

# Drinking Water as an Iron Carrier to Control Anemia in Preschool Children in a Day-Care Center

J. E. Dutra-de-Oliveira, MD, Jacob B. Ferreira, BS, Valeria P. Vasconcellos, BS, and J. Sérgio Marchini, MD

*Department of Clinical Medicine, University of São Paulo, Ribeirão Preto, SP, Brazil*

**Key words:** children, iron fortification, iron anemia, anemia control, water, drinking water

**Objective:** Several foods have been used as iron (Fe) carriers to fight widespread global Fe deficiency and anemia. This paper describes the longitudinal effect of Fe-fortified drinking water given to a group of Brazilian preschool children.

**Design:** The experimental design included 31 preschool children who attended a day-care institution. Hemoglobin and serum ferritin were the blood parameters used to check the Fe status. Fe<sup>++</sup> sulfate (20 mg Fe/L) was added daily to their drinking water container and measurements were obtained before the addition, 4 and 8 months later.

**Results:** The number of Fe-deficient children decreased drastically after they started drinking the Fe-enriched water. Mean hemoglobin values increased from 10.6 to 13.7 g/dL and serum ferritin from 13.7 to 25.6 µg/L. There were no problems related to the salt addition or to the children drinking the Fe-enriched water.

**Conclusion:** Fe-enriched drinking water was shown to be a practical alternative to supply Fe to children attending a day-care institution.

## INTRODUCTION

Iron (Fe) deficiency affects well over 1 billion people in the world, both in developing countries and in affluent societies, and is most common among young children and women of childbearing age. Poor Fe status has severe nutritional and health consequences, such as inadequate growth and mental development in children, increased maternal mortality and fatigue, and low productivity in adults [1,2]. Social and economic development is also affected. The World Health Organization estimates that > 2 billion people are at risk for and/or are affected by Fe deficiency or anemia. Most are in the Western Pacific and Southeast Asia, but they can also be found elsewhere [1]. Even in industrialized countries young children and adolescents are shown to have Fe deficiency, despite food supplementation and fortification programs that have been in place for some time [3]. Data from Southeast Asia and South Africa (1981-1985) show increased prevalence of anemia in these areas [4]. A recent meeting in Latin America indicated widespread anemia prevalence in the area [5]. Findings from our Medical School and other reports from Brazil, both in the developed and underde-

veloped parts of the country [6,7], confirm this high prevalence of Fe anemia in our children, reaching 40-80% of the studied groups. Recently, the Conference on Ending Hidden Hunger held in Canada called world attention to the serious micronutrient malnutrition problem and asked for prompt action on the subject [8]. The same was requested from the 1992 Rome International Conference on Nutrition [9].

In spite of extensive knowledge available on Fe anemia, and in spite of the fact that it may be corrected by simple and low-cost intervention, the ongoing programs are far from effective [10]. Supplementation with Fe tablets is a reliable method to control anemia, but availability and distribution of health care, patient compliance, and the requirement of daily intake reduce its effectiveness in several world communities [10]. Food fortification is an alternative or a companion to Fe tablet supplementation. Several foods have been used as Fe carriers, such as bread, milk, cookies, infant formula and soy products [11]. Problems with distribution, discoloration, taste and/or sufficient daily intake of the fortified product have also reduced its capacity to prevent or to cure Fe anemia [10,11]. No reference to water as a possible Fe carrier is quoted in

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Address reprint requests to J.E. Dutra-de-Oliveira, MD, Faculty of Medicine, 14049 Ribeirão Preto, SP, BRAZIL.

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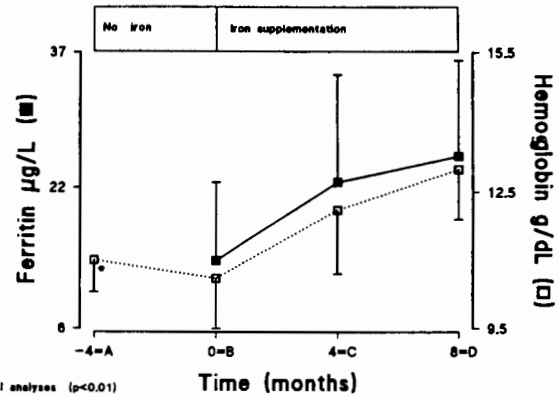
recent reviews on the control of Fe deficiency [10,11].

