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Commentaries

Micronutrient deficiency among children, adolescents, and adult women: Time for additional and innovative approaches

Deficiencies of iron and vitamin A, and of a number of other micronutrients, are widely prevalent and have enormous negative consequences for the survival, growth, development, and welfare of populations in developing countries

Large-scale fortification and supplementation programmes are being carried out in many countries to combat iodine, vitamin A, and iron deficiencies. Adding iodine to salt is the most successful micronutrient programme. About 68% of the world's population currently use iodized salt [1], thereby preventing the adverse consequences of iodine deficiency. Many countries now fortify cereals and cereal products with iron, and a smaller number add vitamin A to selected foods. Most developing countries, however, rely on supplementation to correct widespread deficiencies in iron and vitamin A, and are likely to continue to do so in the coming years until fortified foods become more widely available and/or dietary improvements occur.

Vitamin A capsules are distributed to pre-schoolers once or twice a year, and iron-folate tablets are given to pregnant women as part of antenatal care programmes. UNICEF assists in the implementation of these programmes through the provision and distribution of supplements. In the year 2000, about 400 million vitamin A capsules and 1 billion iron-folate tablets will be distributed worldwide. At present there are few programmes that address the serious problem of iron deficiency in infants and pre-school children. There is no doubt that there is a need to improve the targeting of supplementation programmes, the selection of nutrients to be included in supplements, distribution mechanisms, and compliance.

Gross et al. confirm in this issue [2] that although iron supplementation in pregnancy will, in most cases, prevent the further deterioration of iron status, the global prevalence of anaemia has not decreased significantly during the past decades. This is in spite of many years of programmes. The supplementation of pre-schoolers with vitamin A has been more successful. In 1998, 35 countries were able to provide at least one high-dose vitamin A supplement to more than 80% of their children 6 to 60 months of age [3]. However, there is still a pressing need to increase vitamin A distribution coverage or make dietary approaches more successful.

Gross et al. suggest new concepts to increase the efficiency of supplementation programmes. They propose to increase target groups beyond pregnant women and to include not only infants and pre-school children whose iron deficiency has been seriously neglected, but also school-age children, adolescent girls, and women of child-bearing age before they become pregnant. Failure to correct iron deficiency in infancy can result in lasting cognitive damage. Subclinical vitamin A deficiency in toddlers increases mortality rates. Iron deficiency in schoolchildren increases morbidity from infectious disease and can affect school performance. Folate must be given before pregnancy to reduce the risk of neural tube defects, and iron supplementation in pregnancy is too late to restore normal iron status in a period of high physiological demand. There is also evidence that other B-vitamin deficiencies and low zinc intakes adversely affect some populations.

The authors propose:

» the use of multi-micronutrient supplements that are only marginally more costly than iron-folate tablets alone;
» a weekly rather than a daily supplementation schedule for lower cost, easier administration, and better compliance;
» continuation of daily supplementation for pregnant women, at least until such time as they no longer enter pregnancy with iron deficiency.

The concept of increasing the number of target groups by using multi-micronutrients in a life-cycle approach is based on the following facts and assumptions. The prevalence of micronutrient deficiency among infants and older pre-schoolers is high because of their rapid growth, high incidence of infectious diseases, and inadequate dietary intake. Supplementation at an early age would prevent disease and improve nutritional status and mental development. Supplementation of school-aged children and adolescents is suggested in order to prevent deficiencies at a later stage in life. The use of a multi-supplement is suggested, because many populations in developing countries suffer from multi-micronutrient deficiencies rather than vitamin A or iron deficiency only. Weekly supplementation should reduce costs, make distribution easier, and possibly improve compliance.

Several comments can be made on these innovative concepts. Increasing the number of targeted subgroups of a population beyond pre-schoolers and pregnant women would no doubt improve the micronutrient status of the population as a whole. This would have many beneficial effects. However, experience with ongoing programmes has shown that distributing supplements and obtaining satisfactory compliance with their actual ingestion is not a simple task. Although a number of problems would need to be overcome, it should be feasible to do so. Children younger than two years of age, their mothers, and pregnant women are relatively easy to reach in countries with good immunization and antenatal care programmes. However, in Sub-Saharan Africa less than 50% of the children are immunized [1], indicating the difficulty of reaching the target population through regular programmes of the health sector.

For children in school, closer cooperation with ministries of education could provide an avenue of distribution. Most difficult to reach would be non-pregnant women and adolescent girls, but community-based approaches have proved successful in Thailand and Kazakhstan and should be feasible in many countries. There has been experience with the supplementation of female factory workers in Indonesia.

Little has been published on the use of multi-micronutrient supplements in populations from developing countries. Therefore, the suggestion [2] to use such a supplement in programmes needs to be supported by some additional research providing information on the efficacy as well as the effectiveness of the supplements in improving nutritional status and selected functional indicators such as learning capability and work productivity. The suggestion to use the multi-supplements on a weekly basis is new, and little research has been published on the efficacy of weekly multi-micronutrient supplementation. Without further information, it will be difficult to have weekly multiple supplementation accepted as a programmatic approach, although it can be assumed that even when supplements are taken weekly, micronutrient status will improve with positive consequences. Fortunately, a number of studies to test the use of multi-micronutrients are being planned.

The authors do not mention the use of a multi-micronutrient supplement for pregnant women. However, information is available indicating that large numbers of pregnant women in developing countries suffer from multi-micronutrient deficiencies. Supplementation with iron-folate alone is not enough to address these deficiencies. On the basis of this knowledge, a UNICEF/WHO/UNU workshop [4] recommended that a multi-micronutrient supplement for pregnant women should be available and should be used in a number of carefully monitored pilot programmes to gain information on its effectiveness in improving maternal nutritional status and birth outcome. UNICEF is now preparing to carry out these pilot programmes in collaboration with WHO. These pilot programmes will add to the body of knowledge and can be used to formulate policy.

The important issue of cost is also addressed in the article. Some countries are considering initiating iron-supplementation programmes for young children but are daunted by the cost of supplementing every child with iron syrup for a period of many months. A calculation of the cost of a supplementation programme was made by Gross et al., but more information would be very useful. To convince governments and obtain financial support, more information is needed on benefits, such as lives saved, illnesses prevented, and improvement in school performance or work output. The interventions may actually be very cost-effective.

As the article strongly emphasizes, greater efforts and innovative approaches are needed to effectively reduce micronutrient malnutrition among large parts of the population in developing countries. The concepts presented widen the current scope of micronutrient supplementation. Experiences with multi-micronutrient supplements need to be documented and evaluated for wider policy use. There is a great need for alternative ways to distribute supplements and for increased compliance. Cooperation with other ministries in addition to the ministries of health and with private industry will be required.

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Improving iron status by education and iron supplementation

The paper by Lanerolle et al. [1] in this issue is a valuable contribution to the prevention of iron deficiency in post-menarchial schoolgirls through dietary changes induced by education, with and without supplementary iron. It has some limitations. The duration of the intervention was very short, only 10 weeks. Moreover, even though evaluations were performed at the end of the intervention and three months later in a subsample to estimate the persistence of effects, there is little information on the relative characteristics of this subsample or possible auto-selection bias. It would have been helpful to have a better idea of the distribution of the values of the iron biomarkers in addition to the mean and standard deviation and the proportions falling above or below one or two cut-off points. Distribution analysis is something that should be used more frequently in order to facilitate the biological interpretation of risk associated with iron status and the risks and benefits of interventions. A minor limitation is that no group received iron supplementation alone, but given the emphasis on nutrition education, this limitation is understandable.

Despite these limitations, this paper makes a number of important points. The selection of puberal girls as subjects is most important, not only because they are a well-defined risk group for iron deficiency due to high iron requirements secondary to puberal enhanced growth velocity and the establishment of menses, but also because in many societies teen-age pregnancies are frequent. Iron deficiency diminishes learning capacity and affects behaviour and neurophysiological parameters [2, 3]. Iron requirements significantly increase with pregnancy, and there is also growing evidence that the iron status of women entering pregnancy is the major determinant of iron status during pregnancy, complicating the reproductive process, even where iron supplementation, when pregnancy is recognized, is universal [4–6]. Thus, actions to prevent and correct iron deficiency in this vulnerable group are important both for the girls themselves and for their role as future mothers.

The knowledge, attitudes, and practices of rural girls and their living conditions seemed to predict a better response to interventions than did those of the urban girls, and this proved to be the case. Most impressive was their greater willingness to make a behavioural change: 94% in the former and 68% in the latter. This finding suggests the need for more in-depth study on what favours the willingness to change in rural environments, and what limits it in urban environments.

The impact of a modest nutrition education intervention on knowledge, attitudes, and practice in both groups of girls at the end of the tenth week of study is a very significant finding, well worth pursuing. Even more important was the persistence of some favourable changes three months later, although the number of urban girls available for this follow-up was small. It appears that there may be limitations in the availability of certain foods (meat, mangoes) or other identifiable factors that limit iron intake in the rural area. Whether the presence of home gardens in the rural area helped by increasing the availability of fruits and vegetables was not investigated. Another question to pursue is whether these changes in food habits as a result of the education programmes affected other vulnerable individuals in the families.

It is disconcerting, however, that the prevalence of iron deficiency and anaemia is so high overall, in particular in the urban area, in spite of a higher intake of meat and other foods that should provide more bioavailable iron than in the rural area. Equally disconcerting is the short duration of the positive iron nutrition outcomes in the urban girls compared with the longer duration of effects in the rural girls. Important dietary changes persisted for three months after the intervention period without sustaining the gains in iron nutriture. Deworming may be involved in the more sustained improvement in iron biomarkers in the rural girls, but there is no information in this regard.

The high average compliance rates for unsupervised intake of iron or placebo tablets are encouraging, although more information on the distribution of intakes would have been useful. It appears that the schoolteachers were not involved at all in reinforcing the adherence to both interventions. This is unfortunate, because a simple periodic reinforcement, besides the two discussion sessions that took place during the intervention weeks, could have had a further impact. All actors and sectors, especially teachers, should be involved in sustaining and modifying interventions at the community level. Health and nutrition personnel should guide, supervise, and be available for consultation by the community, but the implementation and sustainability of interventions should be left to the community members themselves.

Given previous information on the high frequency of vitamin A deficiency (21%), it would have been interesting to determine the impact of the interventions on vitamin A nutritional status as well as the impact of the interventions in the girls in regard to their initial vitamin A status. Equally informative would be the comparative evaluation of the response of the 20% of undernourished girls (less than the fifth centile in body mass index) compared with those with adequate body mass index. The persistence of iron deficiency and anaemia in this school-age population could be partially explained by the short duration of the supplementation and by the presence of other nutrient deficiencies that may be affecting the outcomes of the study.

The lack of persistence of intervention effects in the urban setting is compatible with our findings that show a return to pre-intervention status four months after stopping short-term daily iron supplementation (90 tablets in three months), also in an urban setting [7]. This lack of persistence of effects contrasted with the results obtained with the weekly administration of iron supplements for seven months (a total of 30 tablets), which showed a progressive improvement in iron status. There is further evidence of the cumulative desirable effect of long-term weekly iron supplementation in the school setting in Panama [8], where teachers have distributed weekly iron-folate tablets for several school cycles, resulting in a progressive dramatic improvement in iron nutrition in that population. This efficacious modality could be implemented in other parts of the world.

In conclusion, our mutual experiences confirm the complementary enhancing effects of nutrition education and preventive supplementation. Implementing long-term weekly supplementation with iron (60 mg as $FeSO_4$) and folate (3.5 mg folic acid) tablets would also improve pre-conception folate nutriture [9]. The weekly doses should be ingested throughout the school cycles. The schoolteacher could expand her or his role as an agent of change by supervising iron supplement intake and reinforcing the nutrition education messages.

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Evaluation of nutrition education for improving iron status in combination with daily iron supplementation

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Abstract

The effectiveness of nutrition education and unsupervised daily iron supplementation on iron status was studied in adolescent schoolgirls of low socio-economic status. Baseline knowledge, attitudes, and practices related to nutrition and iron status were assessed in 915 girls attending schools in an urban and a rural area of Sri Lanka. Girls in intervention schools received nutrition education and ferrous sulphate or a placebo and were requested to take one tablet per day. Subjects in control schools did not receive any intervention. All subjects were reassessed after 10 weeks. Educational intervention resulted in significant increases in knowledge of nutrition and in iron status among girls in both areas. Good compliance was noted with both iron supplements and the placebo. Iron status was more improved in the groups receiving iron supplementation than in the groups receiving education only, indicating the effectiveness of unsupervised supplementation when combined with nutrition education. The short-term sustainability of intervention was higher in the rural area than in the urban area.

Introduction

Iron deficiency is a major health problem in many developing countries [1, 2]. However, interventions to prevent iron deficiency are targeted mainly to women during pregnancy. Our previous studies have shown that although iron supplementation during pregnancy has some benefit, it cannot correct pre-existing deficits [3, 4]. Adolescent girls belonging to groups of low socio-economic status (SES) may be at risk of nutritional deficiencies because of increased nutritional requirements for growth and development and blood loss during menstruation. Therefore, it is necessary to develop strategies to improve the nutritional status of adolescent girls to ensure that they enter pregnancy with a satisfactory status and are better able to cope with the increased nutritional demands imposed by pregnancy. The need for interventions during adolescence has also been highlighted in a study of the prevalence of anaemia in women of reproductive age in Mumbai, India [5]. Improvement of iron status is also likely to lead to improved educational and physical performance among adolescents.

In Sri Lanka most girls attend school until at least 16 years of age, and intervention programmes could be implemented easily through the schools [6]. A significant improvement in iron and vitamin A status has been reported following supervised micronutrient supplementation of adolescent Indonesian schoolgirls [7]. However, the ideal strategy would be to achieve desirable changes in food habits through education, since this would improve the nutritional status of the girls themselves as well as that of their families and ensure that they enter pregnancy with a satisfactory nutritional status. Also, compliance with iron supplements is likely to be greater if they are given following education [8, 9].

We attempted to evaluate the effectiveness of a nutrition education package in improving the iron status of adolescent girls belonging to groups of low SES attending schools in both an urban and a rural area of Sri Lanka. The compliance with and effectiveness of unsupervised, self-administered, daily iron supplementation when preceded by nutrition education was also studied. The short-term sustainability of the intervention programme was evaluated in both areas to enable it to be implemented in other areas.

Subjects and methods

Subjects

The study population was drawn from schools in which more than 70% of the girls were from low-SES groups. Eleven schools in the urban area and four schools in the rural area were selected randomly (in rural areas there are only a few schools that have higher grades, and all children in the area attend these schools). The total sample consisted of 915 girls: 576 girls attending schools in Colombo, the capital of Sri Lanka (urban area), and 339 girls attending schools in a rural area. The ages of the girls ranged from 13 to 19 years and their grades from 9 to 12. Only girls who had attained menarche and had no history of any major illness were included in the study. All girls who had consented to participate in the study and were present in school on the first day of the study were selected in both areas. Three schools in the urban area and two schools in the rural area served as control schools. These schools were not in close proximity to each other, thus preventing communication between girls in the two groups.

The subjects were grouped into different socio-economic classes according to the classification of Barker and Hall [10]. The subjects in the rural and urban areas were of similar SES, but the living conditions in the rural area were better than in the urban area (table 1).

Study design

The study design is shown in figure 1. Each school was visited on two successive days to collect baseline data from the girls. Information regarding their SES, practices relating to personal hygiene, and age at menarche was obtained by a pre-tested, interviewer-administered questionnaire. Their food intake was assessed by a pre-tested, interviewer-administered, food-frequency questionnaire. The general nutritional status of all subjects was assessed at baseline according to anthropometric measurement, and a 10-ml sample of venous blood was collected between 8:00 and 10:00 a.m. to determine haemoglobin concentration and iron status.

