Iron Interventions for Women and Children in Low-Income Countries¹,²

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Abstract
The WHO estimates that 41% of women and 27% of children suffer from anemia due to iron deficiency. The consequences of iron deficiency anemia include suboptimal mental and motor development in young children, increased risk of maternal mortality, and decreased economic productivity of adults. Recent research also provides evidence that maternal iron deficiency in pregnancy increases neonatal morbidity and mortality. This short review briefly highlights how iron interventions might be positioned within 4 global health initiatives: making pregnancy safer, saving newborn lives, infant and young child feeding, and fortification. The importance of iron nutrition is recognized in the context of child nutrition, fortification, and biofortification, and it is likely that meaningful advances will be made through these initiatives in the coming decade. However, iron nutrition is not yet well integrated into the programmatic agendas for reducing morbidity and mortality of pregnant women and neonates. Iron supplementation in pregnancy has been advocated for decades as a means of controlling anemia, but this outcome has not been sufficient to motivate strong programs and policies, and the evidence base is still sparse for high-priority clinical outcomes. To act on the current evidence for maternal and neonatal health will require stronger advocacy within circles that have not traditionally included nutritionists. Successful implementation will require greater attention to antenatal care for pregnancy women and prioritization of iron-promoting actions (including iron supplementation and deworming) within that platform. J. Nutr. 141: 756S–762S, 2011.

Introduction
Iron deficiency is one of the most common forms of malnutrition and its burden falls mainly on women and children (1). Iron is essential to all cells and organ systems but is also toxic if present in its free forms. Therefore, the human body has developed finely tuned systems for the regulation of iron absorption, metabolism, and excretion (2). In fact, iron is unique among nutrients in that the main mechanism for maintaining homeostasis is the up- or downregulation of absorption. Healthy adult men generally exist in iron homeostasis and are usually capable of balancing iron absorption with their low rate of excretion, even if the iron bioavailability of the diet is low. In contrast, women and children have important additional iron requirements due to menstruation, pregnancy, and childhood in the case of women and growth in the case of children (3). Blood loss and lean tissue accretion are both iron-costly processes (4). Unless the diet is rich in bioavailable iron, the body’s capacity to upregulate iron absorption is often insufficient to meet these costs during pregnancy or childhood, rendering women and children highly vulnerable to iron deficiency.

The global burden of iron deficiency has been estimated from anemia prevalence surveys, an imperfect approach, but is undoubtedly large. The WHO estimates that 41% of women and 27% of preschool children suffer from anemia due to iron deficiency (1). The consequences of iron deficiency anemia include suboptimal mental and motor development in young children, leading to potentially irreversible cognitive deficits in mid-childhood (1). For women, iron deficiency is estimated to cause 18% of maternal mortality worldwide (1) and also reduces quality of life. John Beard’s life work was devoted to elucidating the consequences of iron deficiency, especially those related to the brain and mental function, and these global estimates are indebted to his work. These consequences combine to make iron deficiency number 15 in the ranking of selected risk factors for preventable death and disability (i.e. lost disability-adjusted life years).
years) in the most recent report from the Global Burden of Disease (GBD)\(^3\) (1).

Clearly, the burden is large and the consequences are serious. Where do we then stand in terms of interventions and concerted action? In the current context where global health plays an increasingly important role in international aid and diplomacy (5), and the millennium development goals act as an organizing principal for actions and accountability (6), individual interventions are typically bundled into larger global health initiatives (7). There is no initiative for iron deficiency on its own, but interventions to improve iron status are relevant to several health and development priorities.

My aim in this short review, therefore, is to briefly highlight how iron interventions might be positioned within 4 initiatives: making pregnancy safer, saving newborn lives, infant and young child feeding, and fortification. Given the broad scope of the assignment and the brevity of this forum, my review is illustrative and not meant to be exhaustive.

