Relationship of the availability of micronutrient powder with iron status and hemoglobin among women and children in the Kakuma Refugee Camp, Kenya

Philip Ndemwa, Christine L. Klotz, David Mwaniki, Kai Sun, Erastus Muniu, Pauline Andango, Joyce Owigar, Jee Hyun Rah, Klaus Kraemer, Paul B. Spiegel, Martin W. Bloem, Saskia de Pee, and Richard D. Semba

This article has been amended to include Table 2.

Abstract

Background. *Micronutrient powder is a potential strategy to improve iron status and reduce anemia in refugee populations.*

Objective. *To evaluate the effect of the availability of home fortification with a micronutrient powder containing 2.5 mg of sodium iron ethylenediaminetetraacetate (NaFeEDTA) on iron status and hemoglobin in women and children in the Kakuma Refugee Camp in northwest Kenya.*

Methods. *Hemoglobin and soluble transferrin receptor were measured in 410 children 6 to 59 months of age and 458 women of childbearing age at baseline (just before micronutrient powder was distributed, along with the regular food ration) and at midline (6 months) and endline (13 months) follow-up visits.*

Results. *At the baseline, midline, and endline visits, respectively, the mean (± SE) hemoglobin concentration in women was 121.4 ± 0.8, 120.8 ± 0.9, and 120.6 ± 1.0 g/L (p = .42); the prevalence of anemia (hemoglobin < 120 g/L) was 42.6%, 41.3%, and 41.7% (p = .92); and the mean soluble transferrin receptor concentration was 24.1 ± 0.5, 20.7 ± 0.7, and 20.8 ± 0.7 nmol/L (p = .0006). In children, the mean hemoglobin concentration was 105.7 ± 0.6, 109.0 ± 1.5, and 105.5 ± 0.3 g/L (p = .95), respectively; the prevalence of anemia (hemoglobin < 110 g/L) was 55.5%, 52.3%, and 59.8% (p = .26); and the mean soluble transferrin receptor concentration was 36.1 ± 0.7, 29.5 ± 1.9, and 28.4 ± 3.2 nmol/L (p = .02), in models that were adjusted for age using least squares means regression.*

Conclusions. *In children and in women of childbearing age, the availability of micronutrient powder was associated with a small improvement in iron status but no significant change in hemoglobin in this refugee camp setting.*

Key words: Anemia, children, hemoglobin, iron, micronutrient powder, refugees, women

Introduction

Anemia and iron-deficiency anemia are extremely common among women and children in sub-Saharan Africa [1]. Anemia, as one indicator of micronutrient deficiencies, is largely attributed to iron deficiency, but it is also related to deficiencies of vitamin A, folic acid, and vitamin B_{12} [2]. In addition, non-nutritional factors such as parasitic infections, malaria, infectious diseases, and hemoglobinopathies contribute to anemia [3]. The main cause of micronutrient deficiencies in developing countries is a poor-quality diet that is largely plant-based, with limited inclusion of animal-source foods and fortified food products [4, 5]. Micronutrient malnutrition is common among people who consume a largely plant-based diet that also includes few fortified foods. In diets that are high in unrefined grains and legumes, the amount of nutrients consumed may be adequate, but dietary constituents, such as phytates and tannins, limit their absorption [6].

Home fortification with micronutrient powder has been developed to ensure an adequate intake of micronutrients in specific, high-risk target populations. Micronutrient powder is used to fortify ready-to-eat foods, such as porridge or a solid meal, at home just

Philip Ndemwa, David Mwaniki, Erastus Muniu, and Pauline Andango are affiliated with the Kenya Medical Research Institute, Nairobi. Christine L. Klotz, Joyce Owigar, Martin W. Bloem, and Saskia de Pee are affiliated with the World Food Programme, Rome, Italy. Kai Sun, Jee Hyun Rah, and Klaus Kraemer are affiliated with Sight and Life, Basel, Switzerland. Richard D. Semba is affiliated with the Johns Hopkins University School of Medicine, Baltimore, Maryland, USA. Paul B. Spiegel is affiliated with the United Nations High Commissioner for Refugees, Geneva, Switzerland.

