Public Health Nutrition: 13(1), 107–115 doi:10.1017/S1368980009005254

Evaluation of the effectiveness of stainless steel cooking pots in reducing iron-deficiency anaemia in food aid-dependent populations

Leisel Talley[1,]*, Bradley A Woodruff[2], Andrew Seal[3], Kathryn Tripp[4], Laurent Sadikiel Mselle[5], Fathia Abdalla[6], Rita Bhatia[7] and Zhara Mirghani[8]

[1]International Emergency and Refugee Health Branch, National Center for Environmental Health, Centers for Disease Control and Prevention, 1600 Clifton Road, MS F-60, Atlanta, GA 30333, USA: [2]Department of Global Health, Rollins School of Public Health, Emory University, Atlanta, GA, USA: [3]Centre for International Health and Development, Institute of Child Health, University College London, London, UK: [4]Maternal and Child Nutrition Branch, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, GA, USA: [5]Tanzania Food and Nutrition Centre, Dar es Salaam, Tanzania: [6]United Nations High Commissioner for Refugees, Laayoune, Western Sahara: [7]United Nations World Food Programme, Regional Bureau for Asia, Bangkok, Thailand: [8]United Nations High Commissioner for Refugees, Damascus, Syria

Submitted 13 February 2008: Accepted 18 November 2008: First published online 1 April 2009

Abstract

Objective: To evaluate the effectiveness of stainless steel (Fe alloy) cooking pots in reducing Fe-deficiency anaemia in food aid-dependent populations.

Design: Repeated cross-sectional surveys. Between December 2001 and January 2003, three surveys among children aged 6–59 months and their mothers were conducted in 110 households randomly selected from each camp. The primary outcomes were changes in Hb concentration and Fe status.

Setting: Two long-term refugee camps in western Tanzania.

Subjects: Children (6–59 months) and their mothers were surveyed at 0, 6 and 12 months post-intervention. Stainless steel pots were distributed to all households in Nduta camp (intervention); households in Mtendeli camp (control) continued to cook with aluminium or clay pots.

Results: Among children, there was no change in Hb concentration at 1 year; however, Fe status was lower in the intervention camp than the control camp (serum transferrin receptor (sTfR) concentration: 6·8 *v.* 5·9 μg/ml; $P<0·001$). There was no change in Hb concentration among non-pregnant mothers at 1 year. Subjects in the intervention camp had lower Fe status than those in the control camp (sTfR concentration: 5·8 *v.* 4·7 μg/ml; $P=0·003$).

Conclusions: Distribution of stainless steel pots did not increase Hb concentration or improve Fe status in children or their mothers. The use of stainless steel prevents rusting but may not provide sufficient amounts of Fe and strong educational campaigns may be required to maximize use. The distribution of stainless steel pots in refugee contexts is not recommended as a strategy to control Fe deficiency.

Keywords
Iron deficiency
Anaemia
Refugees
Cooking pots
Stainless steel

Fe deficiency is the most common nutritional deficiency and poses a major public health problem. Two billion people are estimated to be anaemic, with Fe deficiency accounting for about half of the cases[1]. In virtually all populations, children are at particular risk owing to their increased physiological requirement for Fe. Moreover, the long-term consequences of Fe deficiency, including cognitive development delays and reduced immunity, may be more severe in this age group[1]. In addition to these chronic sequelae, anaemia can pose an acute threat to health. Death from heart failure can result from severe anaemia, especially if it develops rapidly[2]. Furthermore, treatment of life-threatening severe anaemia as a result of malaria infection or in severe cases of anaemia often requires blood transfusion, which can lead to fluid overload and death from heart failure in young children. Transfusion also poses a risk of infection by blood-borne pathogens if donated blood is incompletely screened.

Refugees and other populations dependent on food aid are potentially at greater risk of anaemia and Fe deficiency[3–5]. Food rations provided to such populations are frequently deficient in Fe and other micronutrients[6,7].

*Corresponding author: Email Ltalley@cdc.gov

In addition, the usual sources of Fe and other micronutrient-rich foods such as meat, fresh fruits and vegetables are frequently unavailable.

Among the various strategies being investigated to decrease the prevalence and severity of Fe deficiency and Fe-deficiency anaemia is the provision of cooking vessels made from Fe or Fe alloy. Randomized controlled efficacy trials involving children below 5 years of age in Ethiopia and Brazil demonstrated that eating food cooked in cast iron pots increased Hb concentration[8,9].

In 2001, the United Nations High Commissioner for Refugees (UNHCR) and the United Nations World Food Programme (WFP), with technical assistance from the UK Centre for International Health and Development, Institute of Child Health (ICH), the Tanzania Food and Nutrition Centre and the US Centers for Disease Control and Prevention (CDC), and funding from United Nations Fund for International Partnership (UNFIP), evaluated the feasibility of the distribution and use of cooking pots made from stainless steel (an Fe alloy) and their effect on the prevalence of anaemia and Fe-deficiency among children aged 6–59 months and their mothers in two refugee camps in western Tanzania.