**Making pregnancy safer**

**Consequences of iron deficiency.** Pregnancy is a risky time for mother and fetus, and iron status is critical to both. Maternal mortality, although all too common, is sufficiently rare that randomized clinical trials of interventions to prevent this outcome are few (8). The GBD project estimates that 18% of maternal mortality is attributable to low hemoglobin in pregnancy (1). This strikingly high estimate is based on the strong and continuous relationship between hemoglobin concentration in pregnancy and risk of maternal death coupled with assumptions about what proportion of maternal anemia is caused by iron deficiency. Maternal anemia in pregnancy is associated with many factors that might also be causally associated with mortality, including poverty, infections, and inadequate health-seeking behaviors. The GBD estimates took this into account and made conservative assumptions about the degree to which other factors could cause both anemia and maternal deaths (9). However, as with any observational association, the potential for a biased estimate cannot be completely ruled out.

The plausible explanation for a causal relationship between iron deficiency anemia in pregnancy and maternal mortality is that anemic mothers are more likely to die from postpartum hemorrhage (10). Postpartum hemorrhage is the leading cause of maternal mortality (11). It is plausible that, for a given quantity of blood loss, a more anemic mother is more likely to suffer potentially fatal cardiovascular consequences. However, direct evidence from trials of iron supplementation on postpartum hemorrhage is lacking (12).

There is no doubt that iron supplementation during pregnancy prevents maternal iron deficiency and anemia and increases hemoglobin concentrations (12,13). Women who are more anemic benefit most (13). One study in Bangladesh provided intriguing evidence that the first 20 pills (whether taken on daily basis or less frequently) yielded most of the benefit to hemoglobin (14), although longer durations of supplementation are on the whole associated with greater benefits (13) and are recommended (15). It is possible that currently recommended doses are higher than necessary to achieve optimal outcomes (12), except when anemia is very severe.

**Intervention strategies.** There are 3 intervention strategies recommended by the WHO to prevent pregnancy anemia: weekly iron + folic acid (IFA) supplementation in women of reproductive age, daily iron + folic acid supplementation during pregnancy, and presumptive treatment of hookworms during pregnancy in areas where hookworms are known to be endemic. Hookworms cause gastrointestinal blood loss and can contribute to negative iron balance (16), especially during pregnancy when women are physiologically most vulnerable to iron deficiency anemia (17).

The approach of providing weekly IFA to women of reproductive age was advocated in a recent position statement of the WHO (18). This intervention aims to improve the iron status of women prior to conception and also to provide folic acid in the peri-conceptional period when it is most efficacious to prevent neural tube defects in the developing fetus. There is little programmatic experience with this approach, which requires creation of both supply and demand: demand for supplements by women and supply chains by the private sector or through public-private partnerships. Continued monitoring and evaluation is called for along with subsequent reviews of the recommendation.

The other 2 recommendations, IFA supplementation during pregnancy and presumptive treatment for hookworm (15), are better established in programs and policies and are usually delivered through antenatal care services. The WHO currently advocates focused antenatal care (FANC) comprised of 4 visits (19) rather than the older schedule of monthly visits. The clinical guidance for these visits includes distribution of IFA supplements to all women at each of the 4 visits and provision of mebendazole for the presumptive treatment of hookworms once after the first trimester of gestation (20).

Although few would argue with the need for supplemental iron in pregnancy, many have argued that iron supplementation programs are generally poorly implemented and as a result have little global impact (9,21). Several reasons are highlighted in the literature. First is women’s limited access to or participation in antenatal care. Currently, only 47% of women globally have 4 antenatal care visits (22). There are multiple reasons for this, including geographic distance, low motivation and poor interpersonal skills of health staff, and poor quality of supplies and facilities. Additional factors are erratic or insufficient supply of IFA pills to the health facilities and women’s lack of understanding or motivation about the daily use of the supplements, especially in the face of common side effects (23).

In theory, the shift toward the 4-visit schedule of FANC may address each of these factors (19). The fewer number of visits reduces the burden of participation on the mother and potentially increases access. The focused goal orientation of each visit may lead to increased quality of services. The recent clinical guidance includes motivational counseling on the use of iron supplements, which may help women adhere to supplement use (20). But in the short term, the shift to FANC requires retraining of health care workers, changes in health systems processes such as counseling and charting, and communications to women about the new schedule. Initial evaluations of the implementation of FANC have yielded some cause for optimism and also some concerns (24). Particularly in the context of sub-Saharan Africa, the acute shortage of health workers and high turnover rates among staff create serious challenges to the provision of quality antenatal care regardless of schedule. One study in Tanzania found that while FANC requires 15 min of time for counseling at the first visit (a part of which would address IFA supplements and anemia), health workers actually spent 90 s of time counseling (25).