Each girl completed a multiple-choice and a graded answer paper to assess knowledge, attitudes, and practices (KAP) relating to nutrition. After assessment of baseline knowledge, the girls in the intervention schools received nutrition education and were given a single tablet of mebendazole (500 mg) to correct for a possible confounding effect of helminthic infection. They were then assigned to two groups matched for initial haemoglobin. The girls in the group receiving education plus iron supplementation (237 from the urban area and 97 from the rural area) were given ferrous sulphate tablets containing 60 mg elemental iron per tablet. Each girl was given 70 tablets of ferrous sulphate and requested to take one tablet with water every night for 10 weeks before going to sleep. The girls in the other group (239 in the urban area and 111 in the rural area) also received education and were given a placebo and requested to take it in the same manner as the iron supplement. The girls were not told whether the tablets contained iron or a placebo. Each girl was given a calendar on which to mark her intake of tablets daily. The girls in the intervention schools received two additional nutrition education sessions two and five weeks after the baseline assess-

TABLE 1. Socio-economic characteristics and living conditions of adolescent schoolgirls[a] (percentage of subjects)

	Urban (*n* = 576)				Rural (*n* = 339)			
Characteristic	Total	Group 1	Group 2	Control	Total	Group 1	Group 2	Control
Education required for parent's job[b]								
Highest level	17.5	15.6	20.9	14.0	13.6	16.5	12.6	13.0
Primary school	45.0	45.6	37.2	63.0	59.9	56.7	60.4	59.6
None	9.5	8.9	11.9	6.0	8.3	7.2	7.2	9.9
Unemployed	8.2	10.1	7.1	6.0	6.5	5.2	4.5	9.9
Monthly family income (SRL)[c]								
< 3,000	69.8	70.0	70.8	67.0	74.2	72.6	72.2	75.4
3,000–10,000	25.7	26.5	23.4	29.0	25.8	27.4	27.8	24.6
Latrines used								
Public	46.9	43.2	47.9	49.4	7.5[d]	9.6	4.5	8.5
Private	53.1	56.8	52.1	50.6	92.5[d]	90.4	95.5	91.5
Water supply								
Public	58.9	59.7	61.6	49.0	16.9[d]	22.7	9.1	19.2
Private	41.1	40.3	38.4	51.0	83.1[d]	77.3	90.9	80.8

a. Group 1 (237 urban and 97 rural subjects) received education plus iron supplementation. Group 2 (239 urban and 111 rural subjects) received education plus placebo. The control group had 100 urban and 131 rural subjects.

b. The parents of the remainder of the subjects were pensioners.

c. Twenty-six urban families and six rural families did not divulge their incomes. US$1 = 60 Sri Lankan rupees (SRL).

d. Significantly different from value for urban subjects ($p < .001$, χ^2 test).

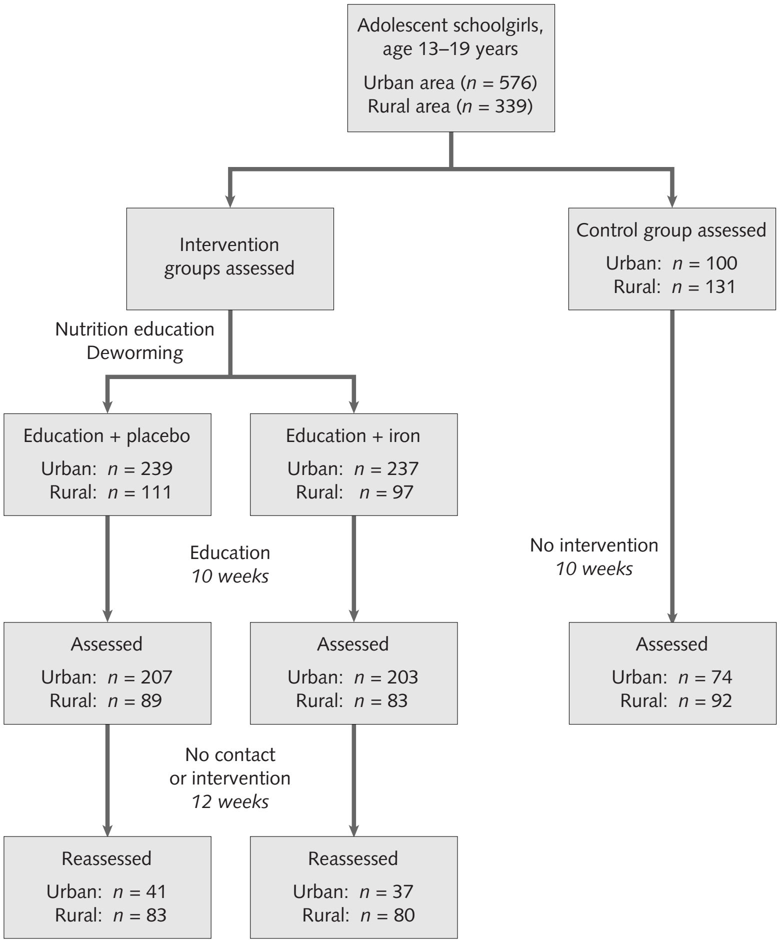

FIG. 1. Study design

ment. Girls in the control groups did not receive any intervention.

All subjects, including controls, were reassessed at the end of the 10-week period of intervention by the same methods that were used for baseline assessment. Knowledge of nutrition, food habits, any change in SES, or a history of major illness during the intervention period were recorded by the interviewers. A 10-ml blood sample was collected from each subject, and the same laboratory tests were performed.

In the urban area, 484 girls (84%) were reassessed after the 10-week period of intervention. Ninety-two girls were lost to follow-up, mainly because of absence from school on days of data collection. Seventy-eight girls from three randomly selected intervention schools were reassessed after a three-month period without contact or intervention to evaluate the short-term sustainability of interventions. In the rural area, 264 girls (78%) were reassessed after intervention, with 75 girls being lost to follow-up, and 163 girls from both intervention schools were reassessed three months after the end of the intervention.

Methods of educational intervention

In the development of educational messages, the girls' current dietary patterns and food habits were considered. The educational package was developed to convey the following key messages: increased nutritional demand during adolescence, identification of adolescent girls as a vulnerable group, importance of maintaining a satisfactory iron status, consequences of iron deficiency, dietary diversification, and identification of cheap iron-rich foods in their diet and combinations of foods that would enhance iron bioavailability. In addition, girls were educated about the beneficial effects of iron supplements, the importance of compliance, and how to deal with side effects, if any. The educational messages were formulated to have a special appeal to adolescent girls. Specially designed cards and flip charts were used as visual aids. These were hand-made and therefore did not require any special equipment for preparation. To carry out the educational programme, only a classroom and a trained facilitator (educator) was required.

The first education session at the commencement of the intervention period was a 45-minute lecture and discussion. Two additional education sessions in the form of interactive group discussions were conducted during the intervention period to reinforce these messages. Because land was available for cultivation of home gardens in the rural area, the educational messages there were suitably modified.

The educators were young adults and not teachers, and discussion was carried out as a separate activity to differentiate it from routine examination-oriented teaching. No attempt was made to link it with routine teaching. However, note was made of nutrition-related information included in the school curriculum to prevent conflicting messages from being given.

Measurements

The anthropometric measurements included weight and height, and the body mass index (BMI) was calculated from these measurements. The haemoglobin concentration was measured by the cyanmethaemoglobin method using standards obtained from Sigma Chemicals [11]. Serum iron and total iron-binding capacity were determined by a colourimetric method (Sigma diagnostic reagent kits, USA, catalogue no. 565). Serum ferritin concentration was measured by a sandwich ELISA (enzyme-linked immunosorbent assay) method [12]. All measurements were carried out in duplicate.

Statistical analysis

Data were entered on a DBase 3+ programme, and statistical analysis was carried out by the Epi-Info version 6.02 programme and SPSS for windows, version 7.0 [13]. Baseline characteristics of the three groups were compared by the chi-square test for categorical variables and analysis of variance (ANOVA) for continuous variables. The significance of effects of intervention was assessed within each group by the paired *t* test, and the changes among groups were compared by ANOVA or the Kruskal-Wallis test (if the variables were not normally distributed or the variances were not homogeneous). Because serum ferritin concentration showed a skewed distribution, log-transformed values were used in all analyses.

Ethical aspects

This study was approved by the Ethical Review Committee of the Faculty of Medicine, University of Colombo, Sri Lanka. Written permission was obtained from the Ministry of Education and from the principals of the respective schools after the importance of the project and its benefit had been explained. Each participant and her parent or guardian gave written informed consent before being recruited for the study.

Results

Baseline KAP regarding nutrition

The questionnaire on KAP regarding nutrition revealed that only 45% of subjects in the urban area and 65% of subjects in the rural area were aware that iron deficiency was a major nutritional problem. More than 70% of urban subjects and more than 90% of rural subjects wanted to know whether they had anaemia and wanted to correct the problem if it was present. Sixty-eight percent of urban subjects and 94% of rural subjects indicated willingness to make a behavioural change following education.

Effect of educational intervention on KAP

There were no significant differences in age, age at menarche, or anthropometric measurements among the group receiving education plus iron, the group receiving education plus placebo, and the control group (table 2). Similarly, there were no significant differences in baseline KAP regarding nutrition among the three groups in each area. However, the baseline knowledge of nutrition was significantly higher in the rural area than in the urban area ($p < .02$).

There was a significant increase in knowledge of nutrition among the intervention groups (those receiv-

TABLE 2. Age, age at menarche, and anthropometric data of adolescent schoolgirls[a] (means ± SD)

	Urban			Rural		
Characteristic	Group 1	Group 2	Control	Group 1	Group 2	Control
Age (yr)	15.5 ± 1.1	15.5 ± 1.0	15.9 ± 1.3	15.5 ± 1.1	15.5 ± 1.2	15.4 ± 1.1
Age at menarche (yr)	13.0 ± 1.2	13.1 ± 1.2	12.7 ± 1.2	12.9 ± 1.2	13.2 ± 1.1	13.1 ± 1.1
Weight (kg)	42.2 ± 6.5	41.5 ± 6.6	42.3 ± 6.4	43.2 ± 6.6	41.9 ± 6.3	41.1 ± 6.3
Height (cm)	152.9 ± 6.6	152.6 ± 5.5	153.3 ± 7.3	154.7 ± 5.9	154.2 ± 5.8	153.6 ± 5.7
BMI (kg/m^2)	18.0 ± 2.3	17.8 ± 2.4	18.1 ± 3.3	18.0 ± 2.5	17.6 ± 2.2	17.4 ± 2.2

a. Group 1 (237 urban and 96 rural subjects) received education plus iron supplementation. Group 2 (236 urban and 100 rural subjects) received education plus placebo. The control group had 97 urban and 123 rural subjects.

ing education plus iron supplementation or education plus placebo) in both the urban and the rural areas ($p < .001$) and no change in the control groups (table 3). In the rural area, the scores on knowledge remained elevated over baseline values ($p < .001$) three months after the end of the intervention. The schools in the urban area were smaller and had fewer children in each class. The questionnaire was administered on the day after blood collection, and the number of girls present in school on that day in the urban area was too small to permit statistical comparison.

Increase in knowledge of nutrition was also associated with desirable changes in intake of some foods that were promoted (tables 4 and 5). A significant ($p < .01$) increase in intake of leafy vegetables and guava, a tropical fruit, was noted in the urban area after educational intervention, and these changes were sustained even three months after the intervention stopped. An increase ($p < .01$) in intake of guava was also noted after intervention in the rural area, and this increase was maintained ($p < .05$) three months after the end of the intervention. An increase in intake of dried fish was noted in both areas, but this increase was not sustained. A significant increase ($p < .001$) in intake of fruits with meals was noted in both areas.

Compliance with iron supplement intake

Each girl received 70 tablets of ferrous sulphate or a placebo. The number of tablets remaining in the container and the number of squares marked on the calendar were counted at the end of the 10-week intervention period. When there was a discrepancy between the number of tablets remaining in the container and entries on the calendar, the data were not included. There was no significant difference in compliance

TABLE 3. Effect of intervention on knowledge of nutrition measured by a multiple-choice questionnaire (mean ± SD score out of 100 points)

Group	n^a	Baseline	End of intervention
Urban			
Education + iron	183	58.7 ± 12.1	64.6 ± 13.6[b]
Education + placebo	182	58.4 ± 12.5	63.5 ± 12.6[b]
Control	44	59.0 ± 13.2	61.6 ± 12.1
Rural			
Education + iron	68	63.2 ± 12.2[c]	70.8 ± 16.0[b]
Education + placebo	69	62.7 ± 10.8[c]	71.9 ± 13.2[b]
Control	86	62.3 ± 8.5	61.1 ± 10.0

a. Only subjects with complete data were included.
b. Significantly higher than baseline values by paired *t* test ($p < .001$).
c. Significantly higher than comparable group in the urban area ($p < .02$).

TABLE 4. Effect of intervention on intake of selected foods among girls in the urban area (percentage of subjects consuming food more than twice a week)

	Groups 1 and 2 (intervention)[a]					Control		
Food	Baseline ($n = 458$)	End of intervention ($n = 393$)	p^b	3 mo after end of intervention ($n = 61$)	p^b	Baseline ($n = 66$)	End of intervention ($n = 74$)	p^b
Dried fish	18.8	28.8	.0006	18.2	NS	19.7	12.2	NS
Meat	13.4	17.5	NS	18.2	NS	45.4	39.2	NS
Eggs	26.9	37.4	.0009	29.1	NS	40.9	40.5	NS
DGLV1[c]	9.1	21.5	.0001	21.8	.0038	24.2	14.9	NS
DGLV2[c]	16.8	30.1	.0001	36.4	.0003	33.3	24.3	NS
Guava	5.8	12.9	.0003	14.5	.0193	4.5	6.8	NS
Papaw	12.3	17.5	.0285	25.5	.0029	18.1	10.8	NS
Mango	20.7	29.8	.0023	29.1	NS	36.4	40.5	NS
Fruit with meals	50.0	67.0	.0001	90.0	.0001	48.5	60.8	NS

a. Group 1 received education plus iron supplementation; group 2 received education plus placebo.
b. The *p* values are for the comparison with baseline values by the test of proportions. NS, Not significant.
c. DGLV1 and DGLV2 refer to two types of dark-green leafy vegetables.

TABLE 5. Effect of intervention on intake of selected foods among girls in the rural area (percentage of subjects consuming food more than twice a week)

	Groups 1 and 2 (intervention)[a]					Control		
Food	Baseline ($n = 175$)	End of intervention ($n = 166$)	p^b	3 mo after end of intervention ($n = 163$)	p^b	Baseline ($n = 108$)	End of intervention ($n = 92$)	p^b
Dried fish	24.3	35.6	.0270	25.5	NS	30.6	34.0	NS
Meat	2.3	5.2	NS	6.4	NS	6.5	5.4	NS
Eggs	26.6	33.3	NS	23.6	NS	18.5	25.0	NS
DGLV1[c]	13.6	20.0	NS	16.6	NS	17.5	18.5	NS
DGLV2[c]	22.6	20.7	NS	17.2	NS	9.3	13.0	NS
Guava	9.0	29.6	.0001	22.9	.0006	25.9	33.7	NS
Papaw	11.9	8.9	NS	18.2	NS	9.3	15.2	NS
Mango	6.8	8.1	NS	7.0	NS	10.2	2.1	NS
Fruit with meals	51.0	71.0	.0001	60.0	NS	50.0	50.0	NS

a. Group 1 received education plus iron supplementation; group 2 received education plus placebo.
b. The *p* values are for the comparison with baseline values by the test of proportions. NS, Not significant.
c. DGLV1 and DGLV2 refer to two types of dark-green leafy vegetables.

between girls given iron supplements and those given a placebo (fig. 2). In the urban area, 71% of subjects in the iron-supplemented group and 77% of girls in the placebo group took more than 50% of the tablets provided; in the rural area, the percentages were 90% and 93%, respectively. Compliance data were not available for 66 girls in the urban area (34 given iron and 32 given placebo) and 36 girls in the rural area (14 given iron and 22 given placebo) who were not present in school for post-intervention assessment. The main reason given for not taking all the tablets was "forgetting." Only seven girls in the urban area and one girl in the rural area in the iron-supplemented group complained of side effects: nausea (two subjects), constipation (three subjects), and headache (three subjects). No side effects were reported by girls in the placebo groups in either the rural or the urban area.