Widespread availability of Fe carriers is needed worldwide. We have been working for the last few years with drinking water as such a vehicle. Physicochemical tests were conducted with several Fe salts to determine their effects on water [12]. Rat assays showed the effectiveness of this Fe-enriched water on the prevention of experimental anemia [13]. Evaluation of adding ferrous sulfate to the daily drinking water of an institutionalized group of preschool children with low levels of ferritin and hemoglobin, for 8 months, was the purpose of this report.

## MATERIAL AND METHODS

A preschool day-care institution for low socioeconomic families, in the edge of the City of Ribeirão Preto, Brazil, was investigated from November 1990 to October 1991. Ethical rules of our Medical School Committee were followed, and permission was obtained from the children's parents and the administrative body of the organization. Thirty-one preschool children, 2-6 years old, participated in the study. They attend the preschool Monday through Friday, 7:00 a.m. to 5:00 p.m., while their mothers work. Food intake include four meals at the institution and, eventually, a quick meal at home after they leave the day-care center. Their dietary Fe intakes were surveyed by our dietitians. A visiting physician in charge was responsible for the health care of all children, including the search for parasitic infestations, which when detected, received the recommended treatment. Nutritional status, including weight and height, was obtained by our nutrition team following standard procedures. Blood (2-4 mL) was collected from an arm vein by a nurse, four times during the 1-year period. It was sent to our laboratory for hematological and chemical analysis. Serum ferritin and hemoglobin levels are reported here. Hemoglobin was measured by a cyanomethemoglobin method and serum ferritin by an immunochemical assay [14,15].

The experimental design (Fig. 1) was carried out as follows: During an initial, baseline period of 4 months, we examined the children and checked their hemoglobin levels. Another hemoglobin value and serum ferritin measurement was obtained at the end of this 4-month period (no Fe intervention). At this point we started the Fe-supplementation period, adding 800 mg ferrous sulfate crystals ( $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ -PA grade) to 8 L of drinking water kept in an earthen container, i.e., 20 mg of elemental Fe per liter of water. The Fe-fortified water was prepared daily and the container cleaned every day. The children had ad libitum access to this water. It was found that they drank about 500 mL daily. The earthen container was their only source of drinking water at the institution.



Statistical analyses ( $p < 0.01$ )  
 ■ Ferritin: B < C = D  
 ○ Hemoglobin: A = B < C < D  
 • Mean ± SD

Fig. 1. Hemoglobin levels before (-4 to 0 months) and after (4 and 8 months) iron supplementation. Serum ferritin values before (0 months) and after (4 and 8 months) supplementation.

The first baseline blood sample was obtained in a subgroup of 15 children; 4 months later, other samples were obtained on the same 15 children plus an additional group of 16 children. Therefore, 31 children were followed during the 8-month Fe-enriched drinking water period.

Data were treated as one-factor analysis of variance with repeated measures over time. The repeated measures were time (months), and dependent variables were ferritin and hemoglobin. Significance of the specific differences among time was explored using Newman-Keuls range test.

## RESULTS

No clinical signs of malnutrition were found in the children. Mean weights and heights, shown in Table 1, are within National Center for Health Statistics standards. Dietary surveys showed they received adequate calories and proteins, mostly from vegetable sources. Parasitic infestation was not found on routine examination.

Table 1. Children's Height and Weight as Compared to NCHS\* Standards

NCHS percentile range	Children %	
	Weight	Height
<5	0	0
5-25	22	30
25-75	59	50
75-95	19	2
>95	0	0

\* National Center for Health Statistics growth curves for children.