Please direct queries to the corresponding author: Richard D. Semba, Johns Hopkins University School of Medicine, Smith Building, M015, 400 N. Broadway, Baltimore, MD 21287, USA; e-mail: rdsemba@jhmi.edu.

before consumption [7]. The powder is generally dosed to provide one full Recommended Nutrient Intake (RNI) of each of several vitamins and minerals in the form of 1 g of powder contained in a sachet. The formulation may vary according to local conditions, such as the availability of fortified food rations and the demographic characteristics of the target group.

Micronutrient powder has been shown to reduce anemia and iron deficiency among young children in various settings [8]. Experience with its use in large-scale programs has been gathered more recently, mainly in development settings, but also in a few emergency and refugee settings, including in Aceh, Indonesia [9].

The Kakuma Refugee Camp is located in Turkana District in the Rift Valley Province, about 110 km from the Sudanese border at Lokichoggio and about 50 km from the Ugandan border. The altitude of the camp is 580 m. The camp was established in 1992 to accommodate about 17,000 southern Sudanese refugees fleeing the civil war in their country. In 2009, the Kakuma Refugee Camp had a population of approximately 51,000 people, mostly Sudanese, Somalis, and Ethiopians. The refugees in the camp are provided with insecticide-treated mosquito nets and have access to medical treatment in the International Red Cross facilities.

The population of the camp relies upon the general food ration distributed by the United Nations World Food Programme (WFP). The food ration consists of maize, fortified wheat flour, pulses, vegetable oil fortified with vitamin A, fortified corn–soy blend, and iodized salt. The refugees also generally receive complementary foods such as green grams or groundnuts from the United Nations High Commissioner for Refugees. The refugees have limited access to fresh foods.

The food ration provides an average of 2,100 kcal/person/day, but it does not contain all the required micronutrients. For the average person, based upon the specific age and sex distribution of the population, the general food ration provides 81% of iron, 43% of vitamin C, 62% of riboflavin, and 89% of thiamin requirements. Moreover, micronutrient intake is further reduced by poor bioavailability of some of the micronutrients, particularly iron and zinc.

Whether home fortification with micronutrient powder can reduce anemia in large refugee camp settings in sub-Saharan Africa has not been well characterized. We hypothesized that the availability of micronutrient powder for home fortification would be associated with an improvement in iron status and hemoglobin concentrations in women and preschool-aged children in the Kakuma Refugee Camp in northwest Kenya. Because the camp is located in a malaria-endemic area, the quantity of iron in the micronutrient powder was reduced compared with the micronutrient powder used in areas where there is little to no malaria. The form of iron in the powder was sodium iron ethylenediaminetetraacetate (NaFeEDTA), which has high bioavailability. To address the hypothesis, we measured iron status using serum soluble transferrin receptor, a marker for tissue iron deficiency [10], and hemoglobin concentrations among women of childbearing age and children aged 6 to 59 months, before and after micronutrient powder was made available in food distribution centers within the camp.

Materials and methods

The study population consisted of 410 children 6 to 59 months of age and 458 women of childbearing age (18 to 49 years) in the Kakuma Refugee Camp in northwest Kenya. Subjects were eligible for the study if they were resident in the camp with no plans to move in the next 12 months, were children aged 6 to 59 months or non-pregnant women of reproductive age (18 to 49 years), and agreed to participate in the study and give written, informed consent or had a parent or guardian who gave written, informed consent. Subjects were excluded from the study and referred to the health center for further management if they had a hemoglobin level < 80 g/L at the time of screening.

The participants in the study were a representative sample of the population in the Kakuma Refugee Camp. Households were selected for the study by cluster sampling (probability proportional to size) of 32 households from 25 administrative units in the camp. Subjects were enrolled in January 2009 in a baseline survey. The cohort was seen at midline and endline follow-up visits at 6 and 13 months after the baseline survey. The study protocol was approved by the Institutional Review Boards of both the Johns Hopkins University School of Medicine and the Kenya Medical Research Institute.