Nduta and Mtendeli camps were established in 1996 after the outbreak of ethnic conflict between the Hutu majority and Tutsi minority in Burundi caused an influx of thousands of Hutu refugees into western Tanzania. For several years before and during the course of this evaluation, both camps were served by the same organization operating health and public health services. At the time of the present study, each camp had an estimated population of 50 000 Burundian refugees and the available health and nutrition data indicated that the camps had similar characteristics. For example, nutrition surveys conducted in 2000 showed that 3·5 % of children aged 6–59 months in Nduta camp and 2·4 % of children in Mtendeli had acute malnutrition, and that crude and under-five mortality rates and the rates of reported malaria were similar in the two camps in 2001 (International Rescue Committee Health Surveillance Data from Nduta and Mtendeli Camps, 2001).

Anaemia is a serious public health problem in all the camps in Tanzania, especially among children under 5 years of age. During the peak of malaria transmission in May 1997, anaemia accounted for 25–45 % of all deaths in under-fives (International Rescue Committee Health Surveillance Data from Nduta and Mtendeli Camps, 1997). A nutrition survey of children 6–59 months of age completed in July 2000 revealed that 55·2 % of children in Nduta and 37·4 % of children in Mtendeli camps were anaemic. Although malaria may play a major role as a cause of anaemia in the Tanzanian camps, Fe deficiency has also been shown to be an important contributing factor[10]. Supplementation programmes were available for individuals identified as anaemic and for pregnant women but appeared to be ineffective at reducing the problem of anaemia at the public health level.

The results of an initial pilot study conducted in Mkugwa camp, a smaller neighbouring camp, along with laboratory testing of food cooked in various types of pots, resulted in the selection of a 5-litre stainless steel cooking pot for distribution in the intervention camp[11]. Cast iron pots proved to be unacceptable to the refugee population due to their heavy weight and rust formation on the cooking surface. These evaluations, the results of the monitoring of pot sales in markets in and around the camps, and a qualitative assessment of pot acceptability one year after pot distribution are reported in an accompanying paper (K Tripp, N MacKeith, BA Woodruff, L Talley, L Mselle, Z Mirghani, F Abdalla, R Bhatia and AJ Seal, unpublished results). Here, we report the results of the intervention on anaemia and Fe deficiency in refugee children and their carers.

Experimental methods

Subjects and study sites

The study was conducted in Nduta and Mtendeli refugee camps in north-west Tanzania. We utilized a pre- and post-intervention design with repeated cross-sectional surveys and the inclusion of a control population. Three surveys were conducted of children aged 6–59 months and their mothers. The pre-intervention survey was conducted in December 2001 and two follow-up surveys were conducted at 6 months (August–September 2002) and 12 months (January 2003) after distribution of the stainless steel cooking pots. Cooking pots were distributed to all households in Nduta, the intervention camp. Existing cooking pots in households were not removed. Households in the control camp, Mtendeli, continued to cook with the aluminium pots previously issued by camp authorities or homemade traditional clay pots.

Population sampling

For each of the three surveys, a separate sample of households was drawn using systematic random sampling from UNHCR computerized registration lists of all registered households in Nduta and Mtendeli camps. All children under 5 years of age and their mothers were eligible for inclusion in the survey samples. Pregnant women were excluded from analysis of anaemia and Fe deficiency. Households that had left the camp permanently were not replaced. To minimize the effect of nutritional differences between new arrivals and long-term residents, the 6-month and 12-month follow-up surveys excluded children and mothers who had not resided in the camps at the time of the baseline survey.

Sample size calculation

Sample size calculations assumed $\alpha = 0{\cdot}05$, a statistical power $(1-\beta)$ of 0·80, a standard deviation for Hb concentration among young children and their non-pregnant mothers of 2·0 g/dl and equal variances in the two groups. Because previous studies indicated a rise in Hb concentration among children eating food cooked in iron pots compared with those eating food cooked in pots containing no Fe, sample size calculations were based on one-tailed tests. The sample size necessary to detect an increase of 0·71 g/dl between the baseline survey and the 6-month or 12-month follow-up survey was 100 women and 100 children per camp for each survey[12]. This allowed for detection of a significant rise in mean Hb of 0·71 g/dl between the baseline survey and the 6-month or 12-month follow-up survey, and a difference of 0·71 g/dl between Nduta and Mtendeli camps at each of the survey time points. This Hb difference was well below the difference found between the intervention and control groups in the two randomized trials of iron pots[8,9]. Assuming a 50 % prevalence of anaemia in all groups at baseline, 100 survey participants in each of the target groups would allow detection of a difference of 20 percentage points or more in the prevalence of anaemia between Nduta and Mtendeli camps[13]. To account for a potential refusal rate of 10 %, the sample size was increased to 110 women and 110 children.