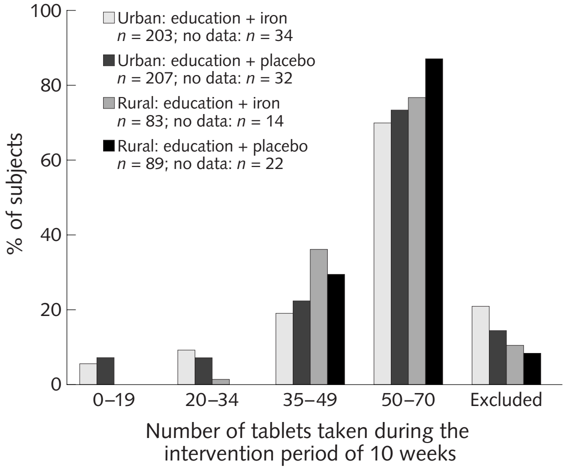

FIG. 2. Intake of iron supplements versus placebo

Effect of intervention on haemoglobin concentration and iron status

There were no significant differences in baseline haemoglobin concentration among the three groups (table 6). A significant increase in haemoglobin concentration was noted in intervention groups in both areas, but not in control groups. However, in both areas the increase was greater among girls receiving education plus iron than among those receiving education plus placebo. The prevalence of anaemia (haemoglobin < 120 g/L) in the urban area decreased by 11% in the group receiving education plus iron and by 6% in the group receiving education plus placebo. The decrease was greater in the rural area: 13% in the group receiving education plus iron and 9% in the group receiving education plus placebo.

Serum transferrin saturation values were not available for some girls because there was insufficient serum for the determination of iron and total iron-binding capacity. The post-intervention transferrin saturation values were significantly higher ($p < .001$) than baseline values in intervention groups in both areas (table 7). A significant increase ($p < .001$) in serum ferritin concentration was also noted in the two intervention groups in both areas, but not in the control groups (table 7). The mean change in serum ferritin concentration in the group receiving education plus iron in the urban area (8.0 µg/L) was significantly higher ($p < .05$) than in the group receiving education plus placebo (4.9 µg/L), but it did not reach statistical significance in the rural area (9.4 vs 4.5 µg/L). The percentage of subjects with depleted iron stores (serum ferritin < 12 µg/L) decreased from 24% to 9% in the

TABLE 6. Effect of intervention on haemoglobin concentration

Group[a]	n	Mean ± SD haemoglobin concentration (g/L)				Change in anaemia prevalence (%)
		Baseline	End of intervention	Mean change	p[b]	
Urban[c,d]						
Group 1	202	130.5 ± 14.5	135.9 ± 10.6	5.31	.000	–11.4
Anaemic	35	107.3 ± 12.9	128.7 ± 13.3	21.34	.000	
Non-anaemic	167	135.4 ± 9.2	137.4 ± 9.3	1.95	.013	
Group 2	207	129.5 ± 12.9	131.3 ± 11.6	1.81	.003	–6.3
Anaemic	44	110.8 ± 7.7	117.6 ± 11.3	6.84	.000	
Non-anaemic	163	134.5 ± 8.6	134.9 ± 8.6	0.45	NS	
Control	57	129.4 ± 14.4	129.4 ± 12.8	–0.06	NS	–5.3
Anaemic	11	106.9 ± 9.5	114.6 ± 16.6	7.64	NS	
Non-anaemic	46	134.8 ± 9.2	132.9 ± 8.6	–1.91	NS	
Rural[c]						
Group 1	79	128.6 ± 11.0	134.2 ± 9.9	5.61	.000	–12.6
Anaemic	16	113.9 ± 5.5	130.6 ± 13.5	16.75	.000	
Non-anaemic	63	132.4 ± 8.1	135.2 ± 8.6	2.78	.049	
Group 2	77	130.4 ± 11.0	133.7 ± 8.8	3.30	.010	–9.1
Anaemic	13	113.8 ± 4.4	127.5 ± 10.8	13.77	.000	
Non-anaemic	64	133.7 ± 8.6	135.0 ± 7.8	13.10	NS	
Control	80	129.2 ± 9.9	128.9 ± 8.9	–0.35	NS	–2.5
Anaemic	14	113.9 ± 6.4	117.8 ± 8.2	3.93	NS	
Non-anaemic	66	132.5 ± 7.1	131.2 ± 7.2	–1.26	NS	

a. Group 1 received education plus iron supplementation; group 2 received education plus placebo. Anaemic girls had haemoglobin concentrations < 120 g/L.

b. Significance was assessed by paired *t* test. Haemoglobin concentration could not be measured in some subjects because the blood was clotted. NS, Not significant.

c. Significant difference in mean change among the three groups in each area ($p <.001$).

d. Significantly greater mean change in group 1 than in group 2 in urban area by ANOVA ($p = .003$).

group receiving education plus iron in the urban area and from 25% to 12% in the corresponding group in the rural area. In the urban group receiving education plus placebo, the percentage decreased from 27% to 18%, but no change was noted in the rural area.

Short-term sustainability of the intervention programme

The sustainability of the intervention was assessed three months after the end of the intervention. Data were available for 36 urban and 80 rural subjects receiving education plus iron, and for 41 urban and 83 rural subjects receiving education plus placebo.

The haemoglobin concentration remained elevated at post-intervention values in the rural area but decreased to baseline values after three months of non-intervention in the urban area (table 8). The serum ferritin concentration remained significantly higher than the baseline values in both intervention groups in the rural area but not in the urban area (table 8). However, in the rural area, a higher ferritin concentration was maintained in the group receiving education plus iron (mean change, 8.1 μg/L; $p < .001$) than in the group receiving education plus placebo (mean change, 5.2 μg/L; $p < .05$).

Discussion

We developed an intervention programme aimed at improving the iron status of adolescent schoolgirls, taking into consideration the differences between urban and rural areas. The programme had two approaches: dietary diversification and iron supplementation. Because adolescent girls belonging to groups of low SES are at high risk of developing micronutrient deficiencies, the effectiveness of the intervention programme was evaluated in schoolgirls belonging to groups of low SES. Girls in both areas had similar SES, but the urban girls had poorer living conditions than those in the rural area. Land for home gardens was available only in the rural area.

The iron, vitamin A, and general nutritional status of these subjects has been reported earlier [14]. Our study population did not have a satisfactory nutritional status: 21% had BMI values less than the fifth percentile for age [15]. Deficiencies of iron and vitamin A

TABLE 7. Effect of intervention on iron status

	Urban				Rural			
	Baseline		End of intervention		Baseline		End of intervention	
Measurement[a]	*n*	Mean ± SD	*n*	Mean ± SD	*n*	Mean ± SD	*n*	Mean ± SD
Mean ± SD transferrin saturation (%)[b]								
Group 1								
Total	89	26.4 ± 11.0	89	31.4 ± 12.1[c]	48	33.1 ± 8.5	48	40.9 ± 11.8[c]
TS <16%	16	10.6 ± 3.8	7	10.6 ± 3.5	2	13.3 ± 1.3	—	—
Group 2								
Total	84	24.0 ± 9.3	84	28.4 ± 9.9[c]	40	31.3 ± 9.4	40	35.2 ± 9.8[d]
TS <16%	20	11.2 ± 3.1	7	12.6 ± 2.8	6	12.8 ± 2.1	—	—
Control								
Total	25	25.9 ± 4.2	25	24.8 ± 7.5	35	36.3 ± 8.6	35	40.1 ± 17.2
TS <16%	—	—	3	14.4 ± 1.7	1	13.7	3	8.2 ± 6.8
Mean ± SD ferritin (μg/L)[e]								
Group 1								
Total	202	18.9 ± 2.0	202	26.9 ± 2.0[c]	73	19.8 ± 2.2	73	29.1 ± 2.1[c]
Ferritin <12 μg/L	49	7.9 ± 1.4	19	7.3 ± 1.5	18	6.6 ± 1.5	9	7.5 ± 1.5
Group 2								
Total	196	16.8 ± 2.0	196	21.7 ± 1.9[c]	78	17.1 ± 2.3	78	1.6 ± 2.3[d]
Ferritin <12 μg/L	52	6.9 ± 1.5	35	7.8 ± 1.4	21	5.6 ± 1.4	21	7.2 ±12.5
Control								
Total	71	16.4 ± 2.1	71	18.0 ± 1.9	84	22.5 ± 1.9	84	22.5 ± 1.9
Ferritin <12 mg/L	20	7.0 ± 1.5	18	8.2 ± 1.4	16	8.3 ± 1.3	11	7.7 ± 1.4

a. Group 1 received education plus iron supplementation; group 2 received education plus placebo. Data were not available for some subjects because serum was insufficient.

b. Transferrin saturation (TS) = serum iron (μg/dl) × 100/serum total iron-binding capacity (μg/dl).

c. Significantly higher than baseline values by paired *t* test ($p < .001$).

d. $p < .01$.

e. The values given are the geometric means. Statistical analysis was carried out on log-transformed values.

were also important problems in this population. The prevalence of anaemia was 18% (urban 19%, rural 17%). Nearly 25% of the girls had depleted iron stores (serum ferritin < 12 μg/L), 29% had borderline iron stores (serum ferritin 12–20 μg/L), and 21% had low serum vitamin A levels (< 0.70 μmol/L), indicating the need to develop strategies to improve their nutritional status.

A higher percentage of subjects in the rural area than in the urban area had more desirable attitudes. The intervention programme was planned for a 10-week period so that it could be carried out and evaluated during one school semester. In both the urban and the rural area, educational intervention resulted in a significant improvement over baseline in scores of nutrition knowledge. Increased awareness of the adverse consequences of iron deficiency and knowledge about dietary diversification resulted in a desirable change in food habits, for example, increased consumption of fruits, such as guavas, and of leafy vegetables, and consumption of fruits with meals to enhance iron absorption.

Only a few studies have attempted to improve nutritional status by educational intervention. Nutrition education was effective in improving feeding practices among poor urban mothers in Bangladesh [16] and in increasing consumption of vitamin A–rich foods in Thailand [17]. Our educational programme used flip charts and posters as visual aids, without any special equipment, so that it could be implemented in schools with limited resources. The programme was implemented by young adults who were close to the age of the participants, not by teachers. It has been reported that Brazilian high-school students responded better when educators perceived as similar to themselves were used to deliver nutritional messages rather than experts [18]. Additionally, the use of such instructors differentiates the programme from routine examination-oriented teaching and is likely to bring about a positive change in behaviour.

Nutrition education is likely to have a smaller immediate impact than supplementation. However, nutrition education may have a greater long-term benefit than supplementation and hence should be an integral part of any intervention package. The failure of many iron-supplementation programmes has been attributed to poor compliance, due mainly to undesirable side effects. Education before supplementation has

TABLE 8. Sustainability of the effect of intervention on iron status

Group[a]	*n*	Baseline	At end of intervention	3 mo after end of intervention
Mean ± SD haemoglobin (g/L)				
Urban				
Group 1	36	125.3 ± 13.9	132.3 ± 7.4[b]	127.5 ± 8.3
Group 2	41	127.7 ± 11.8	128.1 ± 13.1[c]	125.8 ± 10.6
Rural				
Group 1	69	128.5 ± 10.9	134.4 ± 10.1[d]	138.7 ± 12.2[d]
Group 2	60	129.6 ± 10.8	133.9 ± 8.4[d]	136.6 ± 9.7[d]
Mean ± SD ferritin (μg/L)[e]				
Urban				
Group 1	37	19.4 ± 2.2	30.1 ± 2.0[d]	16.7 ± 2.1
Group 2	39	14.9 ± 2.1	18.7 ± 1.9[c]	15.2 ± 1.8
Rural				
Group 1	57	20.7 ± 2.3	30.9 ± 2.0[b]	288 ± 2.1[d]
Group 2	61	16.8 ± 2.2	27.3 ± 2.1[c]	22.0 ± 2.2[c]

a. Group 1 received education plus iron supplementation; group 2 received education plus placebo.

b. Significantly higher than baseline values by paired *t* test ($p < .01$).

c. $p < .05$.

d. $p < .001$.

e. The values given are the geometric means. Statistical analysis was carried out on log-transformed values.

been recommended to increase compliance [8]. In our study, the high compliance in both areas could be due to the fact that supplementation was given in combination with education. An additional reason for increased compliance in our study was that the girls were asked to take the tablet at nearly the same time every day, before going to bed. Furthermore, side effects, which are often short-term, may go unnoticed during sleep. There was no significant difference in compliance between those taking iron and those taking placebo, indicating that any lack of compliance was not due to side effects. The major reason given for not taking all the supplements or placebo was "forgetting" to take the tablets.

In Indonesia and Sri Lanka, weekly supplementation with iron given in school under supervised conditions was found to be as effective as daily supplementation [7, 19]. In our study, in order to minimize disruption of school schedules and reduce the need for personnel to distribute the tablets, the girls themselves were given the responsibility for taking the supplements daily at home. There is an obvious need also to test the effectiveness of weekly iron supplementation under conditions in which the subjects are routinely given a reminder weekly at home or school to take the supplement.

When the impact of intervention on the iron status of the girls was evaluated, nutrition education, either alone or in combination with iron supplementation, resulted in a positive shift in the distribution of haemoglobin. There was also a reduction in the prevalence of anaemia in the intervention groups in both urban and rural areas. However, the improvement was greater among girls receiving education plus iron than among those receiving education plus placebo. The change in haemoglobin concentration could not be attributed to an effect of time, since there was no improvement in control groups in both areas. There was also a significant improvement in iron status, as indicated by an increase in percent transferrin saturation and ferritin concentration in the serum. However, the increase was greater in the group receiving education plus iron than in the group receiving education plus placebo, indicating the need to combine the strategies.

A confounding factor could be the effect of anthelminthic therapy (one 500-mg tablet of mebendazole) in reducing worm load. The prevalence of soil-transmitted helminthic infection and its impact on nutritional status in this population has been reported previously [20]. The prevalence of infection with *Ascaris lumbricoides* and *Trichuris trichiura* was significantly lower in the rural area than in the urban area, whereas the prevalence of hookworm (*Necator americanus*) infection was low in both areas, and only mild infection was noted. However, there was no significant effect of helminthic infection on body mass index or haemoglobin concentration in our study population, probably because only mild helminthic infection was noted. Further, there was no significant difference between initially infected and initially uninfected subjects in the mean change in haemoglobin concentration after intervention. Thus, the change in haemoglobin or iron status is unlikely to be due to anthelminthic therapy.

Sustainability is an important factor influencing the success of an intervention programme. Follow-up was more difficult in the urban area than in the rural area, because some subjects did not attend school regularly or changed schools. Although some desirable dietary practices were maintained in the urban area, the post-intervention increase in haemoglobin or serum ferritin concentration was not maintained. In contrast, in the rural area the scores on knowledge of nutrition remained significantly elevated even three months after the end of the intervention, and the increase in haemoglobin concentration and the improvement in iron status after intervention were sustained. The greater increase in serum ferritin concentration in the group receiving education plus iron than in the group receiving education plus placebo could be due to larger gains in iron stores during the intervention period.

The difference in sustainability between the two areas could be attributable to a number of factors. First, the subjects in the rural area had more desirable attitudes than those in the urban area. Among subjects in the urban area, poor living conditions, lack of land for cultivation of home gardens, and the social pressures of community living may have contributed to dwindling of the initial enthusiasm to modify their diet. Thus, in urban areas, reinforcement of educational messages is necessary to ensure sustainability. In rural areas, however, dietary diversification could be effected more easily, since many girls had home gardens even at the beginning of the study. We propose that nutrition education in combination with iron supplementation should be carried out in all less-privileged schools, possibly in the first semester of the school year. This could be followed by at least two more short education sessions in subsequent semesters. Girls who have completed their schooling could be trained to carry out the nutrition education programme.

In summary, our study showed that a nutrition education programme using educational materials prepared at low cost had a significant positive impact on the iron status of adolescent schoolgirls in both urban and rural areas. Education in combination with unsupervised daily iron supplementation resulted in a greater improvement than education alone. The intervention programme was more sustainable in the rural area than in the urban area, and the sustainability could be increased in the urban area by reinforcement of educational messages. A similar intervention programme could be implemented in other areas, with minor modifications to the education messages to suit each area. Our study confirms the need for supplementation to be carried out with education in order to increase its effectiveness.

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A life-cycle approach to multi-micronutrient supplementation: Rationale and programme concept

Rainer Gross, Guillermo Lopez de Romaña, and John Tomaro

Abstract

In many parts of the world, people suffer from different micronutrient deficiencies due to the same aetiology of micronutrient deficiency and physiological interactions between the micronutrient metabolisms. To reduce and alleviate micronutrient deficiencies, supplementation programmes for different micronutrients are often implemented simultaneously. Since operational strategies and distribution systems can be similar for each micronutrient, efforts and resources are duplicated and cost-effectiveness is therefore reduced. Widespread micronutrient deficiencies in populations have a deep-rooted causality within the life cycle of people. They are strongly associated with poverty and are passed from one generation to the next. Recently, multi-micronutrient supplementation has been suggested to break this vicious circle of micronutrient deficiencies within the life cycle. However, several technical and scientific aspects have to be considered for the implementation of a multi-micronutrient supplementation programme.

