

Food prepared in iron cooking pots as an intervention for reducing iron deficiency anaemia in developing countries: a systematic review

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Abstract

Objective To complete a systematic review of the effect of preparing food cooked in iron pots on haemoglobin concentrations and to assess compliance with pot use.

Design and Search strategy We searched The Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effectiveness, The Cochrane Controlled trials Register, The Cochrane Methodology Register, Health Technology Assessment Database and NHS Economic Evaluation Database (Cochrane Library, Issue 3, 2002). Medline (1966 to May 2002) and EMBASE (1988 to May 2002). Reference lists of published trials were examined for other potentially relevant trials and authors of selected trials were contacted to obtain information about ongoing or unpublished trials. Selection criteria included randomized trials which compared the effect of food cooked in cast iron pots with food cooked in noncast iron pots on participants of a minimum age of 4 months. One reviewer applied inclusion criteria to potentially relevant trials. Two reviewers assessed trial quality and extracted data.

Results Three trials were eligible for inclusion in the review. There is some evidence from these studies that eating food prepared in iron pots increases the haemoglobin concentration of anaemic/iron deficient individuals. This effect seems to be modified by compliance, users age, and the presence of malaria and hookworm. Compliance with pot use varies considerably between countries depending on several factors, including: size of the cooking pot, targeted user group, whether the pot is used as an extra or replacement pot, and familiarity with cast iron pots.

Conclusion The introduction of iron pots or improving their use in communities in developing countries for the preparation of food maybe a promising innovative intervention for reducing iron deficiency and iron deficiency anaemia. Further research is required to monitor the use and effectiveness of this intervention.

Introduction

An estimated 3.6 billion people are iron deficient and of these two billion are anaemic [World Health Organisation (WHO), 1997]. The most vulnerable groups are women of reproductive age and children under 5 years in developing countries. Generally it is considered that the most important factors which cause iron deficiency are nutritional in origin. The composition of the diets may be low in iron content and traditional diets in developing countries often have low iron bioavailability (Jamison, 1993). This is because iron in these diets is mostly in the nonhaem form which is less bioavailable than the haem iron (Harvey *et al.*, 2000). The consequences of iron deficiency have recently been reviewed and are of major public health significance in relation to child morbidity and development, maternal mortality and adult work efficiency (Beard & Stoltzfus, 2001). The two main interventions, aimed at reducing iron deficiency, supplementation and iron fortification, have had limited success in reducing global iron deficiency because of problems with compliance, availability, costs and logistics (Levi, 1986; WHO, 1990; Galloway & McGuire, 1994; Nestel & Alnwick, 1996). In view of this there is interest in evaluating the potential for increasing iron intake by using iron pots for cooking. Early studies have shown their use can increase the iron content of food and that this increased iron content has a good bioavailability (Drover & Maddocks, 1975; Brittin & Nossaman, 1986; Martinez & Vannucchi, 1986; Liu *et al.*, 1990).

The main objective of this analysis was to complete a systematic review of randomized trials examining the effect of food prepared in iron pots on the haemoglobin concentration of users. A second objective was to assess compliance with the use of this intervention.

Methods

Searching

Trials were identified by searching MEDLINE (1966 to May 2002) and EMBASE (1988 to May 2002) using the search strategy developed by the

Cochrane Collaboration adapted for use in PubMed (Dickersin *et al.*, 1994). The optimal search strategy was combined with the key words 'pot*' or 'iron uten*' or 'iron def*'. In MEDLINE related articles to selected studies were also examined. The Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effectiveness, The Cochrane Controlled trials Register, The Cochrane Methodology Register, Health Technology Assessment Database and National Health Service (NHS) Economic Evaluation Database (Cochrane Library, Issue 3, 2002) were searched using the key word 'iron'. The number of hits was 6582. Reference lists of published trials were examined for other potential relevant trials. Authors of selected trials were contacted with the request for additional information and information about ongoing or unpublished studies. The full search strategy is available from the authors. The review was not completed as a Cochrane review.

Selection

Randomized control trials in which participants ate food prepared in cast iron pots compared with participants whose food was prepared in noncast iron pots were eligible for inclusion. The minimum age for the participants was set at 4 months to ensure that only individuals who consumed food in adequate amounts were included.