Boxes containing 30 sachets of MixMe micronutrient powder (DSM Nutritional Products Ltd., Kaiseraugst, Switzerland) were offered at the monthly food distribution at the camp beginning in the month following the baseline study visit. Prior to and in the first months of distribution of the micronutrient powder, social marketing efforts were undertaken to inform the inhabitants of the camp about the potential health benefits and proper use of the micronutrient powder. The micronutrient formulation was specifically tailored for the Kakuma Refugee Camp setting. The refugees were educated to use one sachet per family member each day, mixing the contents with food that was ready for consumption. One sachet of the micronutrient powder (1 g) contained vitamin A (100 µg RE), vitamin D_3 (5 µg), vitamin E (5 mg), vitamin K_1 (30 µg), thiamin (0.5 mg), riboflavin (0.5 mg), pyridoxine (0.5 mg), folic acid (90 µg), niacin (6 mg), vitamin B_{12} (0.9 µg), vitamin C (60 mg), iron (2.5 mg), zinc (2.5 mg), selenium (17 µg), copper (0.34 µg), iodine (30 µg), and maltodextrin as a carrier.

Iron was calculated based upon reference values for medium bioavailability. The iron content of the formulation was reduced from 10 mg per serving to 2.5 mg in order to minimize the risk due to use of iron in malaria-endemic areas [11]. The form of iron was NaFeEDTA, a highly bioavailable form. The iron content of 2.5 mg was meant to complement approximately 3 mg of iron that was provided by fortification iron in corn–soy blend and wheat flour. With total iron absorption from the fortified foods and the micronutrient powder of 10%, it was estimated that the 0.55 mg of iron absorbed would provide most of the daily requirement of a 1- to 3-year-old child. The zinc content was reduced to 2.5 mg to maintain an equal ratio to iron, as zinc can interfere with the absorption of iron. The proportion of families who picked up the boxes of micronutrient powder was monitored at each of the monthly food distribution cycles.

A 4-day training and a 1-day pretest were conducted prior to each of the three surveys to equip the survey staff with the objectives of the micronutrient powder intervention and techniques for accurate collection of data (blood samples, anthropometric measurements, and administration of questionnaires). The teams were composed of local agency staff (community health workers and laboratory staff), national staff supervisors (health personnel and nutritionists), and data entry clerks. Nine teams of six members each (one supervisor, one enumerator, two anthropometrists, and two phlebotomists) collected the survey data at baseline, midline, and endline. Interviews were conducted in the language of the respondent and translated back into English for enumeration in a standardized questionnaire. The same survey staff members were used wherever possible, although many new workers were recruited for the midline and endline surveys due to the high turnover of local workers in the camp. The Principal Investigator from the Kenya Medical Research Institute (P.N.) led a quality control team to recheck anthropometric measurements.

After the mother, father, or guardian gave written, informed consent, data regarding basic demographic characteristics, morbidity, food intake, food security, and knowledge of anemia were collected using standardized questionnaires. Children were weighed with UNICEF Salter scales. Children were minimally or lightly clothed and placed in the weighing pants, with weight recorded to the nearest 0.1 kg. Height was measured to the nearest 0.1 cm with wooden height boards. Children under 24 months of age were measured in the recumbent position; older children were measured in the upright position. Women were weighed to the nearest 0.1 kg with electronic scales. Adult height boards were used to measure heights of women.

According to data from the United Nations High Commissioner on Refugees Health Information System, the crude malaria incidence per month (per 1,000 persons) during the 13-month study period from January 2009 through February 2010 was 20.75, 27.76, 16.04, 32.47, 21.43, 23.93, 19.07, 16.14, 23.09, 27.69, 20.85, 23.17, 48.56, and 32.83, with no temporal trend by logistic regression ($p = .13$). The malaria incidence among children under 5 years of age per month (per 1,000 persons) during the same time period was 74.33, 87.42, 61.48, 154.27, 85.66, 95.35, 68.89, 66.61, 92.2, 107.84, 89.77, 85.28, 152.42, and 110.62 ($p = .24$).