Introduction

From a global perspective and in spite of decades of nutrition programmes, micronutrient deficiency is at epidemic proportions in many developing societies, and certainly in the least developed nations. Given the magnitude of the problem and its impact on the development of communities, micronutrient deficiency may represent the most important public health challenge and the most urgent public health need. According to a WHO estimate, about 80% of the world's population is likely to be suffering from iron deficiency [1]. Approximately another 275 million people are at risk of vitamin A deficiency. Although there are no estimates of the number of people afflicted, deficiencies of folate or riboflavin are expected to have adverse health consequences.

At present three food-related interventions are practised to reduce micronutrient deficiencies in communities: supplementation, fortification, and promotion of dietary changes [2]. Each strategy has different strengths and deficiencies in terms of effectiveness, cost, efficiency, sustainability, and replicability. For example, supplementation may be the preferred option if fortification or dietary changes are not feasible in the vulnerable population or if they will take too long to reduce the nutritional problem. In addition, supplementation may be very cost-effective, as in the case of iron. However, supplementation programmes are often too limited in coverage.

In general, the highest physiological risk of micronutrient deficiencies results from negative nutrient balance due to rapid growth of body tissue and/or nutrient losses, combined with insufficient nutrient intake. As indicated in figure 1, the risk of micronutrient deficiency is often greatest when a woman is pregnant and when a child is young and growing. On the basis of these clinical observations, most micronutrients have been administered during one of these developmental stages.

However, a closer look at figure 1 indicates that the micronutrient problem occurs when girls enter adolescence, a time when linear growth accelerates, some micronutrient losses, such as iron, increase due to menarche, and micronutrient intake does not change and in some societies actually decreases. At that moment, micronutrient stores are consumed and depleted. Additionally, the risk of infectious diseases increases.

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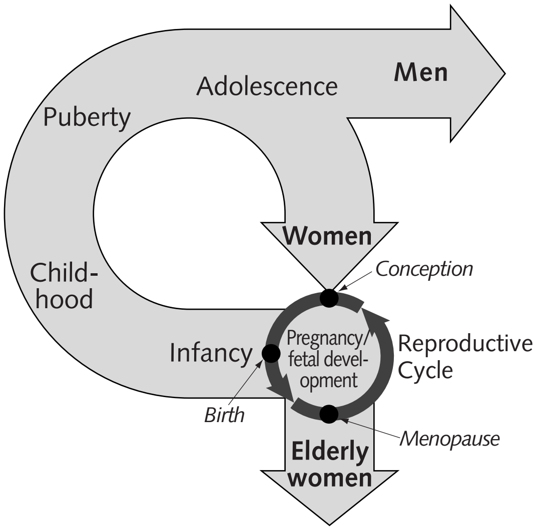

FIG. 1. Critical stages of micronutrients in the female life cycle

Multi-micronutrient deficiencies

In most cases of micronutrient deficiency, individuals are not deficient in only one nutrient. Generally, multi-micronutrient deficiencies occur because micronutrients interact; the deficiency of one micronutrient can cause deficiencies of others. For example, several studies have shown that a poor vitamin A status may contribute to iron deficiency [3]. The low consumption of meat products and increased intake of cereals with high phytate contents may be responsible for iron deficiency. There is a high likelihood that this eating pattern will also lead to zinc deficiency [4]. At the same time, the presence of a key micronutrient can catalyse another. For example, zinc has been shown to be essential for the metabolism of vitamin A from the liver [5]. The limitations of single-micronutrient interventions have been stressed recently by Solomons et al. [6], with the example of zinc.

Furthermore, the supplementation of a limiting micronutrient may itself impair the status of another. For example, it has been shown that iron or folate supplementation may inhibit zinc or copper absorption [7–9]. Another cause of a simultaneous deficiency of several micronutrients is the occurrence of infectious and invasive diseases. In the case of infection, the requirements of several micronutrients increase and losses occur [10].

Low compliance with supplementation

The effectiveness of supplementation programmes is very often low because of low compliance [11]. Some data indicate that there is an inverse relation between compliance and frequency of iron administration [12]. This may be because of the higher organizational and economic requirements for purchasing and distributing daily dosing supplements. Moreover, daily consumption of some micronutrients, e.g., iron during pregnancy, may cause side effects that affect compliance. Weekly administration may help to overcome these constraints.

The life-cycle approach to multi-micronutrient supplementation

From a practical as well as a physiological standpoint [3], micronutrient interventions based on the curative, therapeutic administration of micronutrients may be another reason for low effectiveness. It has been repeatedly suggested that, for example, iron-supplementation programmes should shift from a curative to a preventive approach [13, 14]. This argument is valid for other micronutrient deficiencies as well [15]. Micronutrients should be administered during phases of the life cycle in which micronutrient requirements start to increase, not just when body stores are depleted and deficiencies occur. A cost-effective and preventive public health strategy is needed that addresses all major micronutrients. The life-cycle approach to multi-micronutrient supplementation is the preventive administration of supplements containing a range of micronutrients needed to promote proper growth and development for the physiologically most vulnerable age groups and their offspring.

Multi-micronutrient weekly administration

Table 1 indicates the micronutrients in tablets and liquids and the doses that should be administered weekly to non-pregnant women and small children. These two supplements would cover the major micronutrient needs of these two nutritionally vulnerable groups. One tablet (or capsule) should contain all the micronutrients required by school-age children until puberty. Two tablets (or capsules) should meet micronutrient needs that arise with the onset of puberty. The dosage suggested is based on the minimum daily requirements for pregnant women defined by the US Food and Drug Administration (FDA) [16] and suggested at a recent UNICEF/WHO/UNU technical meeting [17]. An additional tablet could be administered daily during pregnancy. However, pregnant women are not considered here for intervention because the proposed supplementation approach should not interfere with conventional daily iron-supplementation programmes as long as there is no general recommendation available for multi-micronutrient supplementation during pregnancy. Women might take the

TABLE 1. Suggested micronutrient composition for weekly administration in children and women

Micronutrient	Capsule[a]	Liquid[b]
Vitamin A (IU)	2,500	8,000
Vitamin D (IU)	200	700
Vitamin C (mg)	70	70
Vitamin E (mg)	10	35
Vitamin B_1 (mg)	1.4	4.9
Vitamin B_2 (mg)	1.4	4.9
Vitamin B_6 (mg)	1.9	6.6
Vitamin B_{12} (µg)	2.6	4.5
Niacin (mg)	18	63
Folic acid (µg)	400	1,400
Iron (mg)	30	35
Zinc (mg)	15	25
Copper (mg)	2	7
Selenium (µg)	65	65

a. Children 6–11 years of age: one capsule; adolescent girls and non-pregnant women: two capsules.

b. For children 0–5 years of age.

supplements during the first trimester of pregnancy when they are unaware of their changing physiology.

Concern has been expressed that high doses of vitamin A at this early stage of pregnancy may have a teratogenic effect. However, the dose of vitamin A in the two tablets is well below the WHO recommendations for supplementation of pregnant women living in endemically vitamin A–deficient areas. "A weekly supplementation of up to 25,000 IU (8,500 g RE) is a safe alternative to daily supplementation during pregnancy"[18].

Iron and zinc deficiencies often occur simultaneously. The similar causes of iron, zinc, and probably also copper deficiency and the low price of the three elements suggest that they should be incorporated in the same dose. Because of the competition between iron and zinc during absorption, they should be administered at a ratio close to 1:1 [19].

In addition to its physiological function, vitamin C should be incorporated because it increases the bioavailability of iron. Furthermore, the antioxidant characteristic of ascorbic acid functions as a stabilizer for other micronutrients. This is especially relevant for liquid supplements.

The efficacy of riboflavin supplement given at fortnightly intervals to pregnant and lactating women has been demonstrated [20]. Furthermore, twice-weekly multi-micronutrient supplementation with iron, riboflavin, vitamin C, and thiamine was effective in children [21]. Folic acid should be included in tablets as well, because recent data suggest that weekly dosing of folate is as effective as daily dosing [22].

Approach to intervention

Table 2 presents an intervention approach that varies by age group to follow the life-cycle approach. As suggested in this approach, several micronutrients are simultaneously administered to the physiologically most vulnerable age groups. The intervention approach calls for a once-a-year campaign for a 14-week supplementation designed to reach all pre-schoolchildren and primary schoolchildren aged 2 to 10 years and, starting at age 11, all adolescent girls and non-pregnant women in the reproductive age group. In the first year of the programme, infants and toddlers from 4 to 23 months of age would be

TABLE 2. Intervention groups for a life-cycle approach to a multi-micronutrient supplementation programme

Intervention group	Infants and toddlers		Pre-schoolers	School-children	Adolescent girls	Non-pregnant women	Pregnant women
Age	Newborns at 4 mo	All 4–23 mo	24–71 mo	6–10 yr	11–16 yr	16–40 yr	14–45 yr
Design	Routine	Campaign					Routine Fe + folic acid [a] daily for 6 mo
Supplement	Liquid			1 capsule	2 capsules ("Weekly Fit-All-Pill")		
Duration	Weekly for for 12 mo	Weekly for 3–12 mo	Weekly for 14 wk/yr				
Monitoring and evaluation							
Compliance	1/mo						
Effectiveness	1/yr	4/yr	At beginning and end				
Impact	1/yr						

a. According to the results of a joint UNICEF/UNU/WHO meeting [17], the daily administration of multi-micronutrients is recommended for pregnant women.

included. Up to 1 year of age, infants would receive the weekly supplement for 52 weeks. Children older than 1 year would be given the supplement until they reached 24 months of age. All infants who were under 4 months at the start of the campaign and who did not receive any supplement would begin to receive their supplements at the age of 4 months and continue to receive the supplements for 1 year.

Beginning in the second programme year and thereafter, the supplements would be delivered through two different distribution channels: routine service and campaign. Each infant would receive the supplements from the health service on a routine basis starting at 4 months of age. After 24 months, all individuals would receive their supplements during a region-wide campaign. Since there is little experience with the sustainability of the effect of absorbed micronutrients, close monitoring and evaluation would take place during the first year of the programme to measure compliance, effectiveness (haemoglobin level), and impact (e.g., incidence of diseases, physical activity, and perception of wellness).

To ensure that the programme achieves maximum impact, a comprehensive communication strategy will need to precede and occur simultaneously with the implementation of the approach. The communication programme would consist of an advocacy component that addresses and informs key decision makers and opinion leaders, training of trainers to reach professionals who link directly with the community, and an information component that informs the general population through mass media and other means about the objectives and contents of the programme.

Costs

The administration of several micronutrients to different vulnerable groups at the same time dramatically increases the cost of supplementation programmes. However, effective preventive supplementation achieved through weekly administration of micronutrients would be less expensive than daily dosing [23] and potentially more beneficial in terms of costs and health outcomes. Table 3 presents the cost calculations of the life-cycle approach to multi-micronutrient supplementation based on a population of 100,000 people. As indicated, approximately 50 US cents per capita per year would be needed to purchase the micronutrients. Additionally, in the first year a buffer stock of 25% of the total supplement requirement should be purchased. In addition to the cost of the supplements, the costs of distribution, communication, and monitoring have to be estimated. Still, if a sound communication programme and a thorough monitoring component can achieve compliance, it is anticipated that supplementation can be very efficiently achieved.

TABLE 3. Cost calculation of multi-micronutrient supplements on the basis of a total population of 100,000

Group	Population	Weeks	Doses (thousands)	Costs (US$)	
				Per dose	Total
Infants (4–24 mo)					
Campaign	2,500	14–52	56	0.063	3,530
Routine	1,000	52	52	0.063	3,275
Pre-schoolers (3–5 yr)	7,500	14	105	0.063	6,615
Schoolchildren (6–10 yr)	15,000	14	210	0.03	6,300
Adolescent girls (11–16 yr)	7,500	14	2 × 105	0.03	6,300
Non-pregnant women	25,000	14	2 × 350	0.03	21,000
Total	58,500		Liquid: 213 Capsules: 1,120		13,420 33,600
Total costs					47,020

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Women and sustainable approaches to the management of iron deficiency

G. Oluyemisi Latunde-Dada

Abstract

Iron deficiency is the world's most common nutritional disorder and is predominantly responsible for anaemia in human populations. Its management and control involve iron supplementation and fortification of foods and, in developing countries, the control of parasitic infections as well. It is also important to formulate food-based strategies to improve the bioavailability of dietary iron, for example, by promoting culturally acceptable changes in food choices, processing, and preservation. These require sound scientific data from nutritional research and the participation of women scientists who are familiar with the local and sociocultural preferences of the target communities. Research has shown that the major effects of processing on iron availability are associated with the separation, dehulling, and cooking procedures. The magnitude of losses varies with the food type and processing technique. Blanching and homogenization of vegetables may account for up to 28% and 40% of soluble iron loss, respectively. Moreover, the traditional practice of adding kanwa *(an alkaline salt) to soften beans and to impart a green colour to vegetables during cooking results in reduced iron availability. In contrast, germination and fermentation have been shown to enhance the availability of iron from foods. Thus, traditional-food processing methods, such as fermentation, should be encouraged, actively promoted, and preserved.*

Introduction

The state of health of women and their general well-being constitute an important measure of the health of the whole population. Iron deficiency is the most prevalent nutritional disorder, particularly in third world countries [1]. Apart from young children, adolescent girls and women (table 1) [2] are the groups most vulnerable to anaemia (fig. 1) [3]. Women have additional iron requirements from puberty to menopause. This arises from the physiological requirements of menstruation, pregnancy, and, to some extent, lactation. In adolescent girls, iron loss (basal plus menstrual loss) is 1.4 mg/day, and the requirement for pregnant women is about 1,000 mg during the second and third trimesters. In most developing countries, the high iron demands of these groups are not met [4], mainly because of the poor availability of iron in tropical diets, thus leading to a high incidence of iron-deficiency anaemia among girls and women.

Importance of iron and the consequences of iron-deficiency anaemia

Iron is an important element in energy metabolism and many other metabolic processes in the human body. It is an essential component of haemoglobin in red blood cells. Its deficiency results in anaemia, with the attendant devastating consequences. Even before the onset of anaemia, iron deficiency has been implicated in the impairment of cognition, thermoregulation, physical work capacity [5], and immunocompetence [6] and in other functional abnormalities [7]. Iron deficiency impairs work performance by reducing the rate-limiting iron-dependent enzymes in muscle. The general symptoms of anaemia include weakness, lack of energy, breathlessness, and palpitation on exertion. An association between poor performance on a treadmill and low haemoglobin levels has been demonstrated [8–10]. The productivity of anaemic rubber tappers [11] and tea pickers [8, 12] is reduced.

The administration of iron promptly restores physical capacity. Because girls and women are more subject to iron deficiency and its associated debilitating consequences, the overall effects on their work capacity and productivity significantly reduce and impair their contribution to the economic development of society.

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TABLE 1. Prevalence of anaemia in developing countries based on national data for WHO regions

Region	% prevalence of anaemia (population in millions)				
	Children		Women (15–59 yr)		
	0–4 yr	5–14 yr	Pregnant	All	Men (15–59 yr)
Africa	33.1 (35.5)	52.0 (85.2)	46.9 (9.6)	37.9 (57.6)	28.0 (41.9)
Non-industrialized Americas	22.9 (13.0)	36.9 (39.5)	39.0 (3.8)	31.0 (44.9)	11.0 (15.8)
South-East Asia	52.7 (93.8)	63.9 (207.8)	79.6 (22.2)	60.0 (218.6)	42.4 (184.8)
Eastern Mediterranean	38.3 (28.1)	30.8 (37.9)	63.9 (8.8)	51.1 (60.6)	32.7 (41.5)
Non-industrialized West Pacific	14.7 (19.7)	56.9 (156)	38.5 (9.4)	33.8 (152.9)	36.0 (172.5)
Total	34 (190)	53 (526)	56 (54)	43 (535)	34 (456)

Source: ref. 2.