Survey procedures

Survey personnel in each camp assisted in pre-testing and revising the questionnaires in Kirundi, the household language of the Burundian refugees, to ensure clarity and cultural appropriateness. All survey staff received 3 d of training prior to the baseline survey and refresher trainings for the follow-up surveys. Additional training was provided in anthropometric measurement and laboratory testing, including standardization exercises. During data collection, a health professional from one of the collaborating agencies supervised each survey team.

At each household, after explaining the survey and obtaining consent, we administered a questionnaire to each eligible mother to obtain data on household food preparation and cooking pot use. We also collected data about children aged 6–59 months and their mothers on demographic characteristics, illnesses during the last month for which treatment was sought and diagnosed at the camp clinic (specifically malaria, anaemia, hookworm, schistosomiasis) which may influence Hb concentration, and consumption of specific foods. Children were weighed to the nearest 100 g with a Tanita solar scale (model 1632W; Tanita Corporation, Tokyo, Japan). Height/length was measured to the nearest millimetre using a height board (Shorr Products, Orney, MD, USA) and standard techniques[14]. Oedema was assessed by applying thumb pressure to the dorsal surface of both feet for approximately 3 seconds and then examining for the presence of a shallow print or pit. The team supervisor confirmed each measurement.

All consenting survey participants underwent a finger prick to obtain a blood sample. After cleaning with alcohol, the skin of the fingertip was pierced with a lancet and the first drop of blood wiped away with dry cotton gauze. The second drop of blood was used to fill a cuvette and read in a HemoCue haemoglobinometer (HemoCue Inc., Lake Forest, CA, USA). Finally, at least two blood drops were spotted on Schleicher and Schuell Grade 903 paper (Schleicher and Schuel Inc., Keene, NH, USA) and dried for later testing of serum transferrin receptor (sTfR) concentration[15,16]. All participants found to be anaemic or malnourished were referred to the health centre in the camp for treatment, but were not excluded from the survey.

Biochemical analysis and case definitions

Each filter paper containing blood spots was dried on-site and stored in plastic bags containing desiccant and humidity monitoring cards. Upon arrival in Atlanta, USA, these spots were stored at −20°C until elution and testing with an ELISA for sTfR[16]. Quality control for the sTfR analyses was established by the replicate analysis of two levels of prepared control materials for which the target values had been determined over multiple runs. Analysis was repeated on any specimens with a CV greater than 20 % between replicates.

WHO defines anaemia in a child under 5 years of age as Hb $<$ 11·0 g/dl; however, because the altitude of both Nduta and Mtendeli is about 1400 m, 0·4 g/dl was added to the cut-off to define anaemia for this age group as Hb $<$ 11·4 g/dl[17]. Similarly, the altitude-adjusted definition of anaemia for non-pregnant mothers of selected children was Hb $<$ 12·4 g/dl. sTfR $>$ 8·3 μg/ml defined Fe deficiency in both children and women. Fe-deficiency anaemia was defined when both anaemia and Fe deficiency were present. Acute malnutrition was classified using *Z*-scores calculated from the National Center for Health Statistics/CDC/WHO reference population[18]. Moderate acute malnutrition was defined as a weight-for-height *Z*-score of <-2 and ≥-3. Severe acute malnutrition was defined as a weight-for-height *Z*-score of <-3 and/or the presence of bilateral oedema.

Data analysis

Data were entered into the Epi Info software version 6·04d (CDC, Atlanta, GA, USA). The calculation and analysis of anthropometric indices were conducted in EpiNut, a module within Epi Info. Analysis of all other variables was carried out with the SAS statistical software package version 9·1 (SAS Institute, Inc., Cary, NC, USA). The differences between camps at each survey and between different surveys in the same camp were tested using Student's t test for normally distributed data, the Kruskal–Wallis non-parametric one-way ANOVA test for non-normally distributed data, and the χ^2 test for independent proportions. Fischer exact tests were used when χ^2 tests were not appropriate. The level of significance was set at $P < 0{\cdot}05$. Ethical approval was obtained from the Tanzania Food and Nutrition Centre, Dar es Salaam.

Table 1 Characteristics of children (6–59 months) at baseline and follow-up surveys, Nduta and Mtendeli refugee camps, western Tanzania, December 2001, August 2002 and January 2003

