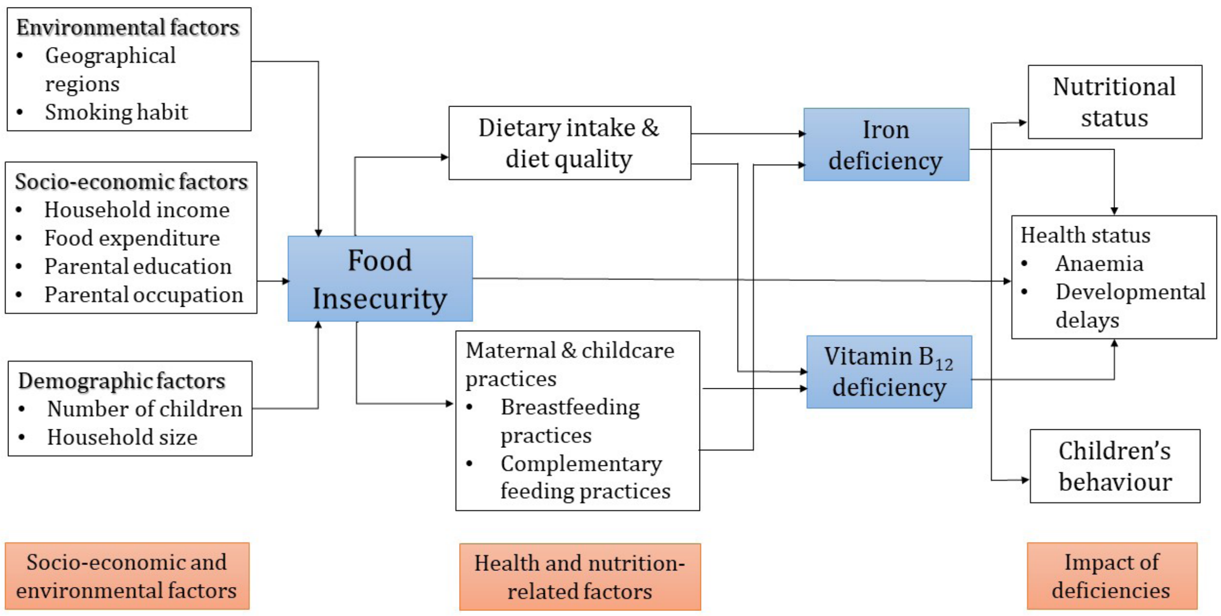

FIGURE 1. Conceptual framework linking food insecurity with iron and vitamin B_{12} deficiency

CONCLUSION AND FUTURE PERSPECTIVES

In conclusion, there are consistent evidence that food insecurity has been linked with iron and vitamin B_{12} deficiency including anaemia notably iron deficiency anaemia, among children that is influenced by socio-economic status, environmental factors, and dietary factors. Since food insecurity affects both micronutrient deficiencies and have negative consequences on children's health and developmental outcome, there is a need for both government and non-governmental organisations to develop effective strategies and interventions that aim to help households improve their socio-economic status, thus enabling them to better secure food and to utilize it. Future research including cohort studies, are needed to further investigate food insecurity and various associated factors and their impact towards iron and vitamin B_{12} deficiency to ensure these factors are well-addressed, thus enabling children to thrive in a secure and healthy environment.

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