Iron also contributes significantly to the development of the brain [13]. Symptoms associated with abnormalities in mental behaviour and reduced intellectual performance have been observed in iron-deficient animals and children [14, 15]. They include apathy, irritability, lack of concentration, low scores in school, and reduced assimilation and learning capability [6, 16]. These are reversed after iron therapy [17].

Significant correlations have been found between iron levels and IQ [18]. Although these abnormalities may have multifactorial causes, iron plays an important metabolic role in changes in some neurotransmitters in the brain and in brain development. Iron-deficiency anaemia is thus deleterious to educational achievement and capability, and nutritional adequacy is a key determinant of the quality of life and the development of human resources. Iron-deficiency anaemia is therefore a key factor in preventing the full social, physical, and intellectual expression of human genetic potential. Maternal anaemia also results in foetal growth retardation, low-birthweight babies, and increased neonatal mortality [19].

The control of iron-deficiency anaemia continues to receive attention both nationally and internationally. The focus has been on iron supplementation, food fortification, and, in developing countries, the control of associated parasitic infection. The Plan of Action for Nutrition that was unanimously adopted in 1992 by governments attending the International Congress on Nutrition included approaches towards the prevention and control of micronutrient deficiencies by giving priority to food-based strategies. This is highly relevant to the developing countries of Africa, where iron supplementation and fortification are faced with seemingly insurmountable obstacles. Since low bioavailability of iron is a major contributory factor

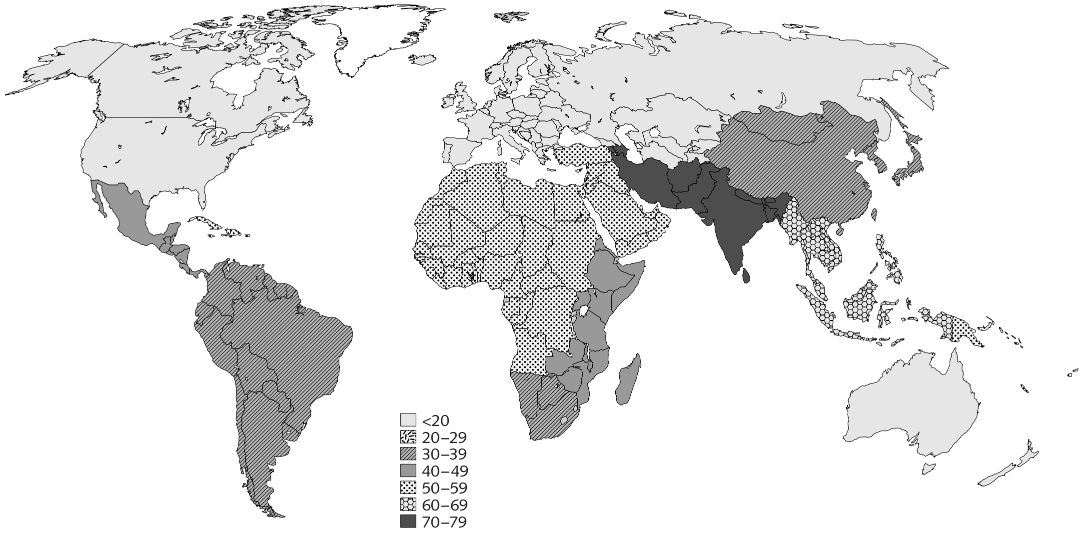

FIG. 1. WHO regional estimates of prevalence (%) of nutritional anaemia around 1988 among pregnant women with below-normal haemoglobin

to iron-deficiency anaemia, the improvement and enhancement of the absorption of dietary iron are the long-term sustainable approaches to the prevention of this nutritional disorder. The aim in formulating food-based strategies is to improve the bioavailability of dietary iron, for example, by promoting culturally acceptable changes in food choices, processing, and preservation. These efforts require a sound scientific database from nutritional research and the participation of women scientists who are familiar with the local and sociocultural preferences of the target communities. The approaches will vary in different countries according to food types, local diets, customs, processing, and traditional food systems. These issues were discussed most recently at the UNICEF/UNU/WHO/MI technical workshop on preventing iron deficiency in women and children held at UNICEF headquarters in October 1998 [20].

Food-based approaches to improving the bioavailability of dietary iron

Iron content of foods

Wide variations occur in the levels of iron in tropical foods. Tropical foods high in iron include legumes, such as soya bean, cowpea, and pigeon pea, and some cereals, such as teff, sorghum, and millet. Differences in iron content of plant foods may be due to crop variety (figs. 2 and 3), soil conditions, and maturity at harvest. Recent advances in maize breeding and genetics have addressed ways of increasing the levels of iron and possibly phytase (an enzyme that degrades phytic acid in the gut) in transgenic seeds [21]. In animal foods, iron levels can be affected by age, sex, nutrition, breed, and amount of activity of the animal. Differences also exist in the amount of iron in different tissues and organs (fig. 4). Exogenous iron in foods can be due to fortification, cooking utensils and cans used in processing, and even dirt. Contaminant iron in soil particles and drinking water may account for a significant intake of this element in Nigeria [22]. A lot of extrinsic iron is introduced into food items during the traditional stone milling still used in many areas of the third world [23].

Effects of processing on iron Levels and availability

Plant foods

Raw vegetables eaten in tropical countries, particularly Nigeria, could contribute significantly to the total iron intake. Green leafy vegetables are subjected to various processing procedures (fig. 5). These include blanching and homogenization to enhance the sensory characteristics of these vegetables and, in some cases, to detoxify antinutritional factors. Unfortunately,

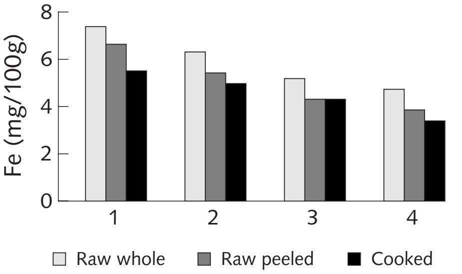

FIG. 2. Effects of plant variety and processing method on iron levels in cowpea. Varieties: 1, IT82D699; 2, IT81D994; 3, IT82E60; 4, IT84S2246-4

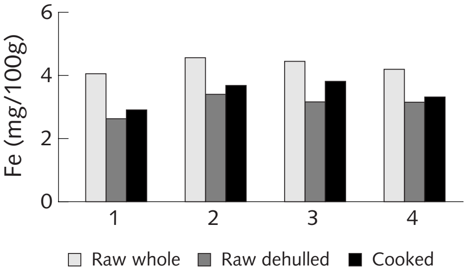

FIG. 3. Effects of plant variety and processing method on iron levels in soya beans. Varieties: 1, TGX536-2D; 2, TGX1083-14E; 3, TGX923-2E; 4, TGX996-28E

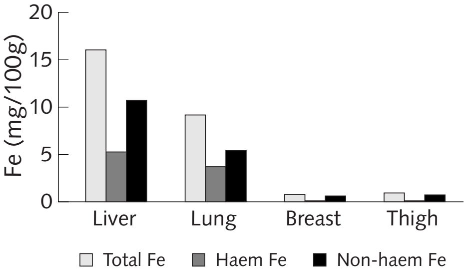

FIG. 4. Haem and non-haem iron contents of pork tissues

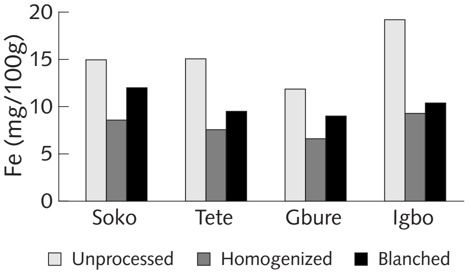

FIG. 5. Effects of processing on iron levels of some Nigerian vegetables

these processes result in the loss of 28% to 47% of the soluble iron [24].

Iron loss during these procedures is aggravated by the loss of ascorbic acid, a potent enhancer of iron availability [25]. Ascorbic acid maintains iron in its highly absorbable soluble form in the intestine. Furthermore, the soluble chelates counteract the inhibitory effects of phytates and polyphenols in grains and vegetables. It is therefore advocated that rich sources of ascorbic acid, such as tomatoes, peppers, and citrus fruits, be incorporated into recipes that use processed vegetables. About 100 g of vegetables, providing 50 mg of ascorbic acid, will significantly increase the amount of iron that is absorbed [26]. Better still, the practice of eating an orange during or immediately after meals should be encouraged. Citric, malic, and tartaric acids, which are present in oranges, lemons, pawpaws, and guavas, also enhance iron absorption. The traditional practice of drinking an herb extract could contribute to mineral intake [27]. Figure 6 shows the amounts of iron extracted from some Nigerian herbs by homogenization and boiling. Drinking these extracts not only improves mineral intake but also enhances the intake of other beneficial vitamins. Significant amounts of iron are also lost by traditional methods of processing soya beans [28](fig. 7).

Traditional techniques of processing cereals and some legumes in most developing countries involve soaking, pre-germination, and fermentation. Germination and fermentation enhance iron availability from cereals and legumes [29]. During these processes, the activity of endogenous phytase in these foods is increased, resulting in hydrolysis of the iron-inhibiting inositol hexaphosphates and pentaphosphates into non-inhibitory lower-inositol inorganic phosphates. Germination and fermentation improve iron availability by improving amino acid availability, decreasing phytate concentrations, increasing fibre degradation, and enhancing the production of organic acids. Moreover, they increase ascorbic acid levels in the foods.

Weaning gruels can be made from whole grains of maize, millet, sorghum, and guinea corn, which are normally soaked and fermented for three to four days before grinding. Although this procedure is beneficial for iron nutrition, the subsequent sieving of the ground gruels in several changes of water, which is ultimately discarded, results in a significant loss of nutrients. Other reasons for loss of iron during food processing include discarding iron-rich cooking broth and removing or dehulling cereals, causing loss of iron in the seed coat (testa). Loss of iron in cooking water is minimized by cooking food in large pieces, cooking food with the testa, and simmering rather than boiling.

It is desirable to preserve, encourage, and promote traditional food-processing methods such as fermentation. Indigenous women are rich reservoirs of knowledge of traditional food-processing and handling systems, and should be involved in the development and conservation of these resources for sustainable development. The compilation of a compendium of traditional African foods as a first step is long overdue. Moreover, women do most food handling and preparation and therefore should be empowered to utilize the various good nutritional practices for the family, society, and the whole population.

Animal products

Meat, fish, and poultry are sources of highly bioavailable haem iron, the concentration of which varies in different types of meat and tissues. Since these food items are costly and are eaten sparingly by most people in developing countries, animals should be slaughtered by methods that ensure minimal loss of blood. High residual blood in meat will increase the concentration of highly available haem iron. At the household level, blood from slaughtered poultry and game could be collected and incorporated into local recipes. With improved hygienic conditions, this could be extended on a larger scale to abattoirs where most of the larger animals are slaughtered for the community. A proportion of haem iron in meat is degraded to non-haem iron during cooking [30]. Precipitation and insolubilization of haem iron during cooking of meat decrease the availability of iron (fig. 8). Cooking denatures haem proteins in meat, which are then precipitated.

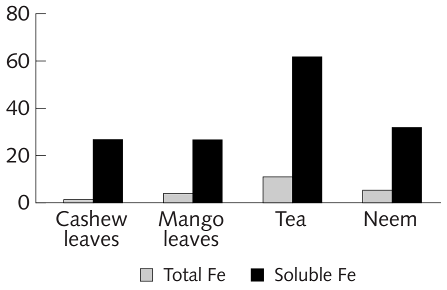

FIG. 6. Total iron (mg/100 g) and soluble iron (%) in some Nigerian medicinal herbs

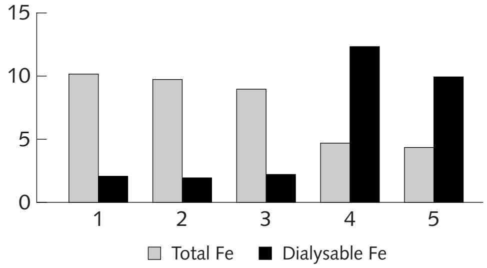

FIG. 7. Total iron (mg/100 g) and available iron (%) in some soy products. 1, Defatted flour; 2, soy concentrate; 3, soy isolate; 4, fermented soy; 5, germinated soya beans

Prolonged cooking reduces the absorption of iron from meat [31]. Eating rare or medium-cooked meat presumably enhances the availability of iron from these sources. However, this practice must be exercised cautiously in developing countries, because prolonged heating effectively sterilizes meats contaminated by microbes and parasites.

When haem iron is present in a mixed meal, the contribution of haem iron as a percentage of total absorbed iron is greater than that of non-haem iron [32]. Haem iron is thus of great nutritional importance in the diet, because it is unaffected by the inhibitors of non-haem iron. The enhancement of iron absorption by meat [33] is probably due to the hydrolysis of meat protein into amino acids and polypeptides, which chelate non-haem iron to facilitate its absorption [34]. However, the mechanism has yet to be fully established. Meat, fish, and poultry should be components of mixed diets of populations at risk for iron deficiency. Unfortunately, however, in many African communities, for cultural reasons women still reserve meat and other animal products for the men in the household.

Composite meals

Vegetarian diets, because of the reported reduced risk of some chronic nutritional disorders, are being widely advocated and embraced by an increasing number of people, particularly women [35] and adolescent girls [36], many of whom desire to maintain slim figures. In third world countries, however, eating predominantly plant-based foods, rather than being a matter of choice and preference, is due to economic more than cultural constraints. Populations subsisting mainly on plant foods are at risk of deficiencies of some nutrients, particularly iron [37] and zinc. The solubility of some minerals is lower in vegetarian than in omnivorous diets (fig. 9). Thus, vegetarianism and reliance solely on plant foods can have adverse consequences on women, particularly during the reproductive years.

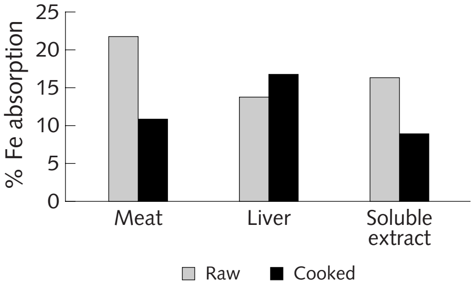

FIG. 8. Effect of cooking on iron absorption in rats

Other culinary and consumption practices

A number of culinary and eating practices influence iron absorption. Drinking coffee or tea within one hour of food consumption results in a decrease in iron absorption of 40% and 85%, respectively [38]. These inhibitors of iron absorption should be consumed sparingly by groups at risk for iron deficiency. *Kanwa* and other alkaline salts used to reduce the cooking time of legumes decrease the availability of iron from such foods. As observed earlier, vegetables and fruits are maximally beneficial to iron absorption when eaten fresh. The practice of eating kola nuts and other masticatories (chewable fruits from tropical trees), which is common in parts of Nigeria, can negatively affect iron utilization, particularly in pregnant women (fig. 10). Because of the high bioavailability of iron in human milk, the amount of iron provided by breast-milk in iron-replete mothers is adequate to prevent iron-deficiency anaemia in babies for the first four to six months of life. The importance of exclusive breast-feeding during this period cannot be overemphasized. The practice of eating cereal-legume mixtures could, in addition to enhancing the efficiency of protein utilization, also improve micronutrient utilization.

Conclusions

Food guides for Nigeria and other developing countries should aim at the selection of a variety of foods that

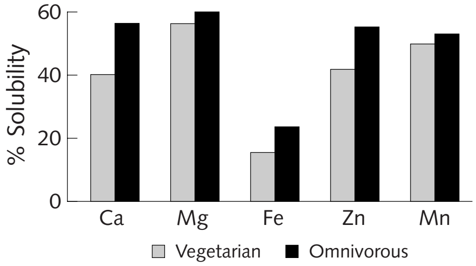

FIG. 9. Solubility of minerals in vegetarian and omnivorous diets

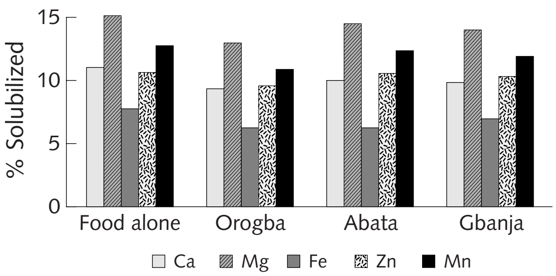

FIG. 10. Effects of masticatories on availability of minerals

together provide meals with high iron bioavailability. Although fortification of foods with iron is only a recent development in Nigeria, local foods can, in the interim, enhance iron availability in the home. Emphasis should be placed on improving the bioavailability of dietary iron by promoting culturally acceptable changes in food choices and preparation [39]. These food-based approaches require a sound scientific basis and intervention studies. They should be built on practical experiences and recognize women's participation in nutrition, the agricultural sciences, food processing, and marketing. The acquisition of skills in problem assessment, management, monitoring, and evaluation by women should be promoted [40]. The success of the initiatives of international organizations to improve iron status is dependent on the support and sustainable commitment of the national governments and the private sector in the implementation of policies aimed at curbing the scourge of iron-deficiency anaemia. The overall policies should embrace the improvement of the diet to enhance iron bioavailability, fortification of staple food with iron, and well-monitored iron supplementation of target groups at high risk for iron-deficiency anaemia [41]. The goal is the control and alleviation of iron-deficiency anaemia among the groups that are most vulnerable.