	Nduta						Mtendeli					
	Baseline (*n* 108)		6-month (*n* 129)		12-month (*n* 113)		Baseline (*n* 101)		6-month (*n* 121)		12-month (*n* 141)	
Characteristic	*n* or Mean	% or range	*n* or Mean	% or range	*n* or Mean	% or range	*n* or Mean	% or range	*n* or Mean	% or range	*n* or Mean	% or range
Sex												
Male	50	47·2	66	51·2	62	54·5	45	44·6	65	53·7	79	56·0
Female	52	49·0	63	49·8	51	45·9	50	49·5	56	46·3	62	44·0
Unknown	4	3·8	0	0	0	0	6	5·9	0	0	0	0
Mean age (months)	26·7	6–58	30·7	6–59	29·6	6–59	29·1	6–58	29·5	6–59	31·5	6–59
Mean WHZ	−0·17	−2·98, 2·65	−0·29	−2·77, 3·40	−0·25	−3·00, 2·57	−0·14	−2·25, 2·30	−0·17	−2·03, 2·49	−0·34	−2·27, 2·37
WHZ < −2												
Yes	1	1·0	4	3·1	6	5·5	2	2·0	2	1·7	4	2·9
No	102	99·0	125	96·9	103	94·5	99	98·0	119	98·3	135	97·1
Illness in previous 4 weeks*												
Yes	56	52·8	63	48·8	52	46·8	32	31·7	54	45·6	64	45·4
No	50	47·2	66	51·2	61	53·2	69	68·3	67	55·4	77	54·6
Enrolled in SFP												
Yes	0	0	1	0·8	0	0	0	0	2	1·6	2	1·4
No	99	100	128	99·2	111	100	96	100	119	98·3	139	98·6
Fe supplemented in last month												
Yes	17	16·0	4	3·1	3	2·7	11	11·0	3	2·5	4	2·1
No	89	84·0	123	95·3	107	96·4	89	89·0	118	97·5	138	97·9
Sleep under bed net												
Yes	19	18·3	31	24·0	20	18·0	8	8·4	11	9·1	3	2·1
No	85	81·7	98	76·0	93	82·0	87	91·6	110	90·9	138	97·9

WHZ, weight-for-height *Z*-score; SFP, supplementary feeding programme.
*Illness for which treatment was sought at a medical clinic.

Results

Baseline characteristics

Children in Nduta and Mtendeli camps had similar age and sex distributions (Table 1). Acute malnutrition was not a substantial health problem in either camp, and few children were classified as acutely malnourished at the baseline survey or the follow-up surveys. Although there was a slight increase in acute malnutrition from baseline to 12 months in Nduta, the difference was not statistically significant ($P = 0{\cdot}07$, Fischer's exact test). At baseline, the mothers of more children in Nduta reported an illness during the previous 4 weeks than in Mtendeli ($\chi^2 = 9{\cdot}2$, $P = 0{\cdot}002$); however, this difference largely disappeared in the 6- and 12-month surveys. There were no significant changes in the prevalence of self-reported illness within each camp (Nduta: $\chi^2 = 0{\cdot}8$, $P = 0{\cdot}7$; Mtendeli: $\chi^2 = 5{\cdot}3$, $P = 0{\cdot}07$). Enrolment in supplementary feeding programmes was minimal. Similarly, Fe supplementation in the month prior to the survey was uncommon. Nevertheless, more children had taken such supplements at baseline than at the 6- and 12-month surveys. In all surveys, a larger proportion of children in Nduta had slept under a bed net than in Mtendeli ($\chi^2 = 30{\cdot}7$, $P < 0{\cdot}0001$).

In the baseline survey, mothers in Nduta were somewhat younger than mothers in Mtendeli; however, this difference diminished in the subsequent surveys ($P =$ 0·006, 0·4 and 0·8 at baseline, 6 and 12 months, respectively; Table 2). A shift in the duration of camp residency from the baseline to the 12-month survey is apparent in both Nduta and Mtendeli, potentially due to a cohort effect because inclusion in follow-up surveys was restricted to households present at the time of the baseline survey. In the baseline survey, illness was reported by a greater proportion of mothers in Nduta than in Mtendeli; however, this difference also disappeared in the 12-month survey. As with children, enrolment in supplementary feeding programmes was uncommon. Fe supplementation decreased in Nduta between baseline and 12 months, but did not show such a trend in Mtendeli. Bed net usage was higher in Nduta than Mtendeli in all surveys ($\chi^2 = 23{\cdot}5$, $P < 0{\cdot}0001$). Although slight differences existed between mothers in Nduta and Mtendeli in number of pregnancies, time since last delivery and current pregnancy status, none of these differences was statistically significant.

Intervention results

By the time of the 12-month survey, all mothers in Nduta camp had heard of the stainless steel cooking pot (Table 3). Knowledge of the cooking pots also increased in Mtendeli camp even though no mothers in Mtendeli owned a stainless steel cooking pot. In the forty-six households in Nduta camp which retained their pot at 12 months, almost half of the pots were used every day. At 12 months, beans were the food most often prepared in the stainless steel cooking pot; the pots were used to cook corn–soya blend (CSB), a fortified blended flour, and *ugali* (corn porridge) less frequently.

In either camp, Hb concentration in children aged 6–59 months showed little change (Table 4). Although children in Nduta had a higher prevalence of anaemia and lower mean Hb than children in Mtendeli at baseline, these differences had virtually disappeared at the 12-month survey. sTfR concentration decreased significantly in both camps between the baseline and 12-month surveys, but at 12 months was significantly higher in Nduta camp than in Mtendeli camp. The prevalence of Fe deficiency was higher in Nduta children than in Mtendeli children at baseline.

