Original Article

Trial Using Multiple Micronutrient Food Supplement and its Effect on Cognition

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ABSTRACT

Objective. To test the efficacy of a multiple micronutrient food supplement (MMFS) on the nutrition status of school children and its effect on cognition.

Methods. A MMFS was developed containing chelated ferrous sulphate and microencapsulated vitamin A, B2, B6, B12, folic acid, niacin, calcium pantothenate, vitaminC, vitamin E, lysine and calcium and the efficacy of the MMFS was assessed in 7-11 year old school children in Chennai, India by a pre-post test design. In the experimental group (N=51), the food in the school kitchen was cooked with the MMFS for the residential school children for a period of one year. The control group (N=72) consisted of day scholars who did not eat at the school. Hemoglobin, red blood cell count and hematocrit were measured at baseline and at the end of the study (after one year). A battery of 7 memory tests (The personal information test, the Mann-Suiter Visual memory screen for objects, The digit span forward test, The digit span backward test, The delayed response test, The Benton Visual Retention Test and The Cattells retentivity test), one test for attention and concentration (Letter cancellation test) and one test for intelligence (Raven's coloured progressive matrices) were administered to all the children at baseline and endline.

Results. It was seen that there was a significant (P<0.05) improvement in the experimental group in hemoglobin, hematocrit and red cell count whereas in the control group there was a statistically significant decline(P<0.05) in hemoglobin and red cell count. In 5 tests out of the 7 memory tests and in the letter cancellation test for attention, the mean change in scores in the experimental group is significantly more (P<0.05) than the control group. There was no significant improvement in the overall intelligence as seen in the Ravens progressive matrices between the experimental and control groups at endline.

Conclusion. The study shows that the MMFS is effective in improving the nutrition status and cognition in children. **[Indian J Pediatr 2008; 75 (7) : 671-678]** *E-mail: vinodkumar_m_k@hotmail.com.*

Key words : *Multiple micronutrients; Supplementation through food; Iron; vitamin A; Bcomplex vitamins; Cognition*

It has been observed in developing countries that multiple micronutrient deficiencies occur in the poorer segment of the population.[1,2] Among micronutrient deficiencies, iron and iodine deficiencies affect >30 % of the global population.[3] However, the approach to combat micronutrient deficiencies has been to tackle individual micronutrients, for example supply of iron and folic acid tablets to pregnant women, vit A drops to children *etc.* It has been suggested that supplementation with multiple micronutrients may be the best possible way to improve the nutritional status of the malnourished populations.[4] Keeping all these concepts in mind, a multiple micronutrient food supplement (MMFS) was developed which contained vit A, vit B1, vit B2, vit B6, vit B12, niacin, folic acid, calcium pantothenate, vit C, vit E, Iron, calcium and lysine. If used in daily cooking in the family, it would supply all these nutrients to the entire family everyday. The present study is undertaken to test the hypothesis whether the addition of multiple micronutrients during cooking improves the nutrient status and cognition in school children.

MATERIAL AND METHODS

In this study, we have tested the stability of the multiple micronutrient food supplement(MMFS) during storage, and during cooking. We have then tested the efficacy of the MMFS by using it in all the meals cooked for children in a residential school for a period of one year and tested

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[Received January 20, 2007; Accepted May 5, 2008]

the biochemical parameters like hemoglobin, red cell count and hematocrit. We have also tested the memory and cognition in the children to study the effects of improved nutrition on cognition in children.

Process of manufacture of the MMFS

When multiple micronutrients are used, they interact with each other leading to losses in potency. Iron is stable and best bioavailable in an acidic pH whereas vit A is unstable and looses its potency in an acidic environment. To prevent such interactions, the micronutrients are microencapsulated to prevent interactions with each other. All ingredients used were of food grade.