Acknowledgements

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Socio-economic differentials in child stunting are consistently larger in urban than in rural areas

Purnima Menon, Marie T. Ruel, and Saul S. Morris

Abstract

Urban–rural comparisons of childhood undernutrition suggest that urban populations are better off than rural populations. However, these comparisons could mask the large differentials that exist between socio-economic groups in urban areas. Data from the Demographic and Health Surveys for 11 countries from three regions were used to test the hypothesis that intra-urban differentials in child stunting are greater than intra-rural differentials, and that the prevalence of stunting among the urban and the rural poor is equally high. A socio-economic status (SES) index based on household assets, housing quality, and availability of services was created separately for rural and urban areas of each country, using principal components analysis. Odds ratios (OR) were computed to estimate the magnitude of differentials in stunting (height-for-age Z scores < –2) between urban and rural areas and between the lowest and highest SES quintiles within areas. The prevalence of stunting was lower in urban than in rural areas for all countries, but rural–urban odds ratios were relatively small (< 3.3). As hypothesized, the gap between low and high SES was markedly larger in urban (median OR, 4) than rural (median OR, 1.8) areas, and differentials were statistically significant (interaction between area and SES in logistic regression) in all but three countries. Within-urban ORs as high as 10 were found in Peru and the Dominican Republic, whereas within-rural ORs were smaller than 3.5, except in Brazil. In most countries, stunting in the poorest urban quintile was almost the same as that among poor rural dwellers. Thus, malnutrition in urban areas continues to be of concern, and effective targeting of nutrition programmes to the poorest segments of the urban population will be critical to their success and cost-effectiveness.

Introduction

Population growth estimates suggest that the urban population is currently growing about three times faster than the rural population. By the year 2025, it is estimated that over 80% of the developing world will be living in urban areas. Along with such increases in urban population in developing countries come increasing urban poverty and malnutrition. Recently compiled data show that both the absolute numbers of urban poor and the contribution of urban poverty to overall poverty have been increasing over the past two decades [1]. Similar trends are also observed for urban childhood undernutrition. The magnitude of this problem has not been well recognized, despite its potential importance for national policy, given the escalating rates of urbanization and the potential consequences of urban poverty and malnutrition. Most programme and policy analyses intended to support resource allocation decisions continue to rely on simple urban–rural comparisons. The danger of using such comparisons is that they mask the enormous differentials that exist between socio-economic groups in urban areas.

The present paper argues that although socio-economic differentials in malnutrition do exist both in urban and in rural areas, they are of significantly larger magnitude in urban areas. To test this hypothesis, data from the Demographic and Health Surveys (DHS) for 10 countries (2 in Asia, 5 in Latin America, and 4 in Africa) were used. The other hypotheses tested were that intra-urban differentials are also larger than overall urban–rural differentials and that the prevalence of stunting among the urban poor is often as high as that among the rural poor.

Other researchers have noted that using global statistics to characterize poverty and childhood malnutrition in urban areas may be misleading, because city averages do not capture the large heterogeneity between social classes in urban areas [2]. The magnitude of differentials in childhood malnutrition, morbidity, and mortality between socio-economic

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groups in urban areas has been documented previously [2–6]. To our knowledge, however, this is the first study that systematically addressed this question by directly comparing the magnitude of such differentials in the prevalence of childhood stunting between urban and rural areas.

Data and methods

DHS data (rounds II and III) were used to test the study hypotheses. The DHS programme is funded by the US Agency for International Development (USAID), coordinated by Macro International, and data collection is usually carried out in collaboration with country governments. Population sampling frames are used for the data collection, which makes all the data sets nationally representative. These data sets are in the public domain and are available from the DHS website (www.macroint.com/dhs). We used the most recent data sets, available as of June 1997, from Bangladesh and Pakistan for Asia; from Tanzania, Ghana, Senegal, and Zambia for Africa; and from Brazil, Colombia, the Dominican Republic, Peru, and Guatemala for Latin America. The two main criteria for the selection of countries were that information on child anthropometry be available in the data set, and that both the urban and the rural samples include at least 500 children 0 to 36 months of age. The latter criterion was important to allow an adequate sample size for the planned disaggregated analysis of socioeconomic status (SES)by quintile. Stunting was defined as height-for-age Z score less than –2 standard deviations of the WHO/NCHS/CDC reference standards [7].

Creation of a socio-economic index

The first step in the analysis was to create a socioeconomic index for each country and each area (urban and rural), using the type of data available at the household level in the DHS data sets. A valid index of SES should contain variables from different domains, because SES is a multi-dimensional concept [8]. In the DHS data sets, data are available on three main domains of household wealth: characteristics of the dwelling (floor, walls, and roof material), availability of water and sanitation services, and ownership of household durable goods (such as bicycle, television, and radio). Other domains that one might expect to include in a scale of SES are household income and parental education. The DHS data sets do not contain information on household income, and we deliberately avoided including education in this scale, because education has some effects on child health and nutrition that are known to be independent of the effects of SES [9, 10]. For this index to be content valid, therefore, one would expect that at least some variables from all three domains would be included in the final index.

The main purpose of creating the index was to categorize households into SES quintiles and to compare the difference in the prevalence of stunting between the groups of lowest and highest SES. The index was constructed separately for each country and for urban and rural areas within each country, because the characteristics that define wealth were expected to differ between countries as well as between urban and rural areas within a country.

Principal components analysis was used to derive one factor from the selected wealth variables (see table 1 for the list of variables). All variables were categorical and ranked by ascending order (from worst to best). The selection criterion for inclusion of individual variables into the final factor was that factor loadings (defined as the correlation between the variable and the factor) had a value greater than 0.4. (In the case of Ghana, a variable with a factor loading as low as 0.28 was maintained, because no other variables besides drinking water and non-drinking water source loaded strongly with the factor.) We also conducted paired *t* tests to examine whether factor loadings were significantly different between urban and rural areas for the same country. This was done to assess the comparability of the SES indices between urban and rural areas. For each country and area, the newly created variable reflecting the factor scores was then ranked into quintiles to create five SES groups. All further statistical comparisons in stunting prevalence were made between the lowest and the highest SES groups.

Analysis of differentials

We used odds ratios to quantify the magnitude of differentials in stunting prevalence. The overall urban–rural and the lowest SES versus highest SES odds ratios were computed using the formula

$$\frac{p}{(1-p)} \div \frac{q}{(1-q)}$$

where p is the proportion of stunted children in rural areas and q is the proportion of stunted children in urban areas.

Odds ratios were used rather than prevalence rate ratios, because prevalence rate ratios are limited by the fact that there are ceilings on values that prevalence rate ratios can take in situations where the prevalence of the outcome of interest is large even in the lowest-risk group. Odds ratios are not constrained by this statistical artifact and can take any value between zero and infinity [11].

Odds ratios for differentials between SES groups within a given area were computed to determine the magnitude of differentials in stunting prevalence between the highest and the lowest SES groups, within

TABLE 1. Results of principal components analysis to create a household socio-economic index (factor loadings and variance explained by the factor), according to country and to rural (R) or urban (U) area

			Variables used in SES scale (factor loadings)							
Country	Year	DHS round	Drinking water source	Non-drinking water source	Toilet	Floor material	Wall material	Roof material	Durable goods	Variance explained by component (%)
Bangladesh (R)	1993	3	—	—	0.72	0.67	0.71	0.59	0.73	47.4
Bangladesh (U)	1993	3	0.71	0.78	0.74	0.84	0.78	0.75	0.72	57.9
Pakistan (R)	1991	2	0.93	0.93	0.48	—	—	—	0.52	56.1
Pakistan (U)	1991	2	0.80	0.83	0.68	—	0.62	0.69	0.67	51.7
Ghana (R)	1993	3	0.96	0.96	—	0.28	—	—	—	64.1
Ghana (U)	1993	3	0.92	0.91	0.53	—	—	—	0.59	57.0
Senegal (R)	1992	2	0.83	0.80	0.51	0.61	—	—	0.64	47.1
Senegal (U)	1992	2	0.87	0.87	0.65	0.45	—	—	—	50.8
Tanzania (R)	1991	2	0.94	0.94	—	0.43	—	—	0.33	51.6
Tanzania (U)	1991	2	0.90	0.89	0.47	0.71	—	—	0.46	51.0
Zambia (R)	1992	2	0.86	0.87	0.53	0.68	—	—	0.53	50.5
Zambia (U)	1992	2	0.92	0.92	0.79	0.54	—	—	0.53	58.0
Brazil (R)	1996	3	—	—	0.63	0.77	0.76	0.70	0.72	51.8
Brazil (U)	1996	3	0.70	0.73	0.59	0.42	—	—	0.59	35.3
Colombia (R)	1995	3	0.84	0.84	0.68	0.61	—	—	0.62	52.3
Colombia (U)	1995	3	0.93	0.93	0.67	0.44	—	—	—	59.2
Dominican Republic (R)	1991	2	0.70	0.70	0.66	0.60	—	0.56	0.66	42.2
Dominican Republic (U)	1991	2	0.78	0.75	0.73	—	0.47	—	0.70	48.3
Guatemala (R)	1997	3	0.53	—	0.73	0.70	—	—	0.82	49.4
Guatemala (U)	1997	3	0.55	—	0.79	0.59	—	—	0.72	45.9
Peru (R)	1992	2	0.88	0.88	0.63	0.55	—	—	0.62	52.8
Peru (U)	1992	2	0.85	0.85	0.77	0.67	—	—	0.65	58.5

urban and within rural areas, respectively. These were calculated by using the following logistic regression model:

$$\text{Stunting} = \beta_0 + \beta_1(\text{area}) + \beta_2(\text{SES}) + \beta_3(\text{area} * \text{SES})$$

where the variables are defined as follows:

Stunting:	1 = stunted	0 = not stunted
Area:	1 = urban	0 = rural
SES:	1 = low SES	0 = high SES

A statistically significant coefficient ($p < .2$) for the interaction term between area and SES indicated that the magnitude of the socio-economic differentials observed was different between urban and rural areas (i.e., that the within-urban and the within-rural odds ratios were significantly different).

Analyses were performed by EPI-Info 6.0 (for unadjusted odds ratios) and SPSS 8.0 (for logistic regression and factor analysis) [12, 13].

Results

The results of the factor analysis clearly indicate that in all countries, our SES scale was a good reflection of its underlying variables (table 1). The factors were generally strong, in that most of them explained more than 50% of the variance of the variables retained in the factor (ranging from 35.3% for urban Brazil to 64.1% for rural Ghana; see table 1). The factors also included variables from the three dimensions of SES hypothesized (water and sanitation, housing quality, and assets) in 18 out of 22 of the models. There was no systematic difference in the number of variables entering the index in rural and urban areas, nor was there any systematic difference in the proportion of the total variance in these variables explained by the model. Within countries, factor loadings appeared to be broadly comparable in urban and rural areas (paired *t* tests; not shown), although there was a clear and statistically significant tendency for the variable TOILET to load more heavily in urban compared to rural areas.

Figure 1 shows that the prevalence of stunting was consistently higher in rural areas than in urban areas for all countries and regions. Figures 2 and 3 also show that, irrespective of area of residence, the prevalence of stunting among children from groups of lower SES was consistently higher than among children from groups of higher SES. Table 2 summarizes these results

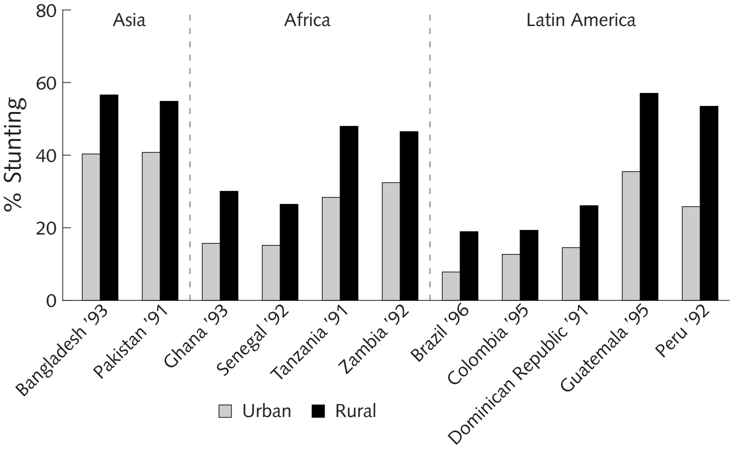

FIG. 1. Prevalence of stunting according to urban or rural residence

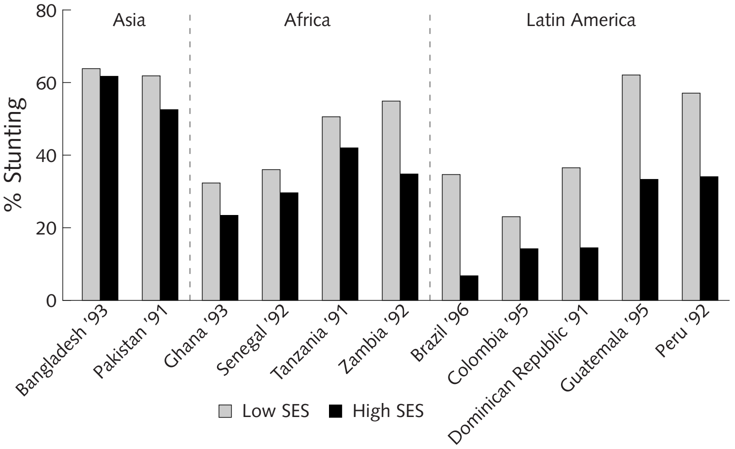

FIG. 2. Prevalence of stunting in rural areas according to SES

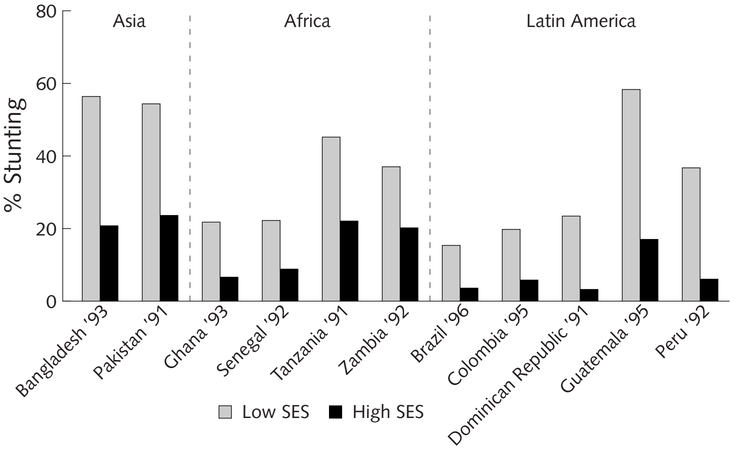

FIG. 3. Prevalence of stunting in urban areas according to SES

by presenting the odds ratios and their 95% confidence intervals for these different comparisons. First, all odds ratios of urban–rural differentials were statistically significant, ranging from 1.3 for Tanzania to 3.3 for Peru. Thus, in the countries studied, the odds of stunting were between 1.3 and 3.3 times higher for rural than for urban children.