In all, forty-five (17·1 %) of 264 mothers in Nduta camp and forty (14·7 %) of 271 mothers in Mtendeli camp were excluded from biochemical analysis because they reported being pregnant at the time of data collection. In Nduta, the mean Hb concentration was higher at baseline but showed a significant decrease during the intervention period (Table 4). In Mtendeli it remained unchanged. There was no statistically significant difference in mean Hb concentration between camps in the 12-month survey. Non-pregnant mothers also showed no statistically significant change in the prevalence of anaemia between baseline and the 12-month survey in either camp. In Nduta, there was no statistically significant change in either the median sTfR concentration or the prevalence of Fe deficiency. In Mtendeli camp by contrast, there was a statistically significant decrease in median sTfR concentration between the baseline and 12-month surveys and the proportion of non-pregnant women classified as Fe-deficient. Fe-deficiency anaemia was rare among non-pregnant mothers in all surveys.

Discussion

The present study found no evidence that the distribution of stainless steel cooking pots increased Hb concentration or improved Fe status in children or their mothers in refugee camps in western Tanzania. This was in spite of detailed preliminary laboratory trials (reported separately) indicating that use of stainless steal cooking pots significantly increased the Fe content of meals prepared using them.

Our findings contrast with the results of two randomized controlled trials of cooking food for children of pre-school age in cast iron cooking pots. In Ethiopia, children who ate food cooked in cast iron pots for 1 year showed greater improvement in haematological indicators than children who ate food cooked in aluminium or clay pots[8]. For children eating food cooked in iron pots, the Hb concentration rose by 1·7 g/dl (1·3 g/dl more than for children eating from non-Fe pots). In addition,

Table 2 Characteristics of mothers at baseline and follow-up surveys, Nduta and Mtendeli refugee camps, western Tanzania, December 2001, August 2002 and January 2003

	Nduta						Mtendeli					
	Baseline (*n* 105)		6-month (*n* 86)		12-month (*n* 75)		Baseline (*n* 101)		6-month (*n* 82)		12-month (*n* 88)	
Characteristic	Mean or *n*	Range or %	Mean or *n*	Range or %	Mean or *n*	Range or %	Mean or *n*	Range or %	Mean or *n*	Range or %	Mean or *n*	Range or %
Mean age (years)	28·1	18–58	30·1	18–50	29·8	18–48	30·7	18–43	29·1	18–43	29·5	18–45
Mean duration of camp residence (years)	3·3	0·1–5·2	4·4	1·3–6·2	4·1	0·8–6·8	3·8	0·1–5·3	4·7	1·5–6·8	5·2	1·7–7·1
Illness in previous 4 weeks*												
Yes	48	46·2	34	39·5	30	40·0	36	35·6	26	31·7	36	40·9
No	56	53·8	52	60·5	45	60·0	64	63·4	55	67·1	52	59·1
Enrolled in SFP												
Yes	7	6·7	3	3·5	3	4·0	5	5·1	9	11·0	6	6·8
No	97	93·3	83	96·5	72	96·0	93	94·9	73	89·0	82	93·2
Fe supplemented in last month												
Yes	18	17·1	8	9·3	6	8·0	13	12·9	14	17·1	11	12·5
No	86	81·9	78	90·7	69	92·0	88	87·1	68	82·9	77	87·5
Sleep under bed net												
Yes	25	23·8	25	29·1	19	25·3	10	9·9	11	13·4	6	6·8
No	80	76·2	60	69·8	56	74·7	91	90·1	71	86·6	82	93·2
Number of pregnancies												
1–2	36	34·3	25	29·1	23	30·7	20	29·8	21	25·6	19	21·6
3–4	32	30·5	23	26·7	19	25·3	31	30·7	20	24·4	28	31·8
5+	37	35·2	38	44·2	33	44·0	50	50·0	41	50·0	41	46·6
Months since last delivery†	17·0	12·0	19·8	12·7	17·8	14·1	17·6	12·1	16·5	12·9	15·2	12·3
Pregnant now												
Yes	22	21·4	14	16·3	9	12·0	14	13·9	13	15·8	13	14·8
No	80	77·7	72	83·7	65	86·7	86	85·1	68	82·9	73	82·9

SFP, supplementary feeding programme.
*Illness for which treatment was sought at a medical clinic.
†Mean and standard deviation.