First sample levels of hemoglobin and the hemoglobin and serum ferritin during the 8 months of the water enrichment period are shown in Table 2 and Figure 1. Table 3 presents the percent of children with low hemoglobin and serum ferritin throughout the 8-month Fe intervention period. Initial mean hemoglobin levels of the first 15 children (8 girls, 7 boys), during the non-Fe intervention period, was  $10.7 \pm 0.7$  (mean  $\pm$  SD) g/dL. Eleven children had values  $< 11.0$  g/dL. Four months later, before starting Fe fortification, the second baseline check on the same 15 initial children plus 16 others (9 girls, 7 boys), showed a mean hemoglobin of  $10.6 \pm 1.1$  g/dL with 18 of the 31 having levels  $< 11.0$  g/dL. Hemoglobin values of the same initial 15 children were the same after 4 months and did not differ from those of the 16 other children included in the study.

After 4 months of Fe-fortified water intake, mean hemoglobin increased to  $12.1 \pm 1.4$  g/dL, with only five measures  $< 11.0$  g/dL. The next hemoglobin samples after Fe supplementation, 4 and 8 months later, and including the same 31 children, showed a mean hemoglobin of  $13.0 \pm 1.1$  g/dL. Only one child had a level  $< 11.0$  g/dL. Serum ferritin values started with a mean of  $13.7 \pm 8.9$   $\mu$ g/L, and increased to  $22.6 \pm 8.9$  and  $25.6 \pm 10.5$   $\mu$ g/L after 4 and 8 months, respectively.

## DISCUSSION

Studies on food fortification as an effective way to prevent micronutrient deficiencies have been conducted both in developed and developing countries [10]. The challenge has been to find a good carrier and effective Fe compounds [16-19]. Despite the fact that Fe deficiency is the most widespread micronutrient deficiency, an appropriate and universal carrier has not been found. Fortification of wheat and maize flours, rice, sugar, milk, beverages, tea, salt, and more recently cooking oil and drinking water have been used or suggested as effective ways to deal with

**Table 3.** Percent of Children with Low Hemoglobin and Low Serum Ferritin during the 8-Month Period

	Months		
	0	4	8
Hemoglobin $< 11$ g/dL	58	16	3
Ferritin $< 12$ $\mu$ g/L	45	21	7

the lack of iodine, vitamin A and Fe in developing countries [11].

A fortification program should use an available and low-cost chemical ingredient with a tested bioavailability and a suitable carrier. The product should also have small influence on the color, taste, appearance and avoid undesirable changes on the physical and chemical features of the carrier [20]. One of the most used is ferrous sulphate, but it was not added to water on previous enrichment programs. We ran basic laboratory studies to check its influence on the physicochemical characteristics of the drinking water [12]. Flavor and acceptance of the water were checked through sensorial analysis carried out on  $> 400$  children.

The bioavailability of the ferrous sulphate and other Fe salts added to the drinking water was also previously tested in our laboratory. Anemia of weaning rats fed an Fe-free diet were prevented when they received Fe-fortified water. Best results were obtained with ferrous sulphate and EDTA Fe [13]. Similar findings were found on children from the present study who drank ferrous sulphate-enriched water during 8 months. These children belonged to a low socio-economic group in an economically sound community in Southern Brazil. They attended a day-care institution supported by a religious group, where the physical infrastructure and the food/health attention were quite good. Their growth pattern was within the expected range for the children's ages, but their Fe-deficient status at the beginning of the study was compatible with hidden hunger (normal growth patterns and micronutrient deficiencies).

**Table 2.** Hemoglobin and Serum Ferritin, Before and After Iron Fortification (20 mg Fe/L)

Age (years)	Months after iron fortification					
	0		4		8	
	Hb	SF	Hb	SF	Hb	SF
<b>Females</b>						
2-4	$10.5 \pm 1.1$	$16.0 \pm 11.6$	$12.0 \pm 1.5$	$19.8 \pm 12.4$	$12.3 \pm 1.2$	$22.7 \pm 14.8$
4-6	$11.2 \pm 0.9$	$14.5 \pm 9.7$	$11.9 \pm 1.5$	$22.2 \pm 9.1$	$13.3 \pm 1.2$	$26.4 \pm 8.4$
<b>Males</b>						
2-4	$10.1 \pm 1.2$	$11.1 \pm 8.8$	$11.7 \pm 1.0$	$22.6 \pm 11.4$	$13.1 \pm 0.7$	$22.8 \pm 8.9$
4-6	$10.7 \pm 1.0$	$15.0 \pm 6.6$	$13.1 \pm 1.5$	$26.1 \pm 17.8$	$13.2 \pm 1.1$	$27.8 \pm 13.2$
<b>Total</b>	$10.6 \pm 1.1$	$13.7 \pm 8.9$	$12.1 \pm 1.4$	$22.6 \pm 11.8$	$13.0 \pm 1.1$	$25.6 \pm 10.5$