Outcome measures were the change in haemoglobin concentration and the proportion of people using iron pots daily.

Validity assessment

The Delphi list was used as a means for quality assessment (Table 1) (Verhagen *et al.*, 1998). Studies were further assessed for their control, or preferable exclusion, of important confounding factors for anaemia: malaria, hookworm, blood transfusions or iron supplements (Table 2).

The study conducted by Adish *et al.* (1999) was adequately randomized but not enough data was available to determine if the allocation was concealed. Also they did not report and therefore may

Table 1 Delphi assessment for randomized controlled trials

Question	Adish <i>et al.</i> (1999)	Borigato & Martinez (1998)	Prinsen Geerligs <i>et al.</i> (2002)	Prinsen Geerligs <i>et al.</i> (2003)
Method of randomization performed	Yes	Yes	Yes	Yes
Treatment allocation concealed?	Don't know	Yes	Don't know	Don't know
Groups similar at baseline regarding the most important prognostic indicators?	Yes	Yes	Yes	No
Eligibility criteria specified?	Yes	Yes	Yes	Yes
Outcome assessor blinded?	Yes	Yes	No	No
Care provider blinded?	Don't know	No	No	No
Patient blinded?	No	No	No	No
Point estimates and measures of variability presented for the primary outcome measures	Yes	Yes	Yes	Yes
Analysis include an intention-to-treat analysis?	Yes	Yes	Yes	Yes

Table 2 Study description of confounding factors

Study	Malaria endemicity	Hookworm exposure	Blood transfusion given	Use of iron supplements
Adish <i>et al.</i> (1999)	Very low	Low	Not monitored?	Not monitored?
Borigato & Martinez (1998)	None	Faeces examinations and infected children were treated	Exclusion factor	Iron supplements were given to the participating children
Prinsen Geerligs <i>et al.</i> (2003)	Age group 1–11 years, parasite rate 45.3%	Unknown	Exclusion factor	Exclusion factor
	Age group \geq 12 years, parasite rate 17.5%	Unknown	Exclusion factor	Exclusion factor

not have monitored whether participants received a blood transfusion or used iron supplements during the study period. Monitoring this would have been especially prudent as the mothers of the participating children received iron supplements which they may have shared with their children. When requested the authors did not supply additional information on this aspect.

The study by Borigato & Martinez (1998) was adequately randomized and blinded but no information was obtained about compliance taking iron or vitamin supplements which were given to all participating children. Also faecal examinations were routinely performed on the participating children and those who were infected received anti-helminthic treatment. However no data was reported to show that there was no significant difference between the two intervention groups

with regard to the number of anti-helminthic treatments received.

Despite the randomization in the trial by Prinsen Geerligs *et al.* (2003), there was a difference with regard to an important indicator at baseline (See Table 1). The zinc protoporphyrin value of participants in the age group \geq 12 years using iron pots was significantly higher than that of the aluminium pot users. However in the sub-groups of users, between which at the end of the study a significant difference in haemoglobin change was found, there was no significant difference at baseline in zinc protoporphyrin values. It was not possible to blind the outcome assessor in this trial as the investigator was also the care provider. There was a considerable loss to follow up (21.3% in aluminium pot group and 35.4% in iron pot group) which reduced the power of the study. The

Table 3 Details of studies included

Study	Country	Year of study	Duration of study (months)	Participants	Inclusion criteria	Exclusion criteria	Intervention
Adish <i>et al.</i> (1999)	Ethiopia	1993	12	407 children aged 2–5 years	Parental consent; PCV 20–34%; residence in Quiha	Severe illness; chronic disorders; physical disability	Consumption of food prepared in iron or aluminium pot
Borigato & Martinez (1998)	Brazil	1998	8	55 children preterm born enrolled at aged 4 months 113 households	–	Illness requiring hospitalization; blood transfusion	Consumption of food prepared in iron or aluminium pot
Prinsen Geerlings <i>et al.</i> (2002)	Malawi	2000	5	All ages	Consent; willing to participate in RCT; residence in Tsamba or Meja village	–	Use of iron or aluminium pot
Prinsen Geerlings <i>et al.</i> (2003)	Malawi	2000	5	322 participants age \geq 1 year	Parental consent; age \geq 1 year; haemoglobin >7 g dL ⁻¹ ; residence in Tsamba or Meja village	Haemoglobin <7 g dL ⁻¹ ; pregnant women haemoglobin <8 g dL ⁻¹ ; use of iron tablets; blood transfusion	Consumption of food prepared in iron or aluminium pot