Table 3 Number and percentage of mothers who owned and used stainless steel pots, baseline and follow-up surveys, Nduta and Mtendeli refugee camps, western Tanzania, December 2001, August 2002 and January 2003

	Nduta						Mtendeli					
	Baseline		6-month		12-month		Baseline		6-month		12-month	
Characteristic	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Heard of stainless steel pot												
Yes	38	36·2	85	98·9	75	100	5	4·9	10	12·2	21	23·9
No	66	62·8	1	1·2	0	0	95	94·1	72	87·8	63	71·6
Has stainless steel pot												
Yes	0	0	70	81·4	46	61·3	0	0	0	0	0	0
No	105	100	16	18·6	29	38·7	101	100	82	100	87	98·9
Frequency of pot use*												
Every day	–		31	44·9	20	43·5	–		–		–	
Every week	–		13	18·8	11	23·9	–		–		–	
Less than once per week	–		10	14·5	6	13·0	–		–		–	
Don't use	–		15	21·7	9	19·6	–		–		–	
Uses stainless steel pot for beans†												
Yes	–		41	75·9	29	78·4	–		–		–	
No	–		13	24·1	8	21·6	–		–		–	
Uses stainless steel pot for CSB†												
Yes	–		10	18·5	8	21·6	–		–		–	
No	–		44	81·5	29	78·4	–		–		–	
Uses stainless steel pot for *ugali*†												
Yes	–		5	9·3	2	5·4	–		–		–	
No	–		49	90·7	35	94·6	–		–		–	

CSB, corn–soya blend.
*Denominator includes only households having a pot.
†Denominator includes only those having and using a stainless steel cooking pot.

the prevalence of anaemia declined more and body Fe stores were greater among children eating from iron pots than among children eating from aluminium pots. Similarly, in Brazilian preterm infants with low birth weight who were fed food cooked in cast iron pots between ages 4 and 12 months, the prevalence of anaemia declined more than in similar infants fed food cooked in aluminium pots[9]. In addition, in that study the iron pot group showed a statistically significantly greater improvement in Fe status than the aluminium pot group as measured by erythrocyte protoporphyrin and serum ferritin.

On the other hand, two other studies showed no or inconsistent effects of eating food cooked in Fe-containing cooking pots. In a randomized trial in Malawi, children less than 12 years of age eating food from cast iron pots had no greater increase in Hb concentration than those eating from aluminium pots; however, they did show a lower level of Fe deficiency[19]. In contrast, persons 12 years of age and older eating from iron pots showed a greater increase in Hb concentration, but no change in the level of Fe deficiency. In a study in Vietnam, households with at least one anaemic person in one of three target groups (infants aged 6–24 months, adolescent girls aged 11–14 years, reproductive-age women aged 15–43 years) were given either a cast iron pot or a blue steel pot[20]. A control group was monitored but did not receive any of the intervention pots. After 4 months, no difference in Hb concentration or the level of Fe deficiency was noted between the control group, the cast iron pot group or the blue steel pot group.

Why did the children and mothers in Tanzania not respond haematologically to eating food from Fe-containing cooking pots? First, the prevalence and severity of anaemia in the two study camps in Tanzania was lower than expected at baseline and this may have reduced the likelihood of seeing an impact. Studies have demonstrated that gastrointestinal Fe absorption is tightly regulated to maintain Fe homeostasis; as a result, absorption is markedly enhanced in the presence of Fe deficiency[21]. Moreover, the study in Ethiopia clearly demonstrated that children with lower baseline Hb concentrations had a larger increase in Hb as a result of eating food cooked in cast iron pots than those with higher baseline concentrations. The participants in the two studies who showed a positive impact from the use of cast iron pots were substantially more anaemic than the residents of the Tanzanian camps. Only anaemic children were recruited into the Ethiopia trial, and the prevalence of anaemia in the Malawi study was >75 % in children and >55 % in adults. In contrast, in Vietnam where the use of neither cast iron nor blue steel pots had any effect, the incidence of anaemia among adolescents and women of childbearing age was low.

Although Nduta and Mtendeli camps were initially chosen because of the severity of anaemia reported in previous assessments, the prevalence of anaemia had declined substantially before distribution of the stainless steel cooking pots. This may have occurred at least partly because of the introduction of fortified CSB into the general food ration. Furthermore, as the camps stabilized, residents had increased access to health care, including

Table 4 Iron and Hb status of children and their mothers, Nduta and Mtendeli refugee camps, western Tanzania, December 2001, August 2002 and January 2003

Characteristic	Nduta (intervention)							Mtendeli (control)							*P* intervention *v.* control	
	Baseline		6-month		12-month			Baseline		6-month		12-month				
	Mean or median	SD or IQR	Mean or median	SD or IQR	Mean or median	SD or IQR	*P*	Mean or median	SD or IQR	Mean or median	SD or IQR	Mean or median	SD or IQR	*P*	Baseline	12-month
Children (6–59 months)																
n	*104*		*128*		*110*			*100*		*121*		*140*				
Hb (g/dl)*	11·5	1·6	12·1	1·3	11·3	1·6	0·602	11·7	1·4	12·1	1·2	11·4	1·6	0·170	0·340	0·850
n	*100*		*126*		*96*			*79*		*119*		*130*				
sTfR (μg/ml)†	7·5	6·0, 9·9	7·8	6·2, 9·8	6·8	5·7, 8·6	0·053	8·4	6·5, 10·8	8·2	6·8, 10·6	5·9	4·3, 8·0	0·006	0·138	<0·001
Non-pregnant mothers																
n	*80*		*71*		*64*			*85*		*68*		*72*				
Hb (g/dl)*	14·5	1·4	14·8	1·3	13·9	1·5	0·034	13·7	1·5	14·7	1·0	14·2	1·5	0·059	<0·001	0·485
n	*74*		*67*		*50*			*81*		*64*		*55*				
sTfR (μg/ml)†	5·9	4·8, 5·9	7·0	5·7, 8·8	5·8	5·2, 6·9	0·817	5·7	3·6, 7·3	6·6	5·1, 8·3	4·7	3·6, 6·3	0·027	0·355	0·003