It is my personal observation over the past decade that the power of vertical health initiatives have contributed to a

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\(^3\) Abbreviations used: FANC, focused antenatal care; GBD, Global Burden of Disease; IFA, iron + folic acid.
fragmentation of antenatal care services in sub-Saharan Africa, in which certain programmatic initiatives (e.g., HIV/AIDS and malaria) attend to their specific components of pregnancy care, but no program or donor is concerned for the overall functioning of antenatal care, focused or traditional. Certainly, I have witnessed several instances where the ANC staff is well equipped and trained to deliver intermittent presumptive treatment for malaria or voluntary counseling and testing for HIV, but the overall functioning of the antenatal care system has not been addressed. The result is that an intervention like IFA supplementation, with no strong champion, is left by the wayside.

Healthy newborns
Consequences of iron deficiency. A healthy newborn is most obviously one who survives the perilous first moments, days, and weeks of life. But a healthy newborn is also born with an adequate iron endowment to sustain its hematopoiesis for the first 6 mo of life (26).

The effects of maternal iron supplementation on the fetus and newborn have been an area of controversy. The randomized trials have varied widely in terms of the degree of iron deficiency in the population, timing of supplementation, composition of the supplement and its comparison treatment, and infant outcomes assessed. Thus, it is very difficult to summarize the findings in a single strong conclusion. The recent Cochrane review on the topic acknowledged this difficulty but concluded that there was no evidence of effect on infant clinical outcomes, including low birth weight or preterm birth (12).

Two large recent clinical trials are noteworthy and strongly suggest benefit of iron supplementation for the fetus and neonate. Zeng et al. (27) compared IFA supplementation to folic acid only in a large cluster-randomized trial in rural China. In women who received the iron-containing supplement, very preterm birth was reduced by 50% (95% CI = 6–73%) and neonatal mortality was reduced by 54% (95% CI = 2–79%). This trial was not included in the most recent Cochrane review (12).

Christian et al. (28) found that Nepalese women who received daily IFA beginning in early pregnancy experienced a significant but modest 16% reduction of low birth weight of their babies (<2500 g). More important are their emerging findings on the subsequent health of the children. Based on 7 y of postnatal follow-up, the children of mothers who had received IFA during pregnancy had childhood mortality rates that were 31% (95% CI = 1–51%) lower than children of mothers who had received placebo (29).

These findings from well-designed trials in populations provide strong evidence that maternal iron deficiency anemia is detrimental to the fetus, with important consequences for neonatal and child mortality and that iron supplementation in pregnancy (over and above folic acid supplementation) can produce large beneficial effects on neonatal and child survival when maternal anemia is prevalent. These trials, supported by a careful analysis of observational data from a large series of births in Indonesia, found that receipt of IFA supplements during pregnancy was significantly protective against early neonatal death, after adjusting for receipt of other antenatal care interventions (30). Similarly, in data from 19 sub-Saharan African countries, receipt of IFA supplements along with intermittent presumptive treatment for malaria was associated with significant protection from neonatal death, although either intervention alone was not protective (31).

From a nutritional perspective, the iron endowment of the neonate is an additional outcome of concern (26). The birth endowment of iron plays a primary role in sustaining adequate iron status of the infant in the first 6 mo and even beyond (32), because breast milk is physiologically low in iron. Given the potentially toxic effects of unregulated iron in the human physiology, the physiological strategy in humans is to provide sufficient iron before birth to safely sustain the infant through a prolonged period of low iron intake concurrent with rapid growth.

Intervention strategies. Three intervention strategies help provide the neonate with adequate iron endowment. The first strategy is the prevention of low birth weight. The iron endowment is directly proportional to the lean tissue mass and blood volume of the baby, both functions of its intrauterine growth (26). Low birth weight babies are therefore most vulnerable to early iron depletion postnatally (33). Thus, interventions to prevent low birth weight, such as maternal nutritional supplementation or the control of infections in pregnancy (34), will also prevent infantile iron deficiency.