loss to follow up was mainly because of the low acceptability of cast iron pots which resulted in a decline in participation as the study progressed. In all the studies blinding of the participants was not possible because of the physical characteristics of the cast iron pots. After considering these individual limitations the overall quality of the studies is regarded as acceptable. However these short comings should be borne in mind when interpreting any results.

Data extraction

One of the authors (PG) applied inclusion criteria to potentially relevant trials and together with another member of the research team (BB) assessed trial quality and completed data extraction forms. Data extracted included: country where the study was conducted; study duration; number and age of participants; inclusion and exclusion criteria; and haemoglobin at enrolment and completion. Data on possible confounding factors were also extracted: prevalence of hookworm, malaria, blood transfusions and use of iron tablets. To determine compliance, the proportion of pot owners who used iron pots daily over a period of time was recorded.

Study characteristics

Three trials were eligible for inclusion. Results from these trials were published in four articles (Table 3) (Borigato & Martinez, 1998; Adish *et al.*, 1999; Prinsen Geerlings *et al.*, 2002; Prinsen Geerlings *et al.*, 2003). Only one trial had compliance with iron pot use as the primary outcome and factors influencing this were studied. (Prinsen Geerlings *et al.*, 2002). One trial only provided data on compliance with pot use over time but did not have it as the primary outcome. No information was given on factors negatively or positively influencing this compliance (Adish *et al.*, 1999). There was considerable clinical heterogeneity in the three studies, particularly with regard to the participant groups and presence of confounding factors, therefore data was not pooled.

Results

Trial flow

Three potentially relevant randomized controlled trials were identified and screened for retrieval. All three had usable information by outcome and

Table 4 Study results

Study	Mean haemoglobin g dL ⁻¹	Significance of Hb change (<i>P</i> -value)	Daily compliance	Iron pot volume (L)	Malaria endemicity	Hookworm exposure
Adish <i>et al.</i> (1999)	Iron pot group (after 12 months) Hb 1.3 g dL ⁻¹ higher	<0.001	Initial 10 weeks: iron pot use 80–85%. Subsequent 10 weeks, 68–70%	2	Very low	Low exposure
Borigato & Martinez (1998)	Iron pot group (after 8 months) Hb 1.3 g dL ⁻¹ higher	0.02	2 of 22 people stopped using iron pot after 4–5 months	2	None	Unknown
Prinsen Geerligs <i>et al.</i> (2002)	–	–	Iron pot use 34.7% after 3 weeks, and 31.1% after 20 weeks	10	–	–
Prinsen Geerligs <i>et al.</i> (2003)	Age 1–11 years. Iron pot group (after 5 months) Hb 0.02 g dL ⁻¹ higher	NS	–	10	Age group 1–11 years; parasite rate 45.3%	Unknown
	Age ≥ 12 years. Iron pot group (after 5 months) Hb 0.3 g dL ⁻¹ higher	NS			Age group ≥ 12 years; parasite rate 17.5%	

NS: not significant.

were included in the meta-analysis. No additional trials were identified which were excluded.

Study characteristics

Haemoglobin concentration

Two of the three studies found a difference in haemoglobin at the end of the trials, with children eating food prepared in iron pots having a significantly higher haemoglobin (Borigato & Martinez, 1998; Adish *et al.*, 1999). The study of Prinsen Geerligs *et al.* (2003) did not find a significant difference between the two pot groups with regard to mean end haemoglobin (Table 4), but a significant difference between the two groups was observed with regard to the mean haemoglobin change in the participants older than 11 years. Participants eating food prepared in an iron pot had a mean haemoglobin change that was 7.5 g L⁻¹ greater compared with the aluminium pot group users (*P* < 0.05).

Compliance

Data was available for two of the three trials. There was a marked difference in compliance after 5 months: 70% vs. 31.1% (Adish *et al.*, 1999;

Prinsen Geerligs *et al.*, 2002) (Table 4). Adish *et al.* mentioned that 98% of all families who had received an iron pot used it at least 3 days a week for the duration of the study (12 months).