IQR, interquartile range (25th, 75th percentiles); sTfR, serum transferrin receptor.
*Mean and SD.
†Median and IQR.

prompt and effective treatment for malaria and other parasitic infections, as well as improved environmental programmes such as residual spraying, which are likely to have decreased the intensity of malaria transmission.

Another possible reason for the lack of response in Tanzania is the lower dose of Fe received by participants using stainless steel pots. The studies in Ethiopia, Brazil, Malawi and Vietnam distributed cast iron pots, which add more Fe to foods than do other types of cooking pot[8,11,19,22]. The increase in food Fe from cast iron pots has been 1·6- to 14·3-fold compared with food cooked in aluminium or glass pots, depending on the specific food[8,11,19,22], whereas the increase in Fe from stainless steel pots is up to 1·5-fold[22]. Untreated blue steel pots add even more Fe than cast iron pots[11,23]. However, as we discovered during the acceptability trial, neither cast iron nor blue steel pots were acceptable to the study population. In addition, the smaller amount of Fe leached from the stainless steel pots used in Tanzania may have been less absorbable because of the type of the food cooked in them. The staple cereal in the camps was maize, which contains high levels of phytates that inhibit Fe absorption[24]. Although the diets are not well described in other intervention trials, the absorbability of Fe into foods commonly cooked by participants in the trials in Ethiopia, Brazil and Vietnam may have been higher. Moreover, the mothers of Brazilian children were told to give their children 50 mg of vitamin C daily, thus enhancing the absorption of Fe added by the use of cast iron pots.

A third possible reason for the lack of response in Tanzania may be due to compliance with use of the Fe-alloy pot. In Ethiopia, 68–70 % of families used the cast iron pot on a daily basis after 20 weeks, and almost all families used it at least three times per week. Although compliance was not quantitatively reported in the Brazilian study, the authors stated that pot use was 'daily routine'. In contrast, the two studies demonstrating a smaller effect had much poorer compliance. In Malawi, only 23 % of children less than 12 years old and 13 % of older study participants lived in households where the cooking pot was used daily.

In the Malawi study, the differences in haematological outcomes between the cast iron pot group and the aluminium pot group are statistically significant only for the minority of persons in those households in which the cast iron pot was used at least seven times per week. In Vietnam, only one-third of households with an Fe-containing pot used it at least seven times per week during the follow-up period. In addition, most of the food eaten by children less than 18 months of age in the Vietnam study was not cooked in the family pot, but in a separate, smaller pot used exclusively for cooking infants' food. In our study in Tanzania, many stainless steel pots were sold, and retained pots were less commonly used for cooking food (K Tripp, N MacKeith, BA Woodruff, L Talley, L Mselle, Z Mirghani, F Abdalla, R Bhatia and

AJ Seal, unpublished results). Overall, only about a quarter of households used the pot daily. Moreover, the stainless steel pots in Tanzania were used primarily to cook beans and not other foods. As a result, not all of the food consumed by residents in Nduta camp would have contained additional Fe.

These conflicting results raise the question of whether distributing Fe or Fe-alloy pots or recommending their use has the potential to be an effective and feasible way to treat or prevent Fe deficiency in a population. Such efforts may better be reserved for populations in which diet diversification or increasing access to food fortification is unrealistic and where high levels of anaemia result from Fe deficiency. In such programmes, stainless steel pots, although avoiding the problem of rusting, may not add enough Fe to food over the long term to have an effect. If other types of cooking pot are considered, good laboratory measurement of Fe levels should be carried out using the specific foods eaten by the population. Specific educational campaigns may be necessary to maximize the use of new types of cooking pot.

Promoting the use of Fe or Fe-alloy pots to address the widespread and severe problem of anaemia may have the potential to be cost-effective when compared with other interventions. However, the currently available data suggest that designing a suitable utensil that delivers an effective but safe dose of Fe to the diet, while also being acceptable to the user, may not be possible.

Acknowledgements

The study was funded by the WFP and the UNHCR via a grant from the UNFIP. There are no conflicts of interest. B.A.W., L.T. and A.S. designed the study and supervised the field work. L.S.M. and K.T. assisted in the design of the study and implementation of the field work. Z.M., F.A. and R.B. facilitated the study and provided technical supervision. The manuscript was prepared by L.T. with additional inputs from B.A.W. and A.S. All authors read and provided comments on the manuscript drafts.