The second strategy is prevention of maternal iron deficiency anemia through the interventions discussed above. For many years, the strongly held conventional wisdom was that the fetus was capable of obtaining sufficient iron, regardless of the status of the mother (35). However, recent evidence from randomized trials and careful observational studies suggests that maternal iron deficiency during pregnancy compromises the status of the neonate (26). This effect is smaller and more difficult to measure than the effect of birth weight itself.

The 3rd strategy is delayed clamping of the umbilical cord after birth (36–38). A short delay of 2–3 min allows a small but important amount of blood to continue to flow to the fetus from the placenta, increasing the red cell mass and therefore the iron endowment of the neonate. The clinical outcomes of delayed cord clamping have been compared with early cord clamping in both preterm and full-term infants in several recent reviews, with clear benefits to infant iron status from the delayed clamping procedure. Many clinical outcomes have been examined, and, although a few remain controversial, all 3 meta-analyses have concluded the practice should be adopted.

This conclusion is timely, given the heightened attention to procedures surrounding childbirth and neonatal care arising from the global initiatives to reduce both maternal and neonatal mortality. Several prominent clinical guidelines around newborn care, nevertheless, omit any emphasis on the practice of delayed cord clamping (39,40). One document produced by PAHO highlights delayed cord clamping as a priority action for newborn care (41). However, it appears that the neonatal health initiative in general has yet to embrace this practice as one of its core recommendations.

Infant and young child nutrition
Consequences of iron deficiency. Fully one-quarter of the world’s children suffer from iron deficiency anemia (1). Iron-deficient children are at risk of defects in neurodevelopment and delays in acquisition of motor and mental milestones. These effects persist into middle childhood and adolescence (42), which is one reason that iron fortification is rated very highly as an intervention for economic development (43). Provision of adequate iron through supplements or iron-rich foods is recommended as one of several evidence-based strategies for promoting healthy child development (44).

Intervention strategies. Whereas the 1980s and 1990s were decades when micronutrient supplementation emerged as the
leading international nutrition intervention, we have just completed a decade in which micronutrients were integrated into a broader child nutrition initiative, now embraced by major donors and governments (45,46). This represents a new opportunity to improve the iron status of young children through large scale programs. The tight regulation of iron absorption and its potential toxicity in large doses necessitates intervention with frequent low doses (15). Few child nutrition programs could achieve this at high coverage with oral iron supplements. Delivery of iron through complementary foods is programmatically and physiologically more feasible and desirable.

Iron requirements of infants are high relative to the quantity of calories that they consume (4). Furthermore, if babies continue to be breast-fed for up to 2 y or more, as is currently recommended, a portion of their calories will be supplied by human milk, which is not rich in iron. Thus, iron is a priority nutrient in complementary foods and often a limiting nutrient (47). Without the regular inclusion of animal-source foods in the infant diet, iron deficiency is almost certain to develop. It has been hypothesized that provision of premasticated meat was an important way that mothers and other caregivers met the iron needs of infants prior to modern times (48). However, this practice is dying out in many if not most modern cultures.

Only a few studies have tested whether targeted education to caregivers on iron and infant feeding can bring about changes in infant diet and iron status. A recent systematic review summarized 4 such studies and found mixed results (49). It was noted that the 2 studies with positive results used more specific messages about which foods to feed, whereas the 2 studies with no benefit employed more general messages. Logically, the success of this approach would also depend on the availability and economic accessibility of iron-rich animal-source foods.

Numerous products have been recently developed to better meet the nutrient gaps of infant and young children, especially during the critical window of 6–24 mo of age (46). These include processed fortified cereal products, point-of-use micronutrient powders, and lipid-based nutrient spreads (50,51). All of these approaches have been shown to be efficacious if the iron content and bioavailability is appropriate and the food is consumed in appropriate quantities by infants. Based on the studies reviewed by Dewey and Adu-Afarwuah (49) in 2008, intervention with point-of-use micronutrient powders yields the largest effect on iron status and anemia, when study effects are combined.