The remaining study did not assess compliance but reported two of the 22 people who used iron pots stopped their use after 4–5 months (Borigato & Martinez, 1998).

Only Prinsen Geerligs *et al.* (2002), studied in detail the factors effecting the acceptability of the use of iron cooking pots for cooking. Factors reported to negatively affect the compliance with pot use were: some physical qualities of the cast iron pots, introduction of cast iron pots together with good quality aluminium pots, unfamiliarity with cast iron pots and local customs of pot use.

Discussion

The different mean end haemoglobin found in the studies may relate to several factors. The study by Prinsen Geerligs *et al.* (2003) which found no difference in the mean end haemoglobin, was conducted in an area with a high malaria prevalence. It was not possible to control this confounding factor and it undoubtedly influenced the

haemoglobin of all the participants. One would expect the effect of this confounding factor to be stronger amongst the children (<12 years) with their lower level of acquired malaria immunity and higher parasitaemia. Older participants (>11 years) who have a higher level of acquired malaria immunity and lower parasitaemia, would not have been affected as severely. This could have resulted in the absence of any measurable effect on haemoglobin amongst children. In older participants a significant increase in mean haemoglobin could have been prevented by this mechanism, but because of the less severe effect a significant difference in haemoglobin change could still be observed between the two intervention groups.

The shorter duration of the study could have also influenced the outcome particularly as compliance with daily pot use was considerably lower than in the study by Adish *et al.* The lower compliance itself could also have modified the effect on haemoglobin.

The considerable loss to follow up could be a factor of importance because of reduction of the power of the study and hence the capability to detect a possible difference. However the study in Brazil by Borigato & Martinez, where a significant difference was detected, also had a small number of participants.

The studies by Adish *et al.* and Borigato & Martinez who reported a significant difference in mean end haemoglobin were conducted in areas with very low endemicity and no malaria respectively. Both studies did not exclude the presence of confounding factors to the desired degree. In the study of Adish *et al.*, iron supplements or blood transfusions may have been given as no information on this was available. In the study conducted by Borigato & Martinez the participants used iron supplementation as well as vitamin C which is a promoting ligand for iron absorption. A difference in compliance with taking either of these supplements between the different pot groups, could have affected the haematological response independently of which pot was used. The routine examination of faeces of the children and treatment of those who were infected could also have lead to a difference in the number of anti-helminthic therapies received by each group.

Any difference in received anti-helminthic treatments between the different pot groups could have been reflected as a difference in haematological parameters.

There was very little information on compliance with the use of iron cooking pots. Higher compliance was observed in the Ethiopian (70%) than the Malawian study (31.1%). In the Ethiopian study the iron pot was relatively small (2 L volume) which may have been more acceptable, and the study was specifically designed to assess the effect of food cooked in iron pots on haemoglobin change in children alone. As a result only children's food was likely to be prepared in that pot, with a 'normal' pot being used for the remainder of the family. As the child's iron pot was used as an additional pot, acceptability may have been higher than in Malawi where a single larger family iron pot (10 L) was used.

The iron pots in the Ethiopian study were purchased locally therefore people were familiar with their use. In the Malawian study the iron pots used were imported from Zimbabwe as it was not possible to obtain them locally. This unfamiliarity of the Malawian participants with the iron pots could have contributed to their lower acceptability.

After considering the limitations of the studies, we conclude that there is some evidence that eating food prepared in iron pots increases the haemoglobin concentration of anaemic/iron deficient individuals. The compliance with this intervention varies between countries depending on multiple factors, of which some are: size of the cooking pot, targeted users group, whether the pot is used as an extra or replacement pot, and familiarity with cast iron pots.

Conclusion

All the studies in this review have some methodological problems which make it difficult to draw a convincing conclusion. However, the introduction of iron pots or improving their use in communities in developing countries for the preparation of food could be a promising innovative intervention for reducing iron deficiency and iron deficiency anaemia in communities where these

are highly prevalent. Their use in the UK or developed countries might be of benefit to certain groups of people at high risk of iron deficiency anaemia (e.g. ethnic minorities). More research is needed to determine the effects of consuming food prepared in iron pots on different age groups and to determine the effectiveness of this intervention in areas with different prevalence and severity of anaemia due to infectious co-morbidity from malaria and intestinal helminths.