Ferrous sulphate is the most bioavailable form of iron. However, it is well known to interact with many vehicles of fortification or with other food ingredients during cooking by producing discolorations. Therefore, Ferrous sulphate monohydrate (Heina Pharma, Mumbai, India) was chelated by us in our laboratory with chelating agents and the absorbtion promoter was further added to enhance the iron absorbtion. Ferrous Sulphate was chelated with malic acid (Thirumalai Chemicals Ltd, Ranipet, Tamilnadu) and sodium hexameta phosphate (Sulux Phosphates, Mumbai). The acidic pH was maintained by sodium dihydrogen phosphate (Sulux Phosphates, Mumbai) which served as an absorbtion promotar. The resultant chelated iron complex was white in color. Vit A (Nicholas Piramal, Mumbai, India) which was supplied microencapsulated in gumaccacia and sugar was coated with butylated hydroxy anisole (P.D Fine Chem, Bangalore, India), butylated hydroxy toluene (P.D Fine Chem Bangalore, India) and tocopherol (Merck Ltd, Bangalore, India) to enhance the stability of vit A. Thereafter, it was encapsulated in cellulose acetate phthalate (GM.Chemicals, Mumbai, India) to protect it form the acidic environment (which is necessary for iron bioabsorbtion) and coated with a layer of silicone to provide heat resistance during cooking. The B complex vit B2, B6 (Romeda Chemicals Ltd, Mumbai) and B12 (Wockhardt Ltd Mumbai, India), niacin (Lasons India P Ltd, Mumbai, India) and folic acid (Shree Krishna Pharmaceuticals Ltd, Hyderabad) were coated together with glyceryl stearate (Om Corporation, Mumbai, India). Coated vit C (Amoli organics, Mumbai, India) was used for the study. Vit E oil (Merck Ltd, Bangalore, India)was adsorbed in silica and the powdered product was used. Calcium pantothenate and lysine were used without any coating. All the above micronutrients were added to calcium carbonate (Ferrous Minerals and chemicals P Ltd, Mumbai)which served as the carrier. The nutrient composition of the MMFS is given in Table 1.

The multiple micronutrient food supplement was manufactured in a ribbon blender (RPM 50) (Bhuvaneshwari Engineering, Chennai, India). The homogeneity of the supplement's micronutrient content was established at the manufacturing level by assessing the micronutrient content at different parts of the ribbon blender. It was found out that the product had a uniform and homogenous distribution of all the micronutrients.

Stability during cooking

A study was done to test the stability of all the micronutrients during cooking. (Table 1) The assays were carried out initially and after subjecting the micronutrients to typical Indian cooking conditions after adding them to an Indian dish- sambar(lentil soup) and cooking for 20 minutes. The required aliquotes from the lentil soup were taken for the analysis of micronutrients. Six samples were taken before and after cooking.

Stability during storage

Samples of the MMFS were stored at 30 degrees C, humidity 45%, for 12 months. (Table 1) and stability tests were done once in 3 months.

Dosage of Iron

Most of the studies reviewed in literature gave iron in the form of ferrous sulphate tablets, ferrous fumerate or other

TABLE 1. Nutrient Composition of the Multiple Micronutrient Food Supplement (MMFS) and Stability of the MMFS During Cooking and Storage

Ingredient	Nutrient composition	Nutrient status after cooking for 20 minutes	Loss in nutrient after cooking %	Nutrient status after one year of storage	Loss in nutrient on storage after one year %
Vitamin A IU/g	1500	1342	10.5	1099	26.7
Vitamin B2 mg/g	1	1	0	1	0
Calcium pantothenate mg/g	1	1	0	1	0
Niacin mg/g	15	15	0	14.94	0.4
Vitamin B6 mg/g	1	1	0	1	0
Folic Acid mcg/gm	100	99.49	0.51	99.5	0.5
Vitamin B12 mcg/gm	1	1	0	1	0
Vitamin E IU/g	30	29.93	0.23	29.9	0.33
Vitamin C mg/g	30	26.6	11.3	22.30	25.6
Iron mg/g	10	10	0	9.97	0.3
Lysine mg/g	250	241.9	3.24	249.56	0.18
Calcium %	15.63	15.63	0	15.63	0

hematinics for periods ranging from 2 months to a year.[5-13] The present study is different in that the experimental group children received 10 mg of elemental iron every day through the multiple micro nutrient food supplement for a period of one year. The iron was in a chelated form with the biopromotor added. Chelated iron compounds have a much higher bioavailability than inorganic iron compounds.