The use of iron-rich foods or food additives, rather than supplements, is furthermore made desirable by the recent experience in a large IFA supplementation trial in Pemba Island, Zanzibar, before effective malaria control and treatment measures were in place. In that trial, children who received IFA supplements at levels close to the RDA experienced 12% higher rates of severe adverse events (i.e. hospitalization or mortality; \( P = 0.02 \)) than children who receive the corresponding placebo (52). It is noteworthy that in a parallel study conducted in the same context with the same supplements, but in which children's iron status was assessed at baseline and malarial cases were actively detected and treated, no increased risk of adverse events was observed in the IFA groups. To the contrary, in children who had iron deficiency anemia at baseline, the IFA-supplemented children had a 49% lower risk of adverse events compared with those who received placebo (\( P = 0.006 \)) (52). Thus, the Pemba trial highlighted both the potential to benefit from supplemental iron, in the case of children with iron deficiency anemia and access to prompt detection and treatment, and the potential for harm in children unprotected from intense transmission of \( P. falciparum \) malaria.

In light of these new findings, the WHO concluded that, in malaria-endemic areas (53): “Universal iron supplementation (i.e. use of medicinal iron as pills or syrups) should not be implemented without the screening of individuals for iron deficiency, because this mode of iron administration may cause severe adverse events in iron-sufficient children” (p. S621). They furthermore deemed that iron-fortified food products for infants were plausibly safer and should be prioritized as interventions to address iron deficiency in young children, especially where malaria is endemic.

Subsequently, a systematic review published in the Cochrane library (54) concluded that: “Iron supplementation does not increase risk of clinical malaria or death, when regular malaria surveillance and treatment services are provided. There is no need to screen for anemia prior to iron supplementation” (p. 2). However, the programmatic translation of “regular malaria surveillance and treatment services” is not straightforward, requiring ongoing research and, in the meantime, professional judgment (55).

In terms of the new array of products described above, I observe that for malaria-endemic areas, the line is being drawn with point-of-use micronutrient powders being treated as supplements and therefore used not at all or with extreme caution, but lipid-based supplements are being treated as fortified foods. At the same time, formulations of lipid-based supplements and point-of-use micronutrient powders with lower doses of iron are being tested in sub-Saharan Africa and some have called for a reexamination of the WHO guidance (56).

Healthy family members through fortification initiatives

Consequences of iron deficiency. Although pregnant women and young children are at especially high risk, iron deficiency is often prevalent across the lifespan where people consume diets of mostly plant-based foods. In older children and adults, iron deficiency constrains learning and economic productivity (42). It may also contribute to postpartum fatigue and depression in women (57).

A number of trials of iron supplementation of adult workers have demonstrated significant effects of iron deficiency on work performance in both aerobic tasks such as tea-picking or road work and nonaerobic tasks such as factory work (58). A recent community-based trial of iron supplementation to adults in rural Java, Indonesia, demonstrates that wide-ranging benefits were observed when iron deficiency is corrected (59). Among men with initially low hemoglobin levels (<125 g/L) compared with men who received placebo pills, those who received weekly iron pills (120 mg) after 8 mo were more likely to be employed and overall had 20% higher earnings. Of the self-employed (50% of the sample), those who received iron experienced a 40% increase in hourly earnings. In addition, the percent of men who reported that normal tasks were an effort decreased by one-half and there was also a decrease in reported anxiety about the future. Measured benefits were less striking in women. This might be because women’s economic activities are more diverse and difficult to capture through economic surveys.

In addition to these benefits not related to reproduction, improving women’s iron status prior to conception will reduce the risk of iron deficiency anemia in pregnancy and its diverse consequences, as discussed above (18).

Intervention strategies. The WHO has recently issued guidance on the technical aspects of food fortification to guide programs (60). Although the effects of iron fortification are difficult to generalize across different types of fortificants, food...
vehicles, diets, and populations, numerous randomized trials of iron fortification of condiments or beverages demonstrate that this strategy can be efficacious (60). Unfortunately, there is limited evidence that iron fortification of flour is efficacious and further research is very much needed in that area.

Biofortification, or plant breeding to achieve iron-rich crop varieties, is an alternative strategy to enhance the iron content of the overall diet (61). If plant breeders succeed in developing crops with high iron content and bioavailability and also good agronomic properties, this intervention could be delivered through the agriculture sector and affect human nutrition on a large scale, without changes in dietary patterns. Target crops for biofortification with iron include beans, rice, and millet. To date, 1 variety of high-iron rice has been evaluated for efficacy in humans and was found to increase the iron status of nonanemic Filipino women of reproductive age (62).