References

1. World Health Organization/UNICEF/United Nations University (1998) *IDA: Prevention, Assessment and Control. Report of a Joint WHO/UNICEF/UNU Consultation*. Geneva: WHO.
2. Glassman A (2002) Anemia. Diagnosis and clinical considerations. In *Clinical Hematology and Fundamentals of Hemostasis*, pp. 74–83 [DM Harmening, editor]. Philadelphia, PA: F.A. Davis Company.
3. Hassan K, Sullivan KM, Yip R & Woodruff BA (1997) Factors associated with anemia in refugee children. *J Nutr* **127**, 2194–2198.
4. Kemmer TM, Bovill ME, Kongsonboon W, Hansch SJ, Geisler KL, Cheney C, Shell-Duncan BK & Drewnowski A (2003) Iron deficiency is unacceptably high in refugee children from Burma. *J Nutr* **133**, 4143–4149.
5. Seal A, Creeke PI, Mirghani Z, Abdalla F, McBurney RP, Pratt LS, Brookes D, Ruth LJ & Marchand E (2005) Iron and vitamin A deficiency in long-term African refugees. *J Nutr* **135**, 808–813.
6. Tomkins A & Henry CJ (1992) Comparison of nutrient composition of refugee rations and pet foods. *Lancet* **340**, 367–368.
7. Weise Prinzo Z & De Benoist B (2002) Meeting the challenges of micronutrient deficiencies in emergency-affected populations. *Proc Nutr Soc* **61**, 251–257.
8. Adish AA, Esrey SA, Gyorkos TW, Jean-Baptiste J & Rojhani A (1999) Effect of consumption of food cooked in iron pots on iron status and growth of young children: a randomised trial. *Lancet* **353**, 712–716.
9. Borigato EV & Martinez FE (1998) Iron nutritional status is improved in Brazilian preterm infants fed food cooked in iron pots. *J Nutr* **128**, 855–859.
10. Tomashek K, Woodruff B, Gotway C, Bloland P & Mbaruku G (2001) Randomized intervention study comparing several regimens for the treatment of moderate anemia among refugee children in Kigoma Region, Tanzania. *Am J Trop Med Hyg* **64**, 164–171.
11. Seal A (2000) *Iron Levels in Refugee Food Rations: The Effect of Different Designs of Cooking Pots. Report On Laboratory Evaluation Study Undertaken by the Institute of Food Research, Norwich, UK*. London: Institute of Child Health.
12. Mace P (1974) *Sample Size Determination*. Huntington, NY: Kreiger.
13. Fleiss J (1981) *Statistical Methods for Rates and Proportions*, 2nd ed. New York: Wiley.
14. United Nations (1986) *How to Weigh and Measure Children. Assessing the Nutritional Status of Young Children in Household Surveys*. New York: UN.
15. Cohen AR & Seidl-Friedman J (1988) HemoCue system for hemoglobin measurement. Evaluation in anemic and nonanemic children. *Am J Clin Pathol* **90**, 302–305.
16. Suominen P, Punnonen K, Rajamaki A & Irjala K (1997) Evaluation of new immunoenzymometric assay for measuring soluble transferrin receptor to detect iron deficiency in anemic patients. *Clin Chem* **43**, 1641–1646.
17. World Health Organization (2000) *Management of Nutrition in Major Emergencies*, p. 18. Geneva: WHO.
18. World Health Organization (1995) *Physical Status: The Use and Interpretation of Anthropometry. Report of a WHO Expert Committee*. Geneva: WHO.
19. Geerlings PP, Brabin B, Mkumba A, Broadhead B & Cuevas LE (2002) Acceptability of the use of iron cooking pots to reduce anaemia in developing countries. *Public Health Nutr* **5**, 619–624.
20. Berti P, Zlotkin S, FitzGerald S, Sharieff W, Le TT, Schauer C, Jenkins A & Hoang MA (2004) The efficacy of iron and steel pots in reducing prevalence in Vietnam: report of midline findings (abstract). International Nutritional Anemia Consultative Group Symposium, Lima, Peru. http://www.healthbridge.ca/assets/images/pdf/Food/INACG2004_final.pdf (accessed February 2009).
21. Schneider BD & Leibold EA (2000) Regulation of mammalian iron homeostasis. *Curr Opin Clin Nutr Metab Care* **3**, 267–274.
22. Liu DY, Chen ZG, Lei HQ, Lu MQ, Li R & Li LX (1990) Investigation of the amount of dissolved iron in food cooked in Chinese iron pots and estimation of daily iron intake. *Biomed Environ Sci* **3**, 276–280.
23. Path Canada (2005) *Efficacy of Iron Pots in Vietnam: Detailed Report on the Analysis of Blood and Compliance Data*. Ottawa: Path Canada.
24. Bothwell T (1995) Overview and mechanisms of iron regulation. *Nutr Rev* **53**, 237–245.