Bioefficacy Study

Subjects

The Research Design was a pre- post test design with experimental(N=51) and control (N=72) groups. It was a randomized controlled trial. The children residing in the residential school constituted the experimental group. The children who lived in communities nearby and attended the day school constituted the control group. There was no intervention in the children belonging to the control group except deworming. The school where this study was conducted was chosen randomly from a list of schools that had residential school children and also admitted day scholars from communities around the school.

A survey was conducted on different schools prior to randomization and the schools were chosen where there were minimum instances of outside cooked food (unfortified) served to the children and where there were minimum intervening holidays when the children would go home and cause a disruption in the study. From this list of schools, one school was randomly chosen to conduct the study.

Sample size calculation

In our earlier study studies[14] we had observed an increase of about 0.5 g / dL in hemoglobin and a standard deviation of about 0.9. If we assume similar increase in the mean and if alpha is assumed to be 0.05 and power assumed to be 80%, then the sample size required for the experimental group would be 50 children in the experimental group and 50 children in the control group. Earlier studies had shown an increase of about 11 points in intelligence tests like the Ravens progressive matrices with a standard deviation of about 20. If alpha is assumed to be 0.05 and power assumed to be 80%, then the sample size required for the experimental group would be 50 children in the experimental group and 50 children in the control group.

The study was approved by the Institutional Ethics committee also referred to as the Institutional Review Board of Sundar Serendipity Foundation and the Doctoral committee of M.S.Swaminathan Research Foundation. Informed written consent was obtained from the School Director and informed oral consent was obtained from the parents / legal guardians of all the children. The parents / legal guardians of the children in the residential school (experimental group) were informed about the use of the MMFS in the cooking of all the meals in the schools, periodic deworming and the periodic blood tests. The parents / legal guardians of the day scholars (control group) were informed about the periodic deworming and the periodic blood tests. All the parents / legal guardians were informed that blood tests would be done in all the children for assessment of anemia and the children with severe anemia (Hb less than 8g / dl) would be treated for the anemia immediately therapeutically. These children were excluded from the study. All the children who were anemic at the end of the study were treated with ferrous sulphate tablets with 60mg elemental iron for 3 months.

Study Procedure

The MMFS was used in all the meals cooked for the children in the experimental group for a period of one year. There was no intervention in the control group except for deworming. Deworming was done in both experimental and control children by giving a tablet of albendazole 400 mgs at baseline, after 6 months of intervention and after one year of intervention (end of study).Deworming was done to ensure that there are no worms which compete for the micronutrients and ensures the intestinal tract is clear for bioabsorbtion of the micronutrients as in other studies.[15, 16]

The MMFS was supplied to the school every month and the continuous use of the MMFS in all the meals prepared everyday was monitored. The dosage of the MMFS was one gram per child per day. Since, the number of children was known the MMFS was weighed and packed in packets which had to be cut and added to the meals cooked for the day. The MMFS was used in all the food preparations. It was dissolved in water and added to liquid food preparations in the final stages of cooking. It was sprinkled as such on solid food preparations. The MMFS did not change the color or taste of any food preparation. It was observed that generally there was no wastage of food prepared in the residential school. All the food prepared is consumed.

Nutritional status

Nutritional status was assessed by estimation of hemoglobin, hematocrit and red blood cell count. Hemoglobin estimation was carried out before the start of the study, six months after the commencement and one year after commencement (end) of the study. The hematocrit and red blood cell count were done before the study began (base line) and at the end of one year of the study (end).

