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RESEARCH INSIGHT

Preventing Iron-Deficiency Anemia in Children in Developing Countries

WHY IT IS NECESSARY AND HOW IT MUST BE APPROACHED

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ABSTRACT Iron deficiency (ID) has been identified as the most common nutritional deficiency condition in the world, with a high prevalence in both developed and developing countries. ID and iron-deficiency anemia (IDA) affect the cognitive, socio-emotional and motor development of children. Using evidence from 2002 onwards, a literature review of the impact of ID and IDA on child development and the interventions preventing them was conducted. Review of recent evidence presents 1) altered cognitive functions, 2) decreased socio-emotional development, and 3) impediment of motor skills development due to ID and IDA. In conclusion, the effects of ID and IDA on child development are significant and often irreversible. Viable and effective preventive programs, such as iron supplementation, diet diversification, food fortification and early and home interventions, are favoured over curative measures.

INTRODUCTION

Two billion people – almost 30% of the world's population – are anemic.[1] Nearly half of the cases result from iron deficiency (ID), which is recognized as the world's most common nutritional deficiency.[2]

Iron has an essential role in the formation and function of blood cells in the human body.[3] As such, ID can lead to iron-deficiency anemia (IDA).[4] According to the World Health Organization (WHO), anemia is defined as having a blood hemoglobin level two standard deviations (SDs) below the mean level for a normal population of the same sex and age bracket.[5] IDA results from an imbalance of iron needs and iron intake and absorption. Increased iron needs are often due to rapid growth (during infancy), pregnancy, and blood loss (heavy menstrual periods, frequent blood donations or gastrointestinal conditions, e.g. hookworm).[4] Decreased iron intake or absorption are often because of a dietary iron deficiency or inefficient utilization of iron ingested from food.[4]

The incidence and prevalence of IDA is particularly high among infants, children and adolescents in low- and middle-income (LMI) countries. 33% to 66% of children in developing countries are affected by this nutritional disorder.[2] The peak prevalence of IDA occurs among infants, reasons for which have been linked to poorer cognitive, motor and socio-emotional development.[6] Furthermore, despite iron therapy, infants with severe IDA are unable to reach the same developmental level as non-ID and non-IDA infants.[7]

While the burden of ID and IDA is well-documented, the current challenge is to provide adequate control and preventative measures for these conditions.

OBJECTIVES OF LITERATURE REVIEW

This literature review serves to provide an understanding of the impact of ID and IDA on infant and child development. Infants and children are defined as individuals <2 years of age and >2 years of age respectively. This literature review also provides an overview of the effectiveness of current intervention programs in LMI countries that target IDA in infants and children.

SEARCH STRATEGY AND SELECTION CRITERIA

The primary literature search was conducted in April 2012. The Ovid database, which included AMED, EMBASE, Global Health, PUBMED, PsychINFO and MEDLINE, was searched for evidence published from 2002 to present.
The following search strategy was applied to the OVID database, which combined the following search terms:

- Iron deficiency OR iron-deficiency anemia
- (Iron deficiency OR iron-deficiency anemia) AND child development
- Child development AND (motor skills OR motor activity OR cognitive development OR socio-emotional development)
- (Iron deficiency OR iron-deficiency anemia) AND prevention
- (Iron deficiency OR iron-deficiency anemia) AND interventions

Limits: Infants and children (0-18 years), English, Humans, 1995 – 2012.
The initial search identified approximately 77 papers that met the review inclusion criteria. After critical appraisal, 10 reviews (a combination of systematic and literature reviews) and 8 primary studies (a combination of observational studies and randomized controlled trials) were selected for inclusion.

THERE IS A NEED TO IMPLEMENT PREVENTIVE PROGRAMS AND INTERVENTIONS FOR INFANTS AND CHILDREN IN LMI COUNTRIES

FIGURE 1: Reducing anemia through iron fortification of grain in Udapur, India. image from http://www.povertyactionlab.org/evaluation/reducing-anemia-through-iron-fortification-grain-udaipur-india

FIGURE 2: Reducing anemia in rural China through education and nutrition. image from: http://reap.stanford.edu/docs/nutrition_and_education

IDA IN INFANTS AND CHILDREN

Anemia is estimated to be the direct cause of 134,000 deaths in young children every year.[7] The prevalence of anemia among infants between 6 to 9 months of age is alarmingly high in many parts of the world, estimated to be 64-93% in Sub-Saharan Africa, 70-85% in Southeast Asia, and 59-75% in Latin America and the Caribbean.[8] Of these cases, approximately 50% are the result of ID (IDA).[8] IDA prevalence peaks during the ages of 6 to 24 months.[6] Rapid development and high nutritional demands during the second six months of life, along with depleting prenatal iron stores, creates vulnerability.

Key factors for ID, and consequently IDA, include dietary factors, elevated iron demands, and the socioeconomic status of infants and children.[9] Dietary factors include low iron content in consumed foods and high iron absorption inhibitor content.[9] For example, tannin in tea and phytic acid in grain fibres inhibits non-heme iron absorption.[10] In Middle Eastern and North African cultures, tea is routinely given to children and infants, which strongly decreases their dietary absorption of iron.[3] Moreover, the related socioeconomic status of individuals contributes to the iron levels of infants and children. Limited food availability, inadequate access to health care, poor environmental sanitation and personal hygiene are all socioeconomic factors that increase the prevalence of ID and IDA.[9]

The presence of anemia during infancy is significant as it inhibits normal cognitive, socio-emotional and motor development later in life. A study by Shafir *et al.* indicated that in a sample population consisting of Costa Rican adolescents who had chronic, severe ID (with or without anemia) during infancy, there are no indications that iron therapy catches them up in terms of motor development.[11] Also, the same cohort exhibited poorer behavioural functions, such as greater anxiety and depressive behaviour, as young adults (19 years of age).[11] Evidently, the effects of ID and IDA in infancy and childhood extend into adulthood.