Within urban and rural areas, all odds ratios for differences between groups of different SES were statistically significant, except for the within-rural differences in Ghana and Senegal. The magnitude of the odds ratios for SES differences in rural areas ranged from 1.4 for Senegal and Tanzania to 7.5 for Brazil, with a median of 1.8. There was some tendency, although it was not entirely consistent, towards higher within-rural odds ratios in Latin America than in Africa and Asia (the four highest odds ratios were found in Latin American countries). In urban areas, the median odds ratio for SES differentials was more than twice as large as the median odds ratio in rural areas (4 vs 1.8); the values ranged from 2.4 in urban Zambia up to 10.2 in urban areas of the Dominican Republic. Again, the magnitude of the odds ratios in urban areas tended to be larger in Latin America than in Africa and Asia, but the pattern was not totally consistent. For each country except Brazil, the within-urban odds ratios were larger than the within-rural odds ratios. Estimates of the coefficients of the interaction term between area and SES revealed that for all but three countries, the within-urban odds ratios were statistically significantly greater than the within-rural odds ratios ($p < .10$ in all cases). The countries for which differences were not statistically significant were Brazil, Ghana, and Zambia ($p > 0.2$; Table 2). Note also that at the national level, the within-urban odds ratios were systematically greater than the overall urban–rural odds ratios.

Figure 4 provides a graphical illustration of the results described above. Each box represents one country. The vertical line forming the left side of the box shows the difference in the prevalence of stunting between groups of low and high SES in rural areas; the line forming the right side of the box shows the corresponding difference in urban areas. The line forming the top of the box shows the difference between rural and urban groups of low SES, and the bottom line shows the difference between rural and urban groups of high SES. In an ideal situation, the box would be slim, with no distortion, indicating no difference in the prevalence of stunting between urban and rural areas or between groups of low and high SES. Figure 4 indicates that this is far from being the case. It shows that the data for most countries form a clearly trapezoidal shape, thus highlighting the marked differences in stunting between groups of different SES, especially in urban areas. The figure also demonstrates that in most countries, the gap between the rural and the urban poor is small (top line), in spite of the fact that the prevalence of stunting is always somewhat higher among the rural poor.

Figure 4 and all previous analyses focused on the extreme quintiles of the socio-economic index scale. Figures 5 and 6 are presented, however, to highlight the fact that differences in the prevalence of stunting in the countries studied generally showed a dose-response relationship. This was true for both urban and rural areas, although differences according to SES were clearly more pronounced in urban areas.

Discussion

Our analyses clearly show that across the developing world, there are large socio-economic differentials

TABLE 2. Odds ratios for stunting in rural compared with urban areas, overall and according to SES within rural and within urban areas

		Sample size		Urban vs rural, overall		Rural low vs high SES		Urban low vs high SES		
Country	Year	Urban	Rural	OR	95% CI	OR	95% CI	OR	95% CI	p^a
Bangladesh	1993	447	4,328	1.9	1.6–2.3	1.8	1.6–2.2	5.0	2.6–9.6	.056
Pakistan	1991	1,382	2,653	1.8	1.5–2.0	1.5	1.1–1.9	3.8	2.6–5.7	.000
Ghana	1993	520	1,297	2.4	1.8–3.1	1.6	0.6–3.8	4.0	1.5–10.6	.277
Senegal	1992	1,423	2,380	2.5	2.1–3.0	1.4	1.0–1.8	3.0	1.7–5.2	.015
Tanzania	1991	1,227	4,720	1.3	1.2–1.5	1.4	1.2–1.7	2.9	1.9–4.7	.032
Zambia	1992	2,290	2,566	1.8	1.6–2.0	2.3	1.8–3.0	2.4	1.7–3.4	.863
Brazil	1996	2,903	912	2.9	2.3–3.5	7.5	3.3–16.8	4.8	2.8–8.5	.426
Colombia	1995	2,776	1,631	1.6	1.4–2.0	1.8	1.2–2.9	4.0	2.3–6.9	.037
Dominican Republic	1991	1,689	1,194	2.2	1.8–2.7	3.5	2.2–5.5	10.2	4.6–22.3	.018
Guatemala	1995	2,505	5,262	2.4	2.2–2.6	3.3	2.7–4.0	6.9	5.2–9.3	.000
Peru	1992	—	2,709	3.3	3.0–3.8	2.6	2.0–3.3	9.9	6.8–14.5	.000

a. All *p* values refer to the statistical significance of the interaction term between area (urban or rural) and SES in a logistic regression model that included both of these factors as main variables and the interaction term between the two.

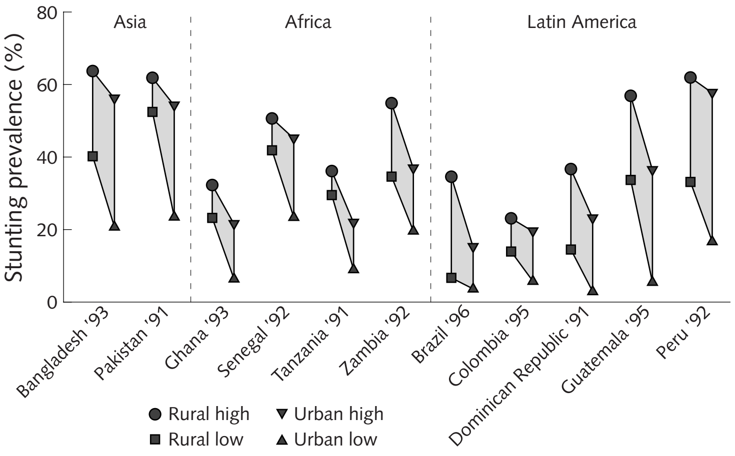

FIG. 4. Summary of prevalences of stunting in urban and rural areas according to SES

in stunting among 0- to 36-month-old children, that these differentials are commonly greater in urban than in rural areas, and that the most disadvantaged urban children have rates of stunting that are on average only slightly lower than those of the most disadvantaged rural children. These conclusions are drawn from large, nationally representative data sets from 11 different countries on three continents. Data collection procedures were similar in all cases, and identical analytic methods were applied.

Many previous studies have addressed socio-economic differentials in the nutritional status of children in either rural [14–16] or urban [5, 17] areas. However, the magnitude of socio-economic differentials in urban and rural children has seldom been compared. Ricci and Becker [18] found that in Metro Cebu, Philippines, household socio-economic characteristics were important determinants of stunting in children aged 12 to 29 months in both rural and urban areas, and that the effect of these factors on the risk of stunting was detectable earlier in rural than in urban *barangays*. However, because the regression models for the two strata used different sets of socio-economic indicators, it is difficult to compare the importance of SES across the two strata. In Mozambique, Garrett and Ruel [19] found that household expenditures, parental education, and crowding were similarly associated with the children's height-for-age Z scores in both rural and urban areas. The use of well water, however, was strongly associated with lower height-for-age Z scores only in urban areas. In both studies, the variables used as proxies for SES were not equally common in rural and urban areas, making it difficult to judge whether the *relative* differentials between the more and less disadvantaged were of similar magnitudes in rural and urban areas.

In the present study, this difficulty was overcome by using compound indices of SES that were able to divide the population into five equal-sized groups in both the rural and urban areas, thereby ensuring that in each case the upper quintile of SES was compared with the lower quintile. This approach aimed only to rank these households relative to other households *in the same residential stratum*. There was no implication that households in the lowest SES quintile in urban areas of a given country experienced similar economic

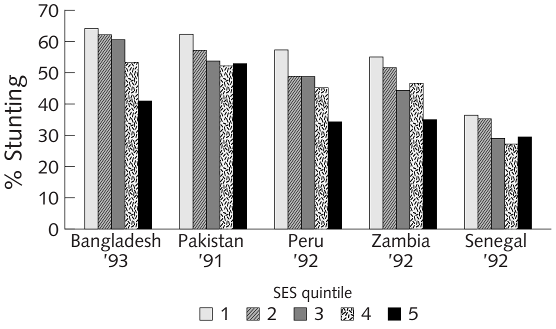

FIG. 5. Prevalence of stunting in rural areas according to SES quintile

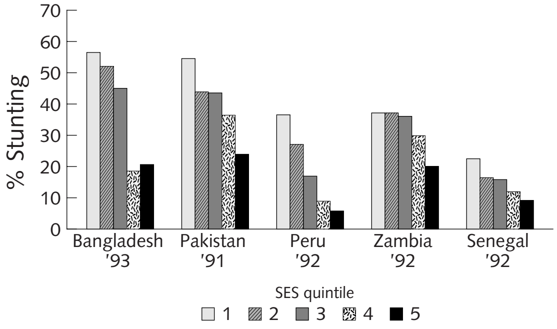

FIG. 6. Prevalence of stunting in urban areas according to SES quintile

conditions to households in the lowest quintile in rural areas of the same country. For this reason, it is not possible to strictly compare the rural poor with the urban poor; it is possible only to compare the size of the differentials between the first and the fifth quintiles within rural and urban areas.

Krieger and collaborators [20] have suggested that, ideally, valid measures of SES should include variables that reflect both household resources, such as assets, income, and education, and prestige- or rank-based characteristics, such as social class. Although our SES index does not contain measures of social rank, we believe that the area-specific indices created for each country in this study are valid indicators of the socio-economic position of these households within area and country, particularly for the purpose that they were designed to serve. We also believe that variables that reflect household resources are more likely to be associated with health and nutrition outcomes than variables that reflect social rank. The content validity of our indices [8] is clearly demonstrated by the fact that in virtually all countries, the three domains that we had set out to include in an SES index were in fact included in the final factor that made up the index. These domains were ownership of durable goods, construction of the dwelling, and access to water and sanitation. As mentioned earlier, the domain of parental education was purposely left out, and data on income are not available in the DHS surveys.

Our study showed that the risk of stunting may be up to 10 times higher for urban children of low SES than for urban children of high SES. The fact that such strong socio-economic gradients are consistently found in urban areas of developing countries implies that reliance on global average statistics to allocate resources between rural and urban areas could be dangerously misleading, a point originally made by Basta in 1977 [2]. We have previously shown that the “average” urban child is consistently less likely to suffer from stunting than the “average” rural child [21], yet in virtually every case studied in the present analysis, there was a distinct group of highly vulnerable urban children who should be high on the list of national priorities for nutrition-oriented interventions. We were unable to determine from these data whether intra-city or inter-city differences are likely to account for most of the overall within-urban sector differences observed. Previous research, however, suggests that even within neighbourhoods of the same city, there is a great deal of variation in attained nutritional status [22]. Targeting the nutritionally vulnerable in urban areas, therefore, may require imaginative and far-reaching programmes to respond to the growing numbers of urban poor and undernourished.

Policy implications

Our research is part of an increasing body of research on the conditions in which poor urban dwellers live and on the deleterious effects of these conditions on health and disease outcomes [23]. It demonstrates an urgent need for programme and policy attention to ameliorate the nutritional situation of the urban poor. Health and nutrition interventions, in conjunction with poverty reduction measures, are priorities for the urban poor as much as they are for the rural poor.

Acknowledgements

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Assessment of the rate of low birthweight and its related factors in Ahvaz, Iran, in 1995 and 1996

Reza Amani

Abstract

The prevalence of low birthweight (LBW) and its possible risk factors in Ahvaz, Iran, were determined in 10 health centres and 3 main hospitals in the city from 876 randomly selected mother-infant files. The variables included maternal pre-pregnancy and pre-labour weight, infant weight, maternal haemoglobin level, pregnancy history, and socio-economic status. The rate of LBW was 7.3%. LBW was significantly related to pre-pregnancy maternal weight, weight gain during pregnancy, maternal haemoglobin level, and mother's literacy ($p < .05$)*. Mothers given iron supplements starting at four months of pregnancy had elevated haemoglobin levels* ($p < .0001$)*. Evidence is provided that educating young mothers can reduce the rate of LBW.*

Introduction

Prevention of low birthweight (LBW), defined as birthweight less than 2,500 g, is an important health priority in Iran. Birthweight is determined by a variety of factors, including maternal deficiencies of dietary iron, folate, protein, and energy [1–3] and chronic infection during pregnancy [4]. It is associated with low socio-economic status (SES), smoking, alcohol consumption, low haemoglobin levels, low pregnancy weight gain, and history of stillbirth [5–8]. The mother's weight and weight gain are predictors of both maternal nutritional status and infant birthweight [1, 3]. Birthweight is also a determinant of infant morbidity and mortality. For example, infant mortality is 2 per 1,000 in infants of normal birthweight and 86 per 1000 in LBW infants.

LBW is an important health indicator. Recent data have shown that 7% of urban and 8% of rural infants in Iran are of LBW [9]. The prevalence was 13.6% in Saudi Arabia [10], 9.5% in Lebanon after the civil war [11], and 6.8% in the United States [12, 13]. Because of the need for new data for health planning and the importance of this issue, this study was undertaken to provide current information.

Methods

Ahvaz, a city in south-west Iran in Khuzestan Province, is divided into five areas: north, south, west, east, and central. Two health centres were randomly selected in each area. The three main hospitals in the city were also selected. In total, 876 mothers and children were assessed. The mothers were 20 to 30 years old, with no history of alcohol consumption or smoking. Data obtained included parents' education and occupation, maternal pre-pregnancy and pre-labour weights, birthweight, number of previous pregnancies, haemoglobin level of the mother, and whether iron supplements were taken during pregnancy. Statistical analysis was performed by Student's *t* test, Z scores, chi-square tests, the Kruskal-Wallis test, and the Bartlett test. The statistical software was Epi-Info version 6 (Centers for Disease Control, Atlanta, GA, USA, and WHO, Geneva).

Results

Low weight at term was found in 3.9% of live births, and 3.4% were premature. Thus, the overall prevalence of LBW in this study was 7.3%. Parity did not influence birthweight (table 1). Forty-six percent of the mothers had not been pregnant before, 31% had been pregnant once before, and the remainder had been pregnant two or more times before. Among mothers with haemoglobin values below 11 g/dl, the prevalence of LBW was doubled ($p <.05$). Maternal weight gain was significantly lower (8.2 kg) in mothers with LBW infants than in those with newborns in the normal

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TABLE 1. Characteristics of mothers of normal and LBW infants

Birthweight	Haemoglobin <11 g/dl—no.(%)[a]	Mean ± SD weight before pregnancy (kg)[b]	Mean ± SD weight before labour (kg)[c]	Mean ± SD parity	Iron supplemented—no. (%)[d]
Low	9 (14)	51.2 ± 8.5	59.4 ± 8.9	1.9 ± 1.2	47 (77)
Normal	56 (6.9)	56.7 ± 9.5	67 ± 9.8	1.9 ± 1.1	594 (80)

a. $\chi^2 = 4.66$, $p < .05$.
b. $p < .0005$.
c. $p < .00003$.
d. $\chi^2 = 24.9$, $p < .00001$.

TABLE 2. Educational levels of parents of normal and LBW infants

	Mothers' education—no. (%)				Fathers' education—no. (%)			
Birthweight	None	1st	2nd	High	None	1st	2nd	High
Low	18 (28)	19 (30)	20 (31)	7 (11)	7 (11)	24 (37)	28 (44)	5 (8)
Normal	135 (17)	229 (37)	328 (40)	49 (6)	61 (7)	241 (30)	414 (51)	95 (12)

a. $\chi^2 = 8.8$, $p <.04$.

TABLE 3. Occupations of parents of normal and LBW infants

	Mothers—no. (%)				Fathers—no. (%)			
Birthweight	Unemployed	Worker	Officer	Self-employed	Unemployed	Worker	Officer	Self-employed
Low	57 (89)	1 (2)	6 (9)	—	7 (11)	19 (30)	21 (33)	17 (27)
Normal	745 (92)	5 (0.6)	58 (7)	3 (0.4)	50 (6)	192 (24)	245 (30)	314 (40)

range (mean, 10.3 kg) ($p < .0001$). Pre-pregnancy weights below 45 kg were associated with a 2.3-fold increase in LBW ($p < .03$). Significantly fewer mothers who were given 60 mg of iron daily from the fourth month of pregnancy had haemoglobin levels below 11 g/dl than those who did not receive the iron supplement (21% vs 71% of mothers, $p < .001$), but mean birthweights were the same in the two groups. Mothers with a higher level of literacy had fewer LBW infants ($p < .04$)(table 2). Parents' occupation did not influence birthweight (table 3).

Discussion

LBW infants fall into two groups: those who are small-for-date as a result of intrauterine growth retardation (IUGR) and those who are born prematurely. The mother's pre-pregnancy weight and weight gain during pregnancy influence the rate of small-for-date births [1, 3]. Maternal deficiencies of iron and folate and low intakes of protein and energy during pregnancy also increase the probability of LBW due to IUGR [5–8, 14–17]. The LBW prevalence of 7.3% is much less than that in many developing countries and only slightly higher than the rate of 7% in the United States (table 4).