Blood collection, storage and laboratory analysis

2 ml of venous blood was drawn from each child. The blood was transferred into vials which had EDTA as anticoagulant. The tests for hemoglobin, hematocrit and red cell counts were carried out in the sample within a

few hours of blood collection. The blood samples were transferred to the laboratory within 2 hours of collection at the school. Hemoglobin was estimated by cyanamethemoglobin method.[17] Hematocrit was estimated by centrifuging blood in wintrobe tubes.[17] Red blood cell count was done by counting the cells using the neubauer counting chamber.[17] Hemoglobin was done in duplicate for all the samples. In hematocrit and RBC count estimations, in 10% of the samples the test was done twice for validation.

Statistics

Statistical analysis was done using SPSS 11.0 (SPSS Inc., Chicago IL, USA) and Microsoft Excel 2000 (Microsoft Corp., Seattle WA, USA). Repeat measures Analysis of variance was done to compare the effects of group*time for hemoglobin, hematocrit, Red blood cell count and all the cognitive tests. Students t test was done to analyze the effects between groups and paired students t tests was done to analyze the effects within groups.

Tests for Memory, Concentration and IQ

Iron deficiency anemia is one of the important causes of lowered concentration abilities and impaired memory skills. The present study involves giving a battery of memory tests and concentration tests to see if there is an improvement in these memory and concentration abilities when anemia is reduced through the nutritive intervention.

To test the memory in children we used the Children's memory test developed by NIMHANS (National institute of mental health and neurological sciences, Bangalore, India). Though the NIMHANS memory test had verbal and nonverbal components, the children we were dealing with are rural children who studied in the regional language and not in English. The verbal component of the NIMHANS memory test was in English. We therefore, chose to give the children only the nonverbal component of the test where English language was not a barrier. This was possible because each test was individually scored. The individual scoring also helps us find out in which aspects of memory does improvement take place when iron and other micronutrients are given.

In both the experimental and control groups, a battery of tests developed and standardized on Indian children to suit Indian conditions by NIMHANS to assess memory and concentration was administered. The children in both the experimental and control groups were also administered the Ravens Children's Progressive Matrices, a test to assess the IQ of these children and a letter cancellation test to assess concentration. These tests were administered before the start of the study (base line) and after one year of nutrient intervention. The results of the Ravens Children's Progressive Matrices at base line showed that there was no significant difference in the IQ of the children in the experimental and control group which shows that it is a homogenous and comparable group of children.

There were no children in both the experimental and control groups whose hemoglobin was more than 12 g/dl. Therefore, this study has no non-anemic controls.

Description of the memory tests

Personal information: This test is a measure of remote memory which constitutes recall of past events of personal life. This is adopted from Wechsler memory scale[18] and PGI memory scale.[19]

Digit span: This subtest is taken from Wechsler memory scale.[18] This comprises of span for digits forward and backward. The maximum number of digits used in the series is limited to 9. This test is a measure of attention and concentration.

Delayed response learning : This subtest is taken from Wechsler memory scale.[18] This essentially requires the ability to delay the previous response in order to arrive at a final solution. This measures delayed memory span. There are 4 sets of fairly simple arithmetical problems. Each problem consists of 2 parts presented one after the other. In the first part a simple arithmetical problem is given, the child solves it and keeps the result in mind and then solves the second part of the problem 10 seconds later incorporating the result from the previous part.

Mann-Suiter Visual memory screen for objects (picture recall test): This is designed to assess the ability to revisualise pictures of common objects presented in groups. There are 4 cards. On the first card there are 2 pictures and it was exposed for 2 seconds. The second card has 3 pictures and it was exposed for 3 seconds, the 3rd card had 4 pictures and the 4th card had 5 pictures and it was exposed for 4 seconds and 5 seconds respectively. The child was expected to recall the pictures in the same sequence. This test measures short term visual memory.[20]

Benton Visual Retention Test (BVRT) : This test is designed to assess visual perception, Visual memory and visuo-constructive abilities. There are 10 cards. Each card is exposed for 10 seconds and the child is asked to reproduce the design from memory. This test measures the visuo spatial perception, visual and verbal conceptualization and immediate memory span.[21]