IMPACT OF IDA ON COGNITIVE, SOCIO-EMOTIONAL AND MOTOR DEVELOPMENT

In many studies, IDA has been linked to cognitive and socio-emotional difficulties, as well as poor development of fine and gross motor skills.[2,6,12-17]

Cognitive dysfunctions and irregular brain development are worrying manifestations. Certain regions of the brain, such as the basal ganglia, substantia nigra and deep cerebellar nuclei, require a considerable concentration of iron.[2] In addition, the hippocampus is particularly susceptible to ID during the brain growth spurt that occurs between 6 to 24 months of age.[13] Many central nervous system (CNS) processes, such as dopamine synthesis, are dependent on iron-containing enzymes, such as tyrosine hydroxylase.[14] Consequently, IDA can adversely affect the neuroanatomical and neurochemical processes and has been shown to result in cognitive developmental delays.

Due to these effects, infants with ID and IDA undergo altered behavioural and socio-emotional development. In a study by Chang *et al.*, preschool-aged IDA children demonstrated lower frustration tolerance and higher passive and physical self-soothing behaviour during a delay-of-gratification situation.[15] Additionally, a separate study linked ID (with or without anemia) with increased shyness, decreased soothability and decreased engagement in infants from 6 to 12 months of age.[16]

Motor functions depend on basal ganglia processes within the brain.[17] Animal model studies suggest that decreased iron changes the density of dopamine receptors in the striatum (part of the basal ganglia), even with iron restoration.[17] As such, it is plausible that ID and IDA impede the normal development of motor skills in infants and children. In a study by Shafir *et al.*, IDA infants demonstrated difficulty in toy retrieval tasks requiring sequential movement with bi-manual coordination. Infants also exhibited delayed development of gross motor skills and delayed refinement of fine motor skills.[17]

There is convincing evidence to support that ID and IDA affect brain growth, often irreversibly. The biological effects of ID and IDA further impact the socio-emotional and motor development of infants and children.

PROGRAMS FOR IDA PREVENTION

Given that iron deficiency is the most common nutrient deficiency and that there is increasing evidence that ID and IDA cause adverse effects among infants and children, it is imperative that governments, health care providers and parents act to prevent ID and IDA among such a vulnerable population.

According to Huma *et al.*, the three main strategies for ID and IDA prevention include iron supplementation, diet diversification, and iron fortification in food. Supplementation is administered through injections, capsules, and tablets, which provide substantial benefits to infants during their first year of life.[18] However, monetary input and costly distribution systems are drawbacks to providing large scale supplementation in LMI countries.[9] Furthermore, vulnerable at-risk groups may not have access to supplementation if they inhabit hard-to-reach places or areas of war.[9]

Food-based strategies, such as diet diversification and fortification, appear to be more sustainable and cost-effective options.[9] Diet diversification programs include those that provide nutritional education and those that promote improved eating practices. For example, some programs encourage increased intake of iron-rich foods (e.g. meat) and consumption of fruits rich in ascorbic acid (e.g. citrus fruits) as a means of increasing iron absorption.[3] These programs also include techniques such as soaking and thermal processing to reduce phytic acid content in whole grains and legumes.[9] However, socioeconomic factors may prevent some families from eating according to the diets promoted by such programs.[9]

Fortification of food entails the addition of essential nutrients to staple foods to prevent nutritional deficiencies.[20] The majority of Western countries fortify staple foods, such as flour and bread, with iron. LMI countries, including Saudi Arabia, Egypt, and Iran have also begun enriching wheat flour with iron as of 2002.[9] Since fortification of wheat is simple and inexpensive, it is a major strategy used to prevent anemia.[1] This may not be successful, however, if foods are discoloured or poor-tasting from the addition of iron, as it may result in poor consumer acceptance.[9] Additionally, one study suggests that food fortification alone, among infants of 4 to 6 months, may not be sufficient for ID prevention, and that routine iron supplementation may be required.[19]

The WHO also promotes prevention of ID and IDA through other programs, including early and home interventions.[21,22] In a meta-analysis of 15 international control studies, it was found that delayed umbilical cord clamping at birth improves the iron status of infants.[21] This practice involves waiting two minutes after birth before clamping the umbilical cord, increasing iron stores in newborn infants.[21] Home and early childhood interventions, targeting mother-child interactions, include verbal and non-verbal activities. Developmentally appropriate playtime activities can improve cognitive, socio-emotional, and motor development in infants and children at risk of ID and IDA.[22]

CONCLUSION

This review demonstrates that iron deficiency and iron-deficiency anemia negatively impact infant and child development. The high prevalence of ID and IDA among infants and children in LMI countries can be attributable to the poor dietary, socioeconomic, and disease conditions in those countries.

The effects of ID and IDA on cognitive, socio-emotional, and motor development are significant and long-lasting. Thus, there is a need to implement preventive programs and interventions for infants and children in LMI countries. This review examined several viable prevention strategies, including diet supplementation, diet diversification and food fortification. Additionally, this review explored early and home interventions that may prevent ID and IDA in infants and children, such as delayed umbilical cord clamping and mother-child interactions.

Future steps include researching the methods of ID and IDA prevention program implementation in LMI countries. Assessing these implementation strategies may provide insight into how to reduce ID and IDA prevalence rates. Ensuring iron sufficiency among infants and children in LMI countries will increase the likelihood for children to be vibrant and productive members of their communities in the future.

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