Fingerstick blood samples were collected using capillary tubes at each visit. Hemoglobin was measured by HemoCue. Capillary tubes were stored in cool boxes with gel packs for 2 to 4 hours until they were processed in a central laboratory. Serum was separated by centrifugation, aliquoted into cryovials, and immediately placed in liquid nitrogen refrigerators in the field. Samples were later transferred to a freezer for long-term storage at −70° C. Soluble transferrin receptor was measured in serum by a commercial ELISA (Human sTfR Quantikine, R & D Systems). In a coinvestigator's laboratory (R.D.S.), the interassay and intra-assay coefficients of variation were 5.3% and 4.7%, respectively. The lower limit of detection of the assay was 0.5 nmol/L, and the range of the assay was 3 to 80 nmol/L, according to the manufacturer's description. No samples were below the limit of detectability or above the range of the assay.

Statistical analysis

The sample size of the study was based upon a 90% power to detect at least a 20% reduction in anemia in both women and children with a two-sided test, $\alpha = .05$, and an estimated loss to follow-up of 30%. Continuous variables were described by means and standard errors. Skewed variables were log transformed to achieve a normal distribution. Weight-for-age, height-for-age, and weight-for-height z-scores were calculated using the World Health Organization (WHO) child growth reference population [12]. Underweight, stunting, and wasting, respectively, were defined as weight-for-age, height-for-age, and weight-for-height z-score < -2. Body mass index (BMI) was calculated as the weight in kilograms divided by the square of the height in meters. Anemia was defined as hemoglobin < 110 g/L for children and < 120 g/L for women, according to WHO definitions [3]. In children, least squares linear regression models were used to examine respective changes in hemoglobin and soluble transferrin receptor over time, with adjustment for child age. All analyses were performed by SAS with a type I error of 0.05.

Results

The demographic and anthropometric characteristics of the 458 women and 410 children at baseline are

TABLE 1. Characteristics of women and children at the baseline visit[a]

Characteristic	Value[b]
Women (n = 458)	
Age—yr	29.4 ± 0.4
BMI (kg/m^2)—%	
< 18.5	59.0
18.5–24.9	20.3
25.0–29.9	14.5
≥ 30	6.2
Ethnic group—%	
Sudanese	49.3
Somali	39.1
Ethiopian	9.4
Ugandan or Congolese	2.2
Children (n = 410)	
Male sex—%	50.7
Age (mo)—%	
6–11	9.3
12–23	21.7
24–35	23.7
36–47	22.4
48–59	22.9
Weight-for-age z-score	–0.57 ± 0.06
% with z-score < –2	8.7
Height-for-age z-score	–0.16 ± 0.08
% with z-score < –2	15.3
Weight-for-height z-score	–0.66 ± 0.06
% with z-score < –2	13.6

BMI, body mass index
a. Data are missing for maternal BMI (12 subjects), ethnicity (3 subjects), and child anthropometric measurements (9 subjects).
b. Plus–minus values are means ± SE.

shown in **table 1**. Of the 458 women seen at baseline, 175 (38.2%) were lost to follow-up by the endline visit. Of the 410 children seen at baseline, 111 (27.1%) were lost to follow-up by the endline visit. There were no significant differences in age, BMI, ethnicity, hemoglobin concentration, or soluble transferrin receptor concentration between women who were lost to follow-up and women who remained in the study (data not shown). There were no significant differences in age, sex ratio, weight-for-age, height-for-age, weight-for-height, hemoglobin concentration, or soluble transferrin receptor concentration between children who were lost to follow-up and children who remained in the study (data not shown).

The proportion of boxes of micronutrient powder picked up at the monthly food distribution in the camp were as follows: February 2009, 99%; March 2009, 85%; April 2009, 71%; May 2009, 60%; June 2009, 49%; July 2009, 30%; August 2009, 45%; September 2009, 40%; October 2009, 48%; November 2009, 46%; December 2009, 47%; January 2010, 49%; and February 2010, 50%.

In women of childbearing age, the mean hemoglobin concentration and the prevalence of anemia did not change significantly from baseline through midline and endline (**table 2**). The mean soluble transferrin receptor concentration decreased between baseline and endline (p = .0006). In children, after adjustment for age by least squares means regression, the mean hemoglobin concentration did not change significantly from baseline through endline (**table 2**). The prevalence of anemia, adjusted for age by least squares means regression, did not change significantly between baseline and endline. After adjustment for age by least squares means regression, the mean soluble transferrin receptor concentration decreased between baseline and endline (p = .02).