Cattells retentivity test

It consists of complex and unfamiliar designs of irregular geometric figures which cannot elicit any verbal associations. On a card 10 geometrical figures are presented for 30 seconds, after a 2 minute pause and from the second card the child has to recognize the geometrical figures which he has already seen in the first card. This measures the visual recall for irregular geometrical

designs and delayed memory span.[22]

Letter cancellation test

This test is a measure of concentration.[23] The children are given the test which has many alphabets typed out in rows and the children are instructed to score out the A's and E's within a period of 2 minutes. If the child has omitted to score a letter or if she has scored a letter which is not A or E, it is considered as a wrong. If the child has correctly struck out an A or E it is considered as right. The final score is obtained by subtracting the total of wrongs from the totals of rights.

Ravens coloured progressive matrices

This is an IQ test to measure intelligence in children.[24]

The same tests were administered before the intervention program and repeated after one year of nutritive intervention.

Scoring for cognitive studies

Based on the age of the child the raw score is converted to the percentile score, *as per* the standardization done by NIMHANS on Indian children. Therefore, age matching between the experimental and control group is taken care of in the scoring itself. The score obtained at the end of the study is subtracted from the initial score to get the change in score. The comparison is made between the experiment and control with regard to the change in scores to offset the increment due to familiarity in the retest.

In earlier studies in India,[25] it was seen that there were increment in scores in arithmetic and digit span subtests in the placebo group also. In a Thailand study,[26] all the children improved their scores at follow-up regardless of their iron status. It can be reasoned out that there is always a familiarity element when a retest is given and this familiarity leads to improvement in scores in the control also. To offset this improvement in scores due to familiarity, the endline score is subtracted from baseline score and the change in scores is taken to consider whether there is an improvement of the experimental group over the control.

RESULTS

Baseline characteristics of the experimental and control groups

The experimental and control groups of children were similar in age, intelligence, nutrient intake and socio-economic status. Analysis of the results of the intelligence tests showed that there was no statistical difference between the experimental and control groups with reference to the baseline scores of the Ravens progressive matrices showing that the experimental and control groups were comparable to intelligence at baseline and hence can be compared for cognitive outcomes. These results are presented in Table 2.

TABLE 2. Baseline Characteristics of the Experimental and Control Groups*

Baseline Characteristics	Experimental group	Control group
Age in years (Mean ± SD)	9.35 ± 1.12	9.03 ± 1.1
Height in cms (Mean ± SD)	120.94 ± 10.02	124.16 ± 8.5
Weight in Kg (Mean ± SD)	20.37 ± 4.49	21.8 ± 4.42
Male	12	28
Female	39	44
Intelligence test-Ravens Children's Progressive Matrices (Mean Scores ± SD)	28.88 ± 30.9	32.26 ± 29.49
Socio economic status Monthly Family income In Rupees (Mean ± SD)	1670 ± 447	1730 ± 400

*No Significance (P<0.05) between the experimental and control groups in all the above baseline characteristics.

Dietary assessment of the households of a sub-sample of control group(N=25) showed that there were no significant differences in the nutrient intake of both the experimental and control groups. The dietary consumption was calculated by assessing the details of food consumed in the past 3 days in the subsample of the control group households and in the residential school which constituted the experimental group.

Efficacy Study-Biochemical Parameters: There was a significant (P<0.05) improvement in the experimental group in hemoglobin, hematocrit and red cell count whereas in the control group there was a statistically significant decline(P<0.05) in hemoglobin and red cell count. (Table 3)

Cognitive study

We find that out of the 7 memory tests administered, in 5 of the tests, namely the Benton Visual Retention Test, the Cattells retentivity test, Mann-Suiter Visual memory screen for objects (picture recall test), Delayed Response Learning test and the digit forward test , the mean change in scores in the experimental group is significantly more(P<0.05) than the control group. Only in the personal information test and the digit backward test, the change in scores in the experimental group is not statistically significant. In the letter cancellation test which is a measure of attention and concentration too the mean change in score in the experimental group is significantly more than (P<0.05) the control. There are no significant differences with respect to the intelligence test-the Raven's coloured progressive matrices in the experimental and control group. This is understandable as there usually will not be an improvement in the overall intelligence but only in certain specific areas of memory which is measured by the memory tests. (Table 4)