It is noteworthy that income growth by itself has a remarkably weak effect on the iron status of populations (63). This is in contrast to other forms of malnutrition, which decrease more markedly with declines in poverty. Therefore, specific intervention strategies to improve iron status of populations will be needed to control the high prevalence of iron deficiency, even in countries with growing economies.

**Summary**

The control of iron deficiency in women and children requires a comprehensive strategy that is based on a lifecycle approach to the problem. Iron absorption and excretion are tightly regulated, precluding the possibility of large dose supplementation, as is often practiced with vitamin A or iodine supplements. However, iron is efficiently conserved and stored once it enters the body, and if incremental improvements in iron status can be maintained, they can create meaningful biological effects over time (64). Thus, in planning effective public health programs to address iron deficiency, planners should consider the whole reproductive cycle and create a combination of strategies that are complementary and comprehensive across the vulnerable periods for women during pregnancy and their infants.

Strategies designed to improve the iron status of women (and men) outside of pregnancy, such as fortification and biofortification, will reduce the risks of severe iron deficiency for the pregnant woman and her infant but will not eliminate the need for targeted strategies for the vulnerable periods of pregnancy and complementary feeding of the infant from 6–24 mo (64), especially in populations that consume few animal-source foods.

The public health benefits of controlling iron deficiency are numerous and integral to current global health initiatives and the millennium development goals (Table 1). The role of iron nutrition is recognized in the context of child nutrition, fortification, and biofortification, and it is likely that important advances will be made through these initiatives in the coming decade.

However, iron nutrition is not yet well integrated into the programmatic agendas for reducing morbidity and mortality of pregnant women and neonates. Iron supplementation in pregnancy has been advocated for decades as a means of controlling anemia, but this outcome has not been sufficient to motivate strong programs and policies, and the evidence base is still sparse for high-priority clinical outcomes [i.e., morbidity and mortality or mother and infant (12)]. At least in part, this is because investigators and ethical review committees are reluctant to stand behind trial designs in which women at risk of anemia do not receive iron supplements during pregnancy. Nevertheless, 2 recent randomized trials of iron supplementation during pregnancy provide strong support for the clinical benefits to the newborn (27,28). It is unlikely that any trial can be launched to address the outcome of maternal mortality, which is important but rare. To act on the current evidence for maternal and neonatal health will require stronger advocacy within circles that have not traditionally included nutritionists. Successful implementation will require greater attention to antenatal care for pregnancy women and prioritization of iron-promoting actions (including iron supplementation and deworming) within that platform.

**Acknowledgment**

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### Table 1 Summary of consequences of iron deficiency for women and children, intervention strategies, and links to global initiatives and development goals

<table>
<thead>
<tr>
<th>Stage of reproductive cycle</th>
<th>Mother</th>
<th>Pregnancy and delivery</th>
<th>Infant</th>
<th>Complementary feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits of intervention</td>
<td>Prevent anemia</td>
<td>Prevent anemia</td>
<td>Prevent anemia</td>
<td>Prevent anemia</td>
</tr>
<tr>
<td></td>
<td>Increase economic productivity</td>
<td>Decrease mortality due to postpartum hemorrhage</td>
<td>Improve motor and cognitive development</td>
<td></td>
</tr>
<tr>
<td>Intervention strategies</td>
<td>Increase intake through diet or supplements</td>
<td>Increase intake through diet or supplements</td>
<td>Delayed cord clamping</td>
<td>Increase intake through education or fortified infant food products</td>
</tr>
<tr>
<td></td>
<td>Treat hookworms</td>
<td>Treat hookworms</td>
<td></td>
<td></td>
</tr>
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<td>Global health initiatives</td>
<td>Fortification</td>
<td>Reproductive health</td>
<td>Neonatal health</td>
<td>Child nutrition</td>
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<td></td>
<td>Biofortification</td>
<td>FANC</td>
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<td>Millenium development goal</td>
<td>End poverty and hunger</td>
<td>Maternal mortality</td>
<td>Universal education</td>
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</tr>
<tr>
<td></td>
<td>Child health</td>
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Literature Cited


47. Lynch SR, Stoltzfus RJ. Iron and ascorbic acid: proposed fortification levels and recommended iron compounds. J Nutr. 2003;133:2978S–85S.