Discussion

The findings of the present study, although relatively modest, corroborate the findings of other studies that show home fortification using micronutrient powder improves iron status. The use of home fortification has consistently improved iron status of children in experimental studies [13–16], even in malaria-endemic areas. Although the present study was limited by the absence of a control group and cannot rule out other factors as being responsible for the observed improvement in iron status, the findings from other studies on home fortification and the efficacy of NaFeEDTA in high-phytate diets support an effect of the iron intervention [17].

Low compliance may have played a role in the results of the present study. The barriers to use of the micronutrient powder in the camp are presented in a separate paper [18]. A common factor in the studies cited above is a compliance rate that exceeded 80% [13, 16, 19]. In a study by Suchdev and colleagues in western Kenya [20], final hemoglobin concentrations were associated with the number of micronutrient powder sachets purchased. Given that availability was assessed in terms of sachets purchased, the likelihood that these were also consumed may be higher than in our study, where picking up micronutrient powder sachets at the distribution center may not necessarily have translated to compliance in terms of consumption.

The micronutrient powder used in the present study should deliver an amount of absorbable iron comparable to that delivered by the formulations used in most of the studies noted above [21] and hence should sufficiently improve iron status if compliance is good. It is probable, therefore, that with improved compliance, home fortification could achieve greater gains in reducing the prevalence of anemia in refugee camps.

The micronutrient powder was especially formulated for the situation of the Kakuma Refugee Camp and did not contain the Recommended Nutrient Intakes (RNIs)

TABLE 2. Hemoglobin and soluble transferrin receptor in women and children at three visits during the study[a]

Variable	Baseline	Midline	Endline	P value: Baseline to midline	P value: Midline to endline	P value: Baseline to endline
Women						
n	458	317	283			
Anemic (hemoglobin < 120 g/L)—%[b]	42.6	41.3	41.7	.72	.82	.92
Hemoglobin—g/L	121.4 ± 0.8	120.8 ± 0.9	120.6 ± 1.0	.57	.81	.42
Soluble transferrin receptor—nmol/L	24.1 ± 0.5	20.7 ± 0.7	20.8 ± 0.7	.0002	.83	.0006
Children[c]						
n	410	320	299			
Anemic (hemoglobin < 110 g/L)—%[b]	55.5	52.3	59.8	.36	.05	.26
Hemoglobin—g/L	105.7 ± 0.6	109.0 ± 1.6	105.5 ± 0.3	.05	.25	.95
Soluble transferrin receptor—nmol/L	36.1 ± 0.7	29.5 ± 1.9	28.4 ± 3.2	.001	.76	.02

a. Plus–minus values are means ± SE.
b. *P* value for anemia prevalence is based upon chi-square test of prevalence at all three visits.
c. Least squares means regression was used to adjust for age in children, since increasing age is associated with a decrease in hemoglobin and an increase in soluble transferrin receptor.

of iron and vitamin A. The iron content was reduced because malaria is endemic in the region. Absorption of iron is expected to be more gradual with the chelated form of iron and less likely to cause a peak of non-transferrin-bound iron. The vitamin A content was reduced because vitamin A–fortified cooking oil is provided in the monthly food basket by WFP.

The limitations of this study include the high rate of loss to follow-up and low uptake of the micronutrient powder. The high loss to follow-up reached nearly 40% for women of childbearing age and nearly 30% for preschool-aged children and is largely attributed to the population dynamics of the camp. The proportion of adults who collected the micronutrient nutrient powder dropped steadily from 99% to 30% within the first 6 months that the powder was available at the food distribution center. In the remaining 7 months of the study, the proportion of adults who collected the micronutrient powder at the center remained fairly steady at 40% to 50%. It is interesting to note that among women of childbearing age and children, the decrease in mean soluble transferrin receptor occurred from baseline to midline visits and then showed no change from midline to endline visits.