TABLE 3. Biochemical Status of the Experimental and Control Groups over a Period of One Year

	Experimental group n=51		Control group n=72	
	Base line	Endline after one year	Base line	Endline after one year
Hemoglobin gms/dl*	9.98 ± 0.75[a] (9.77 - 10.19)	10.23 ± 0.60 [a] (10.07 - 10.4)	10.43 ± 0.83[b] (10.23 - 10.63)	10.13 ± 0.74 [b] (9.95 -10.31)
Hematocrit l/l*	0.2872 ± 0.018[a] (0.2823 - 0.2922)	0.3000 ± 0.021 [a] (0.2941 - 0.3059)	0.3062 ± 0.022 (0.3010 - 0.3115)	0.3013 ± 0.023 (0.2958 -0.3069)
Red blood cells million/cmm	3.24 ± 0.22 [a] (3.18 - 3.30)	3.43 ± 0.27[a] (3.35 - 3.50)	3.62 ± 0.49 [b] (3.5 -3.74)	3.47 ± 0.28 [b] (3.4 -3.53)

a: significant improvement(P<0.05) from baseline to endpoint
b: significant decrease(P<0.05) from baseline to endpoint
Data given as mean+-SD
* ANOVA repeat measures Significant (P<0.05) group*time
95% Confidence interval for mean with lower bound and upper bound values given in brackets

TABLE 4. Results Cognition: Change in Scores

Name of the test	Test measures	Experiment n=51 mean	Control n=72 mean
Benton Visual Retention Test (BVRT)*	memory	13.73 ± 4.52[a]	3.61 ± 2.14[a]
Cattells retentivity test*	memory	6.28 ± 3.11[a]	-0.83 ± 2.82[a]
Mann-Suiter Visual memory screen for objects (picture recall test)*	memory	15.29 ± 3.83[a]	5.62 ± 2.21 [a]
Delayed Response Learning test*	memory	14.51 ± 3.67 [a]	5.49 ± 2.19 [a]
Personal Information test	memory	20.59 ± 6.75	15.35 ± 3.49
Digit Forward test*	memory	3.14 ± 2.20[a]	-2.11 ± 1.76 [a]
Digit Backward test	memory	0.39 ± 3.12	-0.85 ± 3.03
Letter cancellation test*	Attention and concentration	11.78 ± 1.34 [a]	5.50 ± 1.06 [a]
Ravens coloured progressive matrices	intelligence	11.58 ±2.88	11.08 ± 2.53

a: significant improvement of the experimental group (P<0.05) over the control.
* ANOVA repeat measures significant (P<0.05) group*time
Data given as mean ± standard error of mean (SE_M)

DISCUSSIONS

There is strong evidence that among school aged children, initially lower scores on tests of cognition or school achievement due to iron deficiency anemia can be improved and in some cases reversed after iron treatment.[25,26] One reason for this evidence is a large number of placebo controlled trials, which are able to pick up treatment effects. Another reason might be the increased sensitivity of the tests used. It could also be that the effects of iron deficiency in school aged children are more transitory than in infants and are thus more responsive to the effects of iron treatment. Most of the studies [25,26] showed significant improvement in cognitive function or educational achievement of the children who received iron supplements compared to those who received the placebo.

These results are in contrast with those obtained in infants where the benefits of treatment are rarely observed. The adverse effects on cognitive and educational test performance due to iron deficiency anemia in preschool and school aged children appear more transitory in nature than the effects on development on infants and imply that treatment of iron deficiency anemia in preschool and school aged children through iron supplementation programmes may be beneficial and have immediate effects.