Hb = Hemoglobin (g/dL), SF = Serum ferritin ( $\mu$ g/L), mean  $\pm$  SD.

Most of the children had low initial hemoglobin and ferritin values. After treatment, all except one had hemoglobin values  $> 11$  g/dL and mean ferritin values  $\geq 20$  g/L, considered good Fe store levels [18].

Our data confirm the feasibility of adding small amounts of ferrous sulphate to drinking water to improve the Fe status of preschool children. This is quite important to developing countries where low socioeconomic level children eat mostly cereals and legumes, known for their low Fe bioavailability and richness in inhibitor factors. The amount of extra Fe they would receive through drinking water (10 mg/day) supplies them with the recommended dietary allowance for the age group. This level is lower than the preventive dose of 30 mg/day elemental Fe suggested by international organizations [10]. It should also be noted that through this program many children may be reached and specialized personnel was not needed. A helper was instructed to add the ferrous sulphate prepared by us to the drinking water container to a concentration of 20 mg of elemental Fe per liter, with stirring. Traditional and usual treatment of these children would be to offer each one a tablet or a liquid form of an Fe medicine, during a few months. The water had a light metallic Fe taste, noticed mainly by the adults, and some color, but these alterations did not keep the children from drinking it. Further improvements are currently being tested to control taste and color problems through liquid preparations of ferrous sulfate, ascorbic acid addition, maintenance of slightly acidic pH to prevent precipitation and oxidation (the pH of our water solution was 6.0–6.5), and with other Fe salts that could avoid them. FeEDTA, for example, seems very good for this purpose. It gives the water a light yellow color but, practically, no change in taste.

It is also noteworthy that through the enriched water, average levels of serum ferritin and hemoglobin, at the end of the experiment, increased above the value considered critical by the experts [10], both in the anemic and non-anemic children. This brings up the question of cut off levels and minimum values to be considered anemic or adequate, as well as desirable levels or physiological parameters. Is it enough to have 11 g/dL hemoglobin, or is 13–14 g/dL better? We feel higher levels would be more adequate. Our preschool children, after Fe supplementation, not only rose above the level of anemia (except one), but the group reached an average hemoglobin level of 13 g/dL and increased its Fe reserves. This will give them a Fe status better adjusted to the functions where Fe plays a role.

An additional aspect always brought out on the discussion of any Fe supplementation and fortification program is related to Fe overload and its interference with trace mineral absorption. The classical Fe toxicity example is hemochromatosis and some hematological disorders (beta-

thalassemia and sickle cell disease). They should be early identified and treated appropriately. High intakes of Fe may also interfere with zinc and copper absorption. This does not happen with small Fe doses [21–23]. Large Fe supply as a global fortification program is to be viewed with caution [24]. Knowing the consequences and magnitude of Fe deficiencies and being aware of Fe excess makes the possibility of using drinking water as a carrier of small amounts of Fe in preschool children seem a valid and practical nutritional intervention of public health importance. Day-care centers are quite common in many countries and certainly attending children could benefit from this kind of intervention.

Fe fortification programs targeted to other segments or directed to the entire population, including focus on developing countries, selection of vehicles and fortificants, costs, monitoring, potential (based on developed countries experiences) and sources of expert advice, have been addressed elsewhere [10]. We believe water could be better explored as a nutrient carrier. It may be fortified at different environments with no special technology, and most Fe salts are readily available, some at a low price. However, hardness and pH of water supplies are factors that need to be monitored for any successful water supplementation program. Therefore, other field trials with Fe-enriched drinking water should be stimulated and evaluated as an alternate approach to the prevention of Fe deficiency and anemia.

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