Soluble transferrin receptor is a sensitive indicator of tissue iron deficiency and is less affected by inflammation than is serum ferritin [10]. Although there was a significant decrease in soluble transferrin receptor in women of childbearing age and children during the study, it appears that the improvement in iron status was not sufficient to increase hemoglobin concentrations or the prevalence of anemia during follow-up. The mean soluble transferrin receptor concentrations at midline and endline visits in women were close to the mean levels of 19.5 nmol/L reported in a study of 225 healthy white, black, and Hispanic adults and 20.9 nmol/L reported in 61 black adults [22]. Age-specific soluble transferrin receptor concentrations in healthy children aged 2 to 6 years showed a reference interval (2.5th to 97.5th percentile) of 14.0 to 40.8 nmol/L [23]. The mean soluble transferrin receptor concentrations of children in the present study were toward the upper end of this reference interval.

In conclusion, the availability of micronutrient powder was associated with a small improvement in iron status in children and women of childbearing age in the Kakuma Refugee Camp. Further work is needed to address and overcome the barriers to utilization of micronutrient powder in this refugee camp setting.

Acknowledgments

The micronutrient powder program implementation and study at Kakuma Refugee Camp was carried out and funded as part of the WFP–DSM partnership "Improving Nutrition—Improving Lives" aiming to assist WFP in implementing its Nutrition Improvement Approach. The following individuals substantially contributed to the project: Sammy Nadiko, Simon Elimo, Daniel Macharia, and Joseph Kimani (monitoring team); Patrick Mundia, Joyce Mukiiri, and Carolyne Mbuuri (International Rescue Committee staff); Victoria Mwenda and Caroline Wilkinson (United Nations High Commissioner for Refugees staff); Lourdes Ibarra, Peter Otieno, Josiah Osiri, Beatrice Ngugi, Charles Owade, Ronald Erukan, Jecinta Abenyo, Peter Karuri, Thomas Chika, Wilson Ereng, Alfred Lokwang, Daniel Mwangi, and David Kariuki (WFP Kakuma); Emily Madete, Grace Igweta, Stephen Mwenda, Felix Okech, and Josephine Mahiga (WFP Nairobi); Nils Grede (WFP Rome); Sam Okwara, Ezekiel Mukhaye, and Saidi Kisiwa (Kenya Medical Research Institute staff); and Martin Meme and Emily Teshome (survey consultants).