Anemia causes poor attentiveness, poor memory and poor academic performance in school age children. These children are often disruptive, irritable, restless and show behavioral abnormalities like lack of attention, fatigue, insecurity and reduced learning ability. Poor attention span, memory and concentration as well as concept acquisition leading to poor school performance have been attributed to anemia during this phase of critical learning. Restoration of hemoglobin levels to normal by hematinic supplementation, (only iron and iron and folic acid) resulted in significant improvements in over all IQ stores as well as in tests involving specific abilities of attention and concentration in 4-6 year old and 6-15 year old children. [8,27]

We find that when the MMFS is used in cooking for a period of one year, it results in significant improvement in the hemoglobin, hematocrit and red cell count status of the children in the experimental group where as there is a significant decrease in hemoglobin and red cell count and a nonsignificant change in hematocrit of the control group of children. When the cognitive tests are administered, we find that in 5 memory tests out of 7 tests

administered, and in the letter cancellation test which measures attention and concentration, we find that the change in scores in the experimental group is significantly higher($P<0.05$) than the control. Thus the improvement in iron has resulted in concomitant increase in the cognitive parameters in the experimental group of children.

Improvement in the cognitive parameters when anemia was tackled by iron supplementations has been demonstrated by other workers.[8, 13, 25, 26, 28-31]

All the above studies have given iron as ferrous sulphate tablets or other hematinics for a period ranging from 2-8 months. The present study is different in that the iron source is 10 mg of chelated iron given per day ,for a year, through the multiple micronutrient food supplement, which was added to the food during cooking.

The iron sources used in earlier studies were usually inorganic compounds like ferrous sulphate , ferrous fumerate *etc.*[6-9] Since the Indian diet is high in phytates which inhibit iron absorbtion, it was felt that the iron source has to be bioavailable despite the presence of phytates and one way of doing this is to use highly bioavailable compounds like ferrous sulphate and the other is to give the iron source in a chelated form. We have done both in this study and have used chelated ferrous sulphate as the iron source which has resulted in significant improvement of hemoglobin hematocrit and red cell count in this study.

Cost vs benefit: The cost of the multiple micronutrient food supplement is Rs 225 (5.6 US$) for 1 Kg. Each child was given 1 gram per day. So the cost per gram works out to 22.5 paise.(0.0056US$) Therefore, the cost of delivery of the micronutrients through the food supplement costs 22.5 paise per child per day. The cost of the amino acid lysine is the major cost in this costing 10 paise per child per day. Without lysine the cost of delivery of the rest of the micronutrients per child per day works out to 12.5 paise.(0.0031US$) At a mere cost of 12.5 paise (0.0031US$)per day, the child gets 11 micronutrients. We feel that this is one of the most economical ways of delivery of multiple micronutrients.

The reduction of hemoglobin in the control group could be due to the reduced availability from the food during the growing age when iron requirement is needed most. Similar reduction in the hemoglobin levels in control groups of school children have been seen in other studies.[32, 33]

This study was done in a school with residential students as well as day scholars. This is the strength and limitation of this study. The strength is because of the use of the MMFS in a single kitchen of the school which allows close monitoring of the use of the MMFS during cooking. The limitation is because the study was not done in communities.

In conclusion the multiple micronutrients in the MMFS has significantly ($P<0.05$)improved the hemoglobin, hematocrit and red cell count and concurrently improved the scores of cognitive tests in the experimental group where the MMFS was used , thus establishing the efficacy of the MMFS in combating multiple micronutrient deficiencies. This study has been done in a residential school and the delivery of multiple micronutrients through supplementation during cooking has been found useful. Studies need to be further undertaken to test the acceptability of this method of multiple micronutrient delivery by the community and to test whether this improves nutritional status and cognition in children in community settings.

Acknowledgements

We wish to acknowledgement the funding received from Sundar Serendipity Foundation than enabled us to conduct the study. We also acknowledge with thanks the guidance given by Professor M.S.Swaminathan , Chairman, MS Swaminathan Research Foundation who guided and supported us throughout the study.

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