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Short communication

Iron status, malaria parasite loads and food policies: Evidence from sub-Saharan Africa

Alok Bhargava *

University of Maryland School of Public Policy, College Park, MD 20742-1821, USA

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ABSTRACT

This brief article investigates the consequences of improving children's iron status for malaria parasite loads by analyzing data from Cote d'Ivoire, Zambia, and Tanzania; the treatment of iron deficiencies has been argued to flare up malaria in under-nourished populations. The data from a randomized controlled trial in Cote d'Ivoire showed statistically insignificant effects of the consumption of iron-fortified biscuits on children's malaria parasite loads. Second, nutrient intakes data from Zambia showed insignificant correlations and associations between children's iron and folate intakes and malaria parasite loads. Third, malaria parasite loads did not change significantly for Tanzanian children receiving anthelmintic treatment; malaria loads were lower for older children and for those using bed nets. Overall, the evidence from sub-Saharan African countries suggests that small improvements in iron status achieved via suitable food policies are unlikely to have detrimental effects for children's malaria parasite loads.

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1. Introduction

Iron deficiencies are widely prevalent in developing countries (UNICEF/WHO, 1999) and many individuals suffer from their consequences such as lower cognitive development among children (Pollitt, 1993), and reduced physical work capacity of adults (Basta et al., 1979). Treatment against iron deficiency, however, has been argued to exacerbate malaria infections in severely under-nourished populations (Murray et al., 1975). It is therefore important to further investigate such aspects by analyzing the data from studies in malaria endemic countries.

While "non-heme" iron is present in ample quantities in staple foods such as rice and wheat, iron absorption rates are low due to phytates and other inhibitors in the meal (Monsen and Balintfy, 1982). By contrast, "heme" iron from meat, fish and poultry iron is easily absorbed though the costs of diets may be prohibitive for the poor. In addition, helminth infections such as hookworm and Schistosomiasis are widely prevalent in developing countries due to poor sewage disposal and exacerbate iron loss. Because malarial morbidity is common especially in sub-Saharan Africa and claims the lives of millions of children, it is important to reappraise the conceptual and empirical issues surrounding iron supplementation and malaria parasite loads for facilitating the formulation of food policies.

There are several strategies for combating iron deficiencies in developing countries such as supplementing

* Tel.: +1 301 405 6330; fax: +1 301 403 4675.
E-mail address: Bhargava@umd.edu.

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populations via iron tablets (Ekstrom et al., 2002), increasing iron content of staple foods (Harvest Plus, 2010), and higher intakes of enhancers of iron absorption (Garcia-Casal et al., 1998). While the deleterious effects of iron repletion for pulmonary tuberculosis were noted in the nineteenth century by Trousseau (1872), the recent literature has emphasized possible adverse effects of iron supplementation for malaria parasite loads. For example, Murray et al. (1975) reported that severely undernourished populations in drought-stricken Niger had attacks of malaria after their food intakes improved during hospital stay. Furthermore, a study in Pemba, Zanzibar daily supplementing infants between ages of 1 and 35 months with 12.5 mg of iron and 50 μg of folic acid was terminated because of increased malarial morbidity (Sazawal et al., 2006).

2. Some conceptual aspects

There are at least four sets of conceptual issues that merit discussion for analyzing the links between iron status and malaria parasite loads in developing countries. First, iron tablets typically contain between 10 and 90 mg of iron that may be more easily available to parasites infecting the host (Fontaine, 2007). By contrast, iron intakes via fortified foods such as rice entail increases of less than 1 mg per meal that are accompanied by phytate intakes inhibiting absorption. Thus, despite the evidence from Niger where the subjects were on the verge of starvation, it is likely that small increases in iron intakes via fortified foods do not promote malaria parasite growth among typical sub-Saharan African populations (see below).

Second, the median requirements of absorbable iron for children under the age of 12 years are estimated to be less than 1 mg per day (FAO/WHO, 1988); requirements for adult men and non-menstruating women are approximately 1 mg. A critical aspect not sufficiently emphasized in the iron supplementation literature is the likely absorption rates. While some researchers estimate non-heme iron absorption rates from mixed diets to be 1–3% (Bhargava et al., 2001), others have suggested that they may be around 17% (Haas et al., 2005) which seems rather high in view of iron deficiencies in developing countries. Because iron absorption rates from tablets may also be high (Ekstrom et al., 2002), and iron absorption may be affected by malaria parasite loads (Fontaine, 2007), it is important not to supplement children with excessively high iron doses especially in malaria endemic regions.

Third, while adequate iron intakes are critical for child development (Pollitt, 1993; Bhargava and Fox-Kean, 2003), it is important to delineate the biological, food policy, and economic aspects of interventions. For example, nutritional interventions offering iron tablets to children in a short time frame such as for a few months cheaply provide high amounts of iron; end-points in such studies are biomarkers such as hemoglobin and ferritin concentrations. By contrast, food policies ensuring adequate intakes of absorbable iron throughout childhood are costly and gradually supply low quantities of iron. While iron supplementation via tablets may seem a cost-effective short-term strategy, policies improving diet quality facilitate long-term development without the risks (see Section 6). Such factors were recognized in the early nutrition interventions such as in Guatemala that provided children with a nutritious food supplement (Martorell and Scrimshaw, 1995). From this viewpoint, it would be of interest to investigate if higher iron intakes predict greater malaria parasite loads in sub-Saharan African populations.

Finally, iron status often improves following anthelmintic treatment in developing countries (Smith and Brooker, 2010). With an increase in iron stores, greater quantities of iron can be mobilized and may remain in the plasma for longer periods so that in theory iron can facilitate malaria parasite growth. However, malaria loads fluctuate with seasons and individuals with light loads often remain asymptomatic; it would be of interest to investigate if anthelmintic treatment improving iron status can inadvertently increase malaria parasite loads. Moreover, data on malaria loads can be analyzed to assess the role played by seasonal and socioeconomic factors. Because iron status and malaria loads have not been the main focus of interventions, the next three sections investigate these issues using different approaches (Bhargava, 2008a) by analyzing available data sets from Cote d'Ivoire, Zambia, and Tanzania.

3. The effects of iron-fortified biscuits on children's malaria parasite loads in Cote d'Ivoire

A randomized controlled trial in Cote d'Ivoire in 2006–07 conducted by Rohner et al. (2010) offered iron fortified biscuits containing 20 mg of iron four times per week to 75 children ages 6–14 years in the Treatment Group 1. Another 75 children in Treatment Group 2 received the biscuits along with treatment against malaria at the baseline and after 3 months. Children in the Control Group received biscuits without the iron. Approximately 58% of the children were infected with *Plasmodium* species at the baseline so that malaria was prevalent in this population. However, the effects of consuming higher quantities of iron via fortified biscuits on malaria parasite loads were not investigated by Rohner et al. (2010). Since the data on malaria parasite loads were made available to the author, further comparisons for the malaria parasite loads of children in the Control and Treatment Groups can provide useful insights.

Table 1 presents the sample means of malaria parasite loads in the Control and Treatment Groups 1 and 2, and independent *t*-tests for comparing differences in changes between baseline and 6 months in the Control and Treatment Groups. While malaria parasite loads declined slightly at 6 months in the Control Group, there was an increase in the Treatment Groups. However, the standard deviations were large and null hypotheses that differences between changes in Control and Treatment Groups were zero were accepted in both cases. In fact, both the *t*-statistics were 1.16 with *p*-values 0.25.

Further, because malaria parasite loads were high for certain children, malaria loads were transformed into natural logarithms with the zero values set to unity prior to the transformations; the logarithmic transformation

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