References

1. Kraemer K, Zimmermann MB, eds. Nutritional anemia. Basel, Switzerland: Sight and Life Press, 2007.
2. Allen LH. Causes of nutrition-related public health problems of preschool children: available diet. J Pediatr Gastroenterol Nutr 2006;43:S8–12.
3. World Health Organization. Iron deficiency anaemia: Assessment, prevention and control: a guide for programme managers. WHO, 2001. Available at: http://www.who.int/nutrition/publications/micronutrients/anaemia_iron_deficiency/WHO_NHD_01.3/en/index.html.
4. de Pee S. Need, efficacy and effectiveness of multiple vitamin/mineral supplements for young children and considerations for programs. In: Semba RD, Bloem MW, eds. Nutrition and health in developing countries, 2nd ed. Totowa, NJ, USA: Humana Press, 2008:793–830.
5. Zimmermann MB, Hurrell RF. Nutritional iron deficiency. Lancet 2007;370:511–20.
6. Sotelo A, González-Osnaya L, Sánchez-Chinchillas A, Trejo A. Role of oxate, phytate, tannins and cooking on iron bioavailability from foods commonly consumed in Mexico. Int J Food Sci Nutr 2010;61:29–39.
7. de Pee S, Kraemer K, van den Briel T, Boy E, Grasset C, Moench-Pfanner R, Zlotkin S, Bloem MW. Quality criteria for micronutrient powder products: report of a meeting organized by the World Food Programme and Sprinkles Global Health Initiative. Food Nutr Bull 2008;29:232–41.
8. Dewey KG, Yang Z, Boy E. Systematic review and meta-analysis of home fortification of complementary foods. Matern Child Nutr 2009;5:283–321
9. de Pee S, Moench-Pfanner R, Martini E, Zlotkin SH, Darnton-Hill I, Bloem MW. Home fortification in emergency response and transition programming: experiences in Aceh and Nias, Indonesia. Food Nutr Bull 2007;28:189–197.
10. Beguin Y. Soluble transferrin receptor for the evaluation of erythropoiesis and iron status. Clin Chim Acta 2003;329:9–22.
11. Sazawal S, Black RE, Ramsan M, Chwaya HM, Stoltzfus RJ, Dutta A, Dhingra U, Kabole I, Deb S, Othman MK, Kabole FM. Effects of routine prophylactic supplementation with iron and folic acid on admission to hospital and mortality in preschool children in a high malaria transmission setting: community-based, randomised, placebo-controlled trial. Lancet 2006;367:133–43.
12. World Health Organization Multicentre Growth Reference Study Group. WHO child growth standards: Growth velocity based on weight, length and head circumference: methods and development. Geneva: WHO, 2009.
13. Adu-Afarwuah S, Lartey A, Brown KH, Zlotkin S, Briend A, Dewey KG. Home fortification of complementary foods with micronutrient supplements is well accepted and has positive effects on infant iron status in Ghana. Am J Clin Nutr 2008;87:929–38.
14. Christofides A, Asante KP, Schauer C, Sharieff W, Owusu-Agyei S, Zlotkin S. Multi-micronutrient sprinkles including a low dose of iron provided as microencapsulated ferrous fumarate improves haematologic indices in anaemic children: a randomized clinical trial. Matern Child Nutr 2006;2:169–80.
15. Giovannini M, Sala D, Usuelli M, Livio L, Francescato G, Braga M, Radaelli G, Riva E. Double-blind, placebo-controlled trial comparing effects of supplementation with two different combinations of micronutrients delivered as sprinkles on growth, anemia, and iron deficiency in Cambodian infants. J Pediatr Gastroenterol Nutr 2006;42:306–12.
16. Zlotkin S, Arthur P, Schauer C, Antwi KY, Yeung G, Piekarz A. Home-fortification with iron and zinc sprinkles or iron sprinkles alone successfully treats anemia in infants and young children. J Nutr 2003;133:1075–80.
17. Andang'o PE, Osendarp SJ, Ayah R, West CE, Mwaniki DL, De Wolf CA, Kraaijenhagen R, Kok FJ, Verhoef H. Efficacy of iron-fortified whole maize flour on iron status of schoolchildren in Kenya: a randomised controlled trial. Lancet 2007;369:1799–806.
18. Kodish S, Rah JH, Kramer K, de Pee S, Gittelsohn J. Understanding low usage of micronutrient powder in the Kakuma Refugee Camp, Kenya: Findings from a qualitative study. Food Nutr Bull 2011;32:291–302.
19. Zlotkin S, Antwi KY, Schauer C, Yeung G. Use of microencapsulated iron(II) fumarate sprinkles to prevent recurrence of anaemia in infants and young children at high risk. Bull World Health Organ 2003;81:108–15.
20. Suchdev P, Ruth L, Mandava U, Quick R, Mbakaya C, Kaduka L, Jefferds ME, Woodruff BA. Effectiveness of sprinkles sales in Western Kenya in reducing childhood anemia and iron deficiency [poster]. In: Proceedings of the Micronutrient Forum Meeting, 12–15 May, 2009, Beijing. Available at: http://www.micronutrientforum.org/Meeting2009/PDFs/Poster%20Presentations/3_Thursday/SNT/TH41_Suchdev.pdf. Accessed 13 May 2011.
21. Verhoef H, Veenemans J. Safety of iron-fortified foods in malaria-endemic areas. Am J Clin Nutr 2009;89:1949–50.
22. Allen J, Backstrom KR, Cooper JA, Cooper MC, Detwiler TC, Essex DW, Fritz RP, Means RT Jr, Meier PB, Pearlman SR, Roitman-Johnson B, Seligman PA. Measurement of soluble transferrin receptor in serum of healthy adults. Clin Chem 1998;44:35–9.
23. Kratovil T, DeBerardinis J, Gallagher N, Luban NLC, Soldin SJ, Wong ECC. Age specific reference intervals for soluble transferrin receptor (sTfR). Clin Chim Acta 2007;380:222–4.