Nevertheless, the findings of the present study suggest that LBW in Iran could be further reduced by increasing dietary energy in the second and third trimesters of pregnancy by promoting increased consumption of milk, fruits, and dates, which are easily available, and by improving the literacy of young

TABLE 4. Percentage of LBW infants in developing countries in the region compared with that in the United States and Japan (1990–1994)

Country	% LBW
Bangladesh	50
India	33
Pakistan	25
Iraq	15
Egypt	10
Lebanon	10
Syria	11
Iran	9
USA and Japan	7

Source: ref. 18.

mothers and promoting better child spacing [3, 17]. This will require better planning and effectiveness of health centres and emphasis on nutrition education and good maternal nutrition as a basic health need. Nutritionists, physicians, midwives, and other health personnel will be of critical importance in this effort.

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Plasma lipid levels in 10- to 13-year-old Costa Rican elementary schoolchildren

Rafael Monge, Ileana Holst, Francisco Faiges, and Alejandra Rivero

Abstract

An adverse lipid profile is a major risk factor for atherosclerosis. This study evaluated the lipid profiles of 683 schoolchildren aged 10 to 13 years. The prevalence of both high LDL and high total cholesterol levels was significantly ($p < .001$*) higher in private schoolchildren than in public schoolchildren. There were no significant differences in the prevalence of high triglyceride levels among the schoolchildren. Mean total cholesterol and LDL cholesterol levels were significantly higher in children whose parents had completed over 11 years of schooling. Private schoolchildren were more sedentary and tended to have a more atherogenic diet. Our data suggest that prevention programmes in primary schools are required to decrease the prevalence of cardiovascular risk factors, including abnormal lipid profiles.*

Introduction

The clinical consequences of coronary artery disease show up later in life; however, the mechanisms leading to atherosclerosis are clearly present in childhood [1, 2]. Aortic fatty streaks occur in children as young as 3 years [3], and coronary fatty streaks occur in more than half of children aged 10 to 14 years [4, 5]. Approximately 8% of children aged 10 to 14 have more advanced lesions [4, 5].

Elevated serum lipid levels, particularly low-density lipoprotein (LDL) cholesterol and triglycerides, promote the development of atherosclerosis and are a major cause of coronary artery disease. The Bogalusa Heart Study, the Muscatine Study, and the CARDIA Study have shown that cholesterol measurements obtained in childhood are predictive of adult levels of total and LDL cholesterol [1, 2, 6–8]. About 25% to 70% of adult cholesterol variability has been explained by childhood levels [6, 7].

Overweight, low physical activity, high saturated fat intake, and cigarette smoking cause unfavourable alterations in plasma lipids [1, 2, 8]. Avoidance of these factors in the early years is essential to prevent an adverse lipid profile in later years. This is vital in Costa Rica, where coronary artery disease is the main cause of death [9].

The aim of this study was to determine the plasma levels of cholesterol, lipoproteins, and triglycerides in 10- to 13-year-old elementary schoolchildren from the urban area of San José.

Methods

Sample

The lipid profiles of 10- to 13-year-old schoolchildren from the urban area of San José, Costa Rica were evaluated. In order to study children independently of the kind of school they attend (public or private), we decided to work with an equal number of children from both groups ($n = 324$ for each). From the 700 eligible children, those who were not authorized by their parents to participate in the study (2%) and those who had a disease that could affect serum lipoprotein levels (0.5%) were eliminated from the study. The total sample consisted of 683 children from 16 elementary schools: 52% from public schools and 48% from private schools. In each school, 42 children (21 boys and 21 girls) were selected randomly from the fourth to the sixth grades. Written consent was obtained from the parents and the children.

Biochemical measurements

After a 12-hour fast, a blood sample was taken from

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an antecubital vein using vacutainer tubes (Becton Dickinson). Serum was obtained by centrifugation at 6,000 rpm for 5 minutes at 25° C. High-density lipoprotein (HDL) cholesterol was separated by using a phosphotungstic acid/Mg^{2+} reagent (Randox, England) and centrifuged at 3,000 rpm for 15 minutes. The colourimetric reaction was determined in a Gilford spectrophotometer Stasar III at 505 nm and 37°C. Total plasma cholesterol, triglycerides, and glucose were determined by enzymatic methods (Wiener) using an automatic analyser ASCA (LSI Instruments) at 505 nm and 37°C. LDL cholesterol was calculated by the equation of Friedwald et al. [10]. The respective intra-assay and inter-assay coefficients of variation were 2.7% and 4.2% for total plasma cholesterol, 7.8% and 18.8% for HDL cholesterol, 3.9% and 6.9% for triglycerides, and 2.1% and 4.0% for glucose. To control for the variability in the measurements of HDL cholesterol and of other biochemical indicators, internal quality control with bovine normal and elevated serum (Randox, England) was performed. In the cases in which the samples exceeded ±2 SD, the average value of the control, the samples were analysed again. Total cholesterol, LDL cholesterol, HDL cholesterol, and triglyceride concentrations were classified according to the guidelines of the Expert Panel on Blood Cholesterol Levels in Children and Adolescents [8].

Instrument and data collection

All data were collected during three consecutive months. Overweight was estimated by using the body mass index (BMI) (weight/height^2). Weight was measured without shoes or heavy outer clothing. Height was measured with the student shoeless and facing away from the scale. Standing height was measured to the nearest 0.1 cm, and weight was measured to the nearest 0.1 kg. Independent duplicate measurements were obtained for height and weight, and the average of two readings, required to be within ±0.5 cm or 0.5 kg, respectively, was used in data analysis.

Children with BMI at or above the 85th percentile but below the 95th percentile were considered overweight, as suggested by the World Health Organization Expert Committee [11]. In the absence of other data specifying optimum cut-off values for BMI in children, the BMI for age data for US children were used, as recommended by the WHO Expert Committee [11].

Parental educational level and family history of premature coronary artery disease were determined by a previously validated 10-question multiple-choice test developed for this study [12]. Questions regarding family history of premature coronary artery disease and parental education were given to the children to take home and answer with parental assistance.

Dietary patterns were determined by previously self-administered food-frequency questionnaires. The questionnaires listed 50 food items in 11 food groups of 3 to 8 foods each. Physical activity patterns were determined by a previously validated 15-question multiple-choice test [12].

Statistical analysis

Data were examined with SPSS for Windows with the use of analysis of variance as appropriate for continuous variables and the chi-square test for categorical data. Multiple regresssion analysis was used to develop models with the different lipids as dependent variables. After univariate relationships between variables had been examined, multivariate stepwise models were initially used to identify which of the correlated variables provided the best model with a particular dependent variable. Collinearity was minimized by this approach, and correlation coefficients between independent variables included in the regression models did not exceed 0.3. Differences with $p < .05$ were considered significant.

Results

Table 1 shows the distribution of the study population. All students were of the same ethnic background (mestizo). Their mean age was 11.2 ± 1 years.

The prevalence of overweight children was similar in both groups (31%). Children from private schools spent more time watching television than children from public schools ($p = .000$). Children from both types of school spent an average of about two hours a day in physical activity ($p > .05$). Parents of children in private schools had an average of about five more years of education than parents of children in public schools ($p = .000$).

TABLE 1. Characteristics of the study population[a]

Variable	Public school	Private school	*p*
Number	358	325	
Age (yr)	11.2 ± 1.1	11.2 ± 0.9	NS[b]
Body mass index (kg/m^2)	20 ± 3.7	20 ± 3.2	NS
Overweight (%)	30.7	31.4	NS
TV viewing (h/day)	2.2 ± 1.4	2.8 ± 1.4	.000
Physical activity (h/day)	2.1 ± 1.4	2.3 ± 1.6	NS
Mother's education (yr)	9.4 ± 3.7	14.4 ± 2.9	.000
Father's education (yr)	10.3 ± 4.0	14.8 ± 3.2	.000

a. Plus-minus values are means ± SD.

b. NS indicates that the difference between public and private schoolchildren is not significant ($p > .05$ by analysis of variance).

Biochemical levels

Boys and girls had similar mean levels of total cholesterol, HDL cholesterol, and LDL cholesterol (table 2). Girls had significantly higher triglyceride levels than boys (1.11 and 1.01 mmol/L, respectively; $p = .0336$).

Boys from public schools had significantly lower mean values of total cholesterol and LDL cholesterol than boys from private schools ($p < .01$). Boys from public schools had significantly higher plasma triglyceride levels ($p = .0045$). The mean values of LDL cholesterol, HDL cholesterol, and triglycerides were similar for girls from public schools and for girls from private schools. However, girls from private schools had higher mean levels of total cholesterol than girls from public schools (4.68 and 4.42 mmol/L, respectively; $p = .0019$).

Table 3 shows the mean levels of serum lipids for schoolchildren according to the parents' educational level. Mean total cholesterol and LDL cholesterol were significantly higher in children whose parents had completed at least 11 years of schooling. There were no significant differences between the groups in HDL cholesterol and total cholesterol levels.

Table 4 provides the classification of plasma lipids for elementary schoolchildren based on the guidelines of the National Cholesterol Education Program. The prevalence of borderline levels of total cholesterol (4.42–5.17 mmol/L) was significantly greater in boys (39%) than in girls (30%; $p = .016$). Likewise, the prevalence of high total cholesterol levels was significantly greater in private schoolchildren than in public schoolchildren ($p < .001$).

The prevalence of borderline levels of LDL cholesterol was similar in private and public schoolchildren (about 26%). However, the prevalence of high levels of LDL cholesterol was greater in children from private schools than in children from public schools (33% and

TABLE 2. Serum lipid and glucose levels (means ± SD) of urban Costa Rican children in public and private schools ($n = 683$)

	Sex			Boys			Girls			Total		
Value (mmol/L)	M ($n = 320$)	F ($n = 363$)	p	Public ($n = 170$)	Private ($n = 150$)	p	Public ($n = 188$)	Private ($n = 175$)	p	Public ($n = 358$)	Private ($n = 325$)	p
TC[a]	4.51 ± 0.7	4.50 ± 0.8	NS[b]	4.42 ± 0.7	4.66 ± 0.8	.0050	4.42 ± 0.7	4.68 ± 0.8	.0019	4.40 ± 0.7	4.70 ± 0.8	.0000
HDL-C[a]	1.15 ± 0.2	1.13 ± 0.2	NS	1.13 ± 0.2	1.16 ± 0.2	NS	1.11 ± 0.2	1.11 ± 0.2	NS	1.14 ± 0.2	1.13 ± 0.2	NS
LDL-C[a]	2.91 ± 0.5	3.01 ± 1.8	NS	2.76 ± 0.7	3.08 ± 0.8	.0001	2.90 ± 1.8	3.21 ± 1.8	NS	2.81 ± 1.4	3.11 ± 1.4	.0050
TG[c]	1.01 ± 0.6	1.11 ± 0.6	.0336	1.10 ± 0.7	0.93 ± 0.5	.0045	1.16 ± 0.5	1.10 ± 0.6	NS	1.14 ± 0.6	1.02 ± 0.5	.0074
Gl	4.39 ± 0.6	4.28 ± 0.6	.0050	4.39 ± 0.61	4.33 ± 0.4	NS	4.28 ± 0.5	4.28 ± 0.6	NS	4.33 ± 0.6	4.33 ± 0.5	NS

TC, Total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TG, triglycerides; Gl, glucose.

a. To convert mmol/L cholesterol to mg/dl, multiply by 38.7.

b. NS indicates that the difference is not significant ($p > .05$ by analysis of variance).

c. To convert mmol/L triglycerides to mg/dl, multiply by 88.6.

TABLE 3. Serum lipid levels (means ± SD) of urban Costa Rican schoolchildren according to parental educational levels

	Mother's education (yr)			Father's education (yr)		
Value (mmol/L)	< 11 ($n = 220$)	≥ 11 ($n = 463$)	p	< 11 ($n = 153$)	≥ 11 ($n = 470$)	p
TC[a]	4.01 ± 0.8	4.61 ± 0.8	.00	4.30 ± 0.7	4.61 ± 0.8	.000
HDL-C[a]	1.10 ± 0.2	1.10 ± 0.2	NS[b]	1.13 ± 0.2	1.14 ± 0.2	NS
LDL-C[a]	2.71 ± 0.8	3.11 ± 1.6	.000	2.71 ± 0.7	3.08 ± 1.6	.006
TG[c]	1.11 ± 0.6	1.10 ± 0.6	NS	1.08 ± 0.5	1.06 ± 0.6	NS

TC, Total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TG, triglycerides.

a. To convert mmol/L cholesterol to mg/dl, multiply by 38.7.

b. NS indicates that the difference is not significant ($p > .05$ by analysis of variance).

c. To convert mmol/L triglycerides to mg/dl, multiply by 88.6.

TABLE 4. Classification of urban Costa Rican children in public and private schools according to serum lipid levels based on the national cholesterol education programme guidelines ($n = 683$)

	Sex			Boys			Girls			Total		
	% of children			% of children			% of children			% of children		
Value (mmol/L)	M ($n = 320$)	F ($n = 363$)	p	Public ($n = 170$)	Private ($n = 150$)	p	Public ($n = 188$)	Private ($n = 175$)	p	Public ($n = 358$)	Private ($n = 325$)	p
TC[a]												
< 4.42	44.0	47.1	NS[b]	50.0	37.3	.022	52.7	41.1	.012	54.1	39.4	.002
4.42–5.17	39.4	30.3	.016	38.2	40.7	NS	30.3	30.3	NS	34.1	35.1	NS
≥ 5.2	16.6	22.6	NS	11.8	22.0	.030	17.0	28.6	.036	14.5	25.5	.000
HDL-C[a]												
<0.91	14.7	17.7	NS	16.4	12.7	NS	17.1	18.3	NS	16.8	15.7	NS
0.91–1.17	44.4	45.9	NS	44.7	44.0	NS	46.5	45.1	NS	45.7	44.6	NS
≥1.17	409	36.4	NS	39.8	43.3	NS	36.4	36.6	NS	37.5	39.7	NS
LDL-C[a]												
<2.86	45.7	49.7	NS	52.7	38.0	.012	54.6	44.6	NS	53.7	41.5	.002
2.86–3.35	28.7	24.7	NS	29.3	28.0	NS	25.4	24.0	NS	27.3	25.8	NS
≥3.38	25.6	25.6	NS	18.0	34.0	.002	20.0	31.4	.018	19.0	32.6	.000
TG[c]												
<1.02	58.3	51.2	NS	50.9	66.7	.006	48.4	54.3	NS	49.6	60.0	.008
1.02–1.46	23.8	26.3	NS	29.6	17.3	.014	26.3	26.3	NS	27.9	22.2	NS
≥1.47	17.9	22.5	NS	19.6	16.0	NS	25.3	19.4	NS	22.5	17.8	NS

TC, Total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TG, triglycerides.

a. To convert mmol/L cholesterol to mg/dl, multiply by 38.7.

b. NS indicates that the difference is not significant ($p > .05$ by analysis of variance).

c. To convert mmol/L triglycerides to mg/dl, multiply by 88.6.

19%, respectively; $p = .000$). There were no significant differences between boys and girls.

More than 30% of elementary schoolchildren had HDL cholesterol levels below 1.17 mmol/L together with LDL cholesterol levels above 2.86 mmol/L. Four percent had HDL cholesterol levels below 0.91 mmol/L together with LDL cholesterol levels above 3.38 mmol/L.

Among boys the prevalence of borderline levels of triglycerides was greater for public schoolchildren (30%) than for private schoolchildren (17%; $p = .014$). There was no significant difference between girls from public and private schools in the prevalence of borderline levels of triglycerides.

Around 30% of the children had triglyceride levels above 1.02 mmol/L together with HDL cholesterol levels below 1.17 mmol/L. Six percent had triglyceride levels above 1.47 mmol/L together with HDL cholesterol levels below 0.91 mmol/L. Fifteen percent had at the same time triglyceride levels above 1.02 mmol/L, HDL cholesterol levels below 1.17 mmol/L, and LDL cholesterol levels above 2.86 mmol/L.

Multiple regression analysis

BMI is related to triglyceride levels ($p = .000$) and accounts for 84% of the variance. BMI is also related to HDL cholesterol levels ($p = .0094$) but accounts for only 9% of the variance. The kind of school attