
CHILD DEVELOPMENT AND IRON DEFICIENCY

**Early Action Is Critical for Healthy Mental, Physical,
and Social Development**

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To examine the role of iron status in the development of children, the Office of Health and Nutrition, U.S. Agency for International Development, through the Opportunities for Micronutrient Intervention (OMNI) Project and the Partnership for Child Development, University of Oxford, convened a group of concerned scientists and policy makers in Oxford, United Kingdom, on September 16–17, 1996. The group examined existing scientific data on the biologic role of iron in brain development, including clinical and observational data, as well as correlation, cross-section, and controlled community-based intervention studies. The policy and program implications also were examined and discussed. The deliberations and conclusions of the group are summarized here.

Iron deficiency anemia

Iron deficiency anemia is a major health problem affecting more than 2 billion people — more than one-third of the entire world population. Pregnant women and preschool children are the two groups that suffer the most from iron deficiency anemia. The World Health Organization (WHO) has estimated that 51% of children less than 4 years old in developing countries are anemic. The main nutritional cause is iron deficiency owing to a diet that provides too little iron, poor absorption of most dietary iron, and the presence of other dietary factors that inhibit iron absorption.

Infants and young children are the most adversely affected by iron deficiency because they are growing and developing at such a fast rate. If iron deficiency is not corrected, it leads to anemia and is associated with impaired development of mental and physical coordination skills. In older children, iron deficiency leads to impaired school achievement.

Although an inadequate iron diet is by far the major cause of anemia, it also can occur as a result of parasitic infections, inherited disorders, and deficiencies of other nutrients. Parasitic infections include malaria and helminths (notably hookworm). Malaria causes the destruction of red blood cells and hookworms cause blood loss. Inherited disorders that can leave an individual vulnerable to anemia include sickle cell anemia, thalassemia, and hemochromatosis. A much less common cause for anemia results from deficiencies of other nutrients, such as folate (a B-complex vitamin).



Because of the lack of precise data on the percentage of young children affected by iron deficiency anemia, the problem remains largely unrecognized and unaddressed. Clearly, the personal consequences of iron deficiency anemia add to its social and economic costs to society and thereby reinforce the need to eliminate iron deficiency anemia in both preschool and school-age children.

Key points

1. There are strong relations between iron deficiency anemia and:
 - impaired mental and motor (physical coordination) development among *infants and young children* (less than 2 years old),
 - difficulty in learning how to discriminate between visual stimuli or to maintain selective attention among *preschoolers* (2–5 years old), and
 - poor school achievement among *primary school and adolescent children* (6 years and older).
2. Iron deficiency in infants affects their emotional state. They are more hesitant and cautious and maintain closer contact with their mothers. These types of behaviors could hinder infants' ability to interact with, and learn from, their environment.
3. The particular mental, motor (physical coordination), and emotional processes that are altered in iron-deficient anemic infants are critical early-life experiences that affect healthy intellectual and social development years later.
4. School-age children who are iron deficient have problems with attention and short-term memory.
5. Iron deficiency without anemia has not been associated with any of the mental, motor, and social-emotional disturbances observed with iron deficiency anemia in infants.
6. Intervention studies have found the following:
 - Most studies of iron therapy in infants and young children (less than 2 years old) reported no improvement in either mental or motor development of anemic infants following either short- or long-term treatment.
 - Preschool children (2–4 years old), however, displayed marked improvement following successful iron supplementation, consistently eliminating the learning problems associated with anemia.
 - Iron supplementation resulted in significant improvement in school measurements of verbal and other measurable skills among primary school children and adolescents.
7. A combination of risk factors contribute to iron deficiency anemia:
 - Iron deficiency anemia is more common in situations of
 - social disadvantage (e.g., poverty, poor housing and overcrowding, and low levels of parental education),
 - psychological disadvantage (e.g., lack of stimulation), and
 - biological disadvantage (e.g., low birth weight, high infection rates, and other nutritional deficiencies).
 - Studies carried out over several years in child development among economically impoverished communities have shown that
 - continuous exposure to the above risk factors results in an increasingly adverse effect on cognitive (individual awareness and judgment abilities), social, and emotional development in children of different ages, and
 - the larger the number of risk factors to which children are exposed, the more severe the adverse effects.
8. The prevention and treatment of iron deficiency anemia in infants and young children are therefore prudent strategies to ensure readiness to learn.

Scientific rationale

There is good scientific evidence from community-based studies to show that iron deficiency anemia is associated with impaired performance in a range of mental and physical coordination functions in children of different age groups.¹ These include mental development, physical coordination development, cognitive (awareness and judgment) abilities, social and emotional development, and school achievement, although the precise effects vary with the age group studied. Data from animal models also indicate that the behavioral and developmental effects of iron deficiency anemia may not be as easy to correct in infants, compared with preschool or school-aged children and adolescents.

Infants and young children (less than 2 years old)

Studies of this age group have consistently found significant differences between infants and toddlers with and without iron deficiency anemia in development of their mental and physical coordination. Problems with coordination and balance have been observed. Also, there is evidence that iron deficiency anemia alters the emotional state of infants so that they are more withdrawn, cautious, and hesitant, and maintain closer contact with their mothers. Because these types of behaviors could hinder an infant's ability to interact with and learn from his or her environment, it is possible that iron deficiency anemia contributes to poor intellectual development. The relationship between the two, however, is not clear. Two studies have found that developmental scores were significantly worse in infants with moderate compared with milder degrees of anemia.

Studies on iron therapy are inconsistent in showing improvement in mental and physical coordination development in the majority of anemic infants and young children (less than 2 years old) following either short- or long-term treatment. However, studies to date may have underestimated the effects of iron deficiency anemia on behavior and development because biologically more vulnerable children were excluded. For methodologic and ethical reasons, most studies of iron therapy have included only well-nourished, relatively healthy children, even though many were disadvantaged socioeconomically.

Preschool children

Iron deficiency anemia has been associated with poor learning performance among preschool children (36–72 months old), particularly in tasks that demand close attention to and discrimination of cues critical to solving visual problems. The successful correction of the iron deficiency anemia has led to significant improvements in such tasks, so that the initial differences in judgment and awareness abilities disappeared between anemic and nonanemic children. Although the particular causes behind these effects are not yet defined, it is suggested that at least part of the poor test performance of the anemic children stems from changes in emotional regulation and motivation.

Although it may seem biologically plausible that iron deficiency without anemia may interfere with normal cognitive (awareness and judgment) function, empirical data (data that can be verified or disproved by observation or experiment) do not support this assumption. The available data indicate that no such interference is present.

Primary school children and adolescents (6 years and older)

School achievement and performance in mental educational tasks is poorer among iron-deficient anemic children compared with previously anemic children given iron supplements. Chronic iron deficiency anemia is likely to produce increasingly unfavorable educational outcomes that will require nutritional treatment and additional education to correct. Unpublished research suggests that the cognitive effects of iron deficiency (poor judgment and awareness) are more severe among children who go to school without eating breakfast.

Laboratory studies

There is now strong supporting biological evidence from laboratory studies of animals that iron deficiency anemia harms brain development.

In the last 10 years, two central nervous system mechanisms have been claimed to cause the behavioral

¹ A detailed summary and review of the scientific evidence on iron and development in children is given in the proceedings of this meeting. For information on availability, contact INACC.

changes associated with iron deficiency. The first is that iron deficiency impairs the myelination (myelin is a soft, fatty material that forms a thick cover around nerve fibers) of nerve cells. The second is that it affects neurotransmitter function (the transmission of nerve impulses). The metabolism of neurotransmitters, including dopamine, is clearly altered. These changes in the central nervous system appear to be readily reversible and could be related to the changes in attention observed in children suffering from iron deficiency anemia and therefore alterations in dopamine metabolism. It is likely that the effects of iron deficiency on dopamine metabolism are independent of the myelination effects. Furthermore, these two effects may be age dependent and relate to the maturity of the brain, with the effects on myelination occurring during the latter part of the spurt in brain growth during infancy. Whether this explains the lack of effect of iron supplements on the poorer mental and physical coordination development test scores of iron-deficient anemic infants remains to be determined.

Policy implications

Adequate iron nutrition in infants and children is necessary for optimal health and growth and to provide a foundation for school and lifelong learning. The costs of iron deficiency anemia are high: children who are slow to learn may limit the ability of teachers to fulfill their tasks and hold back their classmates, they may need special schools, and they may have increased infection rates and therefore increase the load on the health system.

The prevention and control of iron deficiency anemia in infants and young children should, therefore, be a priority on national nutrition and health agendas not only to improve child survival, but also to realize children's full potential and to maximize their contribution to national development. Given the likelihood of long-lasting effects of iron deficiency anemia in infants, policy makers and programmers need to focus on prevention in this age group. Preschool and school-age children, however, should not be forgotten, given the evidence of the reversible impact of iron supplementation in these age groups.

Intervention strategies²

A number of program options are available to prevent and control iron deficiency anemia in young children. These should be integrated with existing health and nutrition programs.

Iron supplements

Because the greatest risk for iron deficiency anemia is between the ages of 6 and 12 months, iron supplements should be initiated as close to 6 months as possible, and supplements should be given for 6 months. Supplementation of longer duration, to 15 months of age, is likely to be more beneficial. Until data suggest otherwise, the use of daily supplements of iron for children between 6 and 24 months old would be the most effective approach if logistically and economically feasible.

Iron supplements can be administered via existing health delivery systems. Supplements can be targeted at high-risk individuals or groups, but where the prevalence of iron deficiency anemia is high (e.g., greater than 30% of pregnant women are anemic), there should be widespread supplementation to all high-risk groups. Contact points to reach infants and young children include national immunization programs. Measles immunization, which is initiated at 9 months of age, would be the most practical contact point. Other Expanded Program on Immunization (EPI) contact points are for infants less than 6 months old; if they are breastfed, their iron status should be adequate. Health care deliverers also need to know how to recognize and diagnose infants and young children displaying obvious signs of anemia so that treatment can be given when children come for immunization.

² The proceedings of the meeting "Iron Interventions for Child Survival," held in London, on May 17–18, 1995, contains full discussion of the different interventions available to treat and prevent iron deficiency anemia in children. The proceedings are available from OMNI.

The private sector also has a potentially important role to play in delivering iron supplements. An appropriate formulation must, therefore, be available in the marketplace.³

Food fortification

Food fortification, the addition of iron to food over and above that naturally found in food, can prevent iron deficiency. The challenge is to identify a widely consumed, centrally processed food appropriate to the age groups of concern. For infants, all commercially produced complementary foods should be fortified with iron (and other micronutrients where necessary). Fortification of complementary foods has been achieved in many countries at low cost, which allows for effective targeting of infants and encourages the development of partnerships between government and the food industry.

Dietary diversification and food habits

Naturally iron-containing foods should not be neglected. Unfortunately, foods rich in absorbable iron, such as meat, are often expensive. Encouraging mothers to feed infants and young children meat and foods rich in vitamin C, such as fruit, and to avoid foods and drinks that inhibit iron absorption, such as tea, during and 2 hours before and after mealtimes can improve iron absorption. Changing food habits, however, is very difficult to achieve. Traditional food practices such as germination (sprouting of seeds) and/or fermentation (the breakdown of nutrients in the presence of bacteria) can also improve the availability of iron in the diet. These practices should be supported where a fermented cereal porridge is traditionally used as a weaning food.

Public health services

A number of public health activities complement the specific iron interventions outlined above. For example, in areas where malaria is endemic, the use of bednets should be promoted. Deworming is also important, particularly for primary school children, who are more likely to have the heaviest worm burden and so will benefit most from deworming. Improvement in environmental sanitation will reduce the risk of repeated infections in all age groups, infections that can indirectly make children susceptible to anemia. The choice of complementary activities will depend on the local environment and the role of nondietary factors, such as parasitic infections, in the causation of iron deficiency anemia.

Interventions at other points in the human life cycle are also important. For instance, iron supplements should be given to teenage girls to ensure adequate iron stores before pregnancy. Exclusive breastfeeding to 4–6 months of age should also be promoted.

The need for advocacy

Iron deficiency anemia in infants and young children is an important but neglected issue. This is due partly to the lack of data on the prevalence of iron deficiency anemia in children 6–24 months old and partly to the lack of understanding about the significant functional (biological, social, developmental, and economic) consequences of the problem in these children. There is a need for better data on the prevalence of iron deficiency anemia at both the global and the national level, but this does not lessen the urgent need to address iron deficiency anemia in infants and young children and its impact on human potential. Advocacy at all levels is needed to ensure that this problem is addressed.

³ The proceedings of the recent meeting held in Copenhagen, which addressed appropriate iron supplements for infants and young children, are available from INACG.

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This report is the summary of the presentations and discussions that took place at the consultative meeting at the University of Oxford, on September 16-17, 1996, and does not necessarily reflect the scientific recommendations or views of INACG, USAID, or the International Life Sciences Institute.

The publication of this report is made possible by support from Opportunities for Micronutrient Interventions (OMNI), a project of the Office of Health and Nutrition, Bureau for Global Programs, Field Support and Research, U.S. Agency for International Development, under Contract HRN-5122-C-00-3025-00, Project 936-5122.

Printed April 1997 in the United States of America.