An improved understanding of factors which influence positively and negatively the acceptability and compliance of iron pots in the different communities is required. The potential to cause iron overload must be considered with long-term use, and appropriate follow-up assessment in intervention areas should be established.

As the increase in iron in food prepared in iron pots varies depending on several factors, laboratory based studies are required to determine the amount of nonhaem iron and its chemical form when it is added to staple foods when cooked by traditional methods in iron pots. This would help determine which countries and/or cultures could benefit from this promising new intervention. The small number of research trials on this subject indicates the considerable need for further research in this area.

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References

- Adish, A.A., Esrey, S.A., Gyorkos, T.W., 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.
- Beard, J. & Stoltzfus, R. (2001) Iron-deficiency anaemia: re-examining the nature and magnitude of the public health problem. *J. Nutr.* **131**, 563S–703S.
- Brittin, H.C.V. & Nossaman, C.E. (1986) Iron content of food cooked in iron utensils. *J. Am. Diet. Association* **86**, 897–901.
- Liu, D.Y., Zuan-Guang, C., Huan-Qiang, L., Lu, M.Q., Li, R. & Li, L.X. (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.
- Drover, D.P. & Maddocks, I. (1975) Iron content of native foods. *Papua New Guinea Med. J.* **18**, 15–17.
- Martinez, G.E. & Vannucchi, H. (1986) Bioavailability of iron added to the diet by cooking food in an iron pot. *Nutr. Res.* **6**, 421–428.
- Harvey, P.W.J., Dexter, P.B. & Darnton Hill, I. (2000) The impact of consuming iron from non-food sources on iron status in developing countries. *Pub. Hlth. Nutr.* **3**, 375–383.
- Nestel, P. & Alnwick, D. (1996) Iron/multi micronutrient supplements for young children. Summary and conclusions of a consultation held at UNICEF, Copenhagen, Denmark, 19–20 August 1996.
- Jamison, D. (1993) *Disease Control Priorities in Developing Countries*. eds P. Moseley, A. Mesham, J. L. Bobadilla, Oxford Press for the World Bank, New York.
- Levi, H.M. (1986) A benefit-cost analysis of nutritional programs for anemia reduction. *Res. Obser.* **1**, 219–237.
- Borigato, E.V.M. & Martinez, F.E. (1998) Iron nutritional status is improved in Brazilian preterm infants fed food cooked in iron pots. *J. Nutr.* **128**, 855–857.
- Dickersin, K., Scherer, R. & Lefebvre, C. (1994) Identifying relevant studies for systematic reviews. *B.M.J.* **309**, 1286–1291.
- Galloway, R. & McGuire, J. (1994) Determinants of compliance with iron supplementation: supplies, side effects or psychology. *Soc. Sci. Med.* **39**, 381–390.
- Prinsen Geerligs, P.D., Brabin, B.J., Mkumbwa, A., Broadhead, R. & Cuevas, L.E. (2002) Acceptability of the use of iron cooking pots to reduce anaemia in developing countries. *Public Health Nutr.* **5**, 619–624.
- Prinsen Geerligs, P.D., Brabin, B.J., Mkumbwa, A., Broadhead, R. & Cuevas, L.E. (2003) The effect on haemoglobin of the use of iron cooking pots in rural Malawian households in an area with high malaria prevalence: a randomised trial. *Trop. Med. Int. Hlth.* **8**, 310–315.
- Verhagen, A.P., de Vet, H.C.W., de Bie, R.A., Kessels, A.G.H., Boers, M., Bouter, L.M. & Knipschild, P.G. (1998) The Delphi list: a criteria list for quality assessment of randomised clinical trials for conducting systematic reviews developed by Delphi consensus. *J. Clin. Epid.* **51**, 1235–1241.
- World Health Organisation. (1990) *Iron supplementation during pregnancy: why aren't women complying? A review of available information*. WHO/MCH/90.5, Geneva.
- World Health Organisation. (1997) *The World Health Report: Conquering Suffering Enriching Humanity*. WHO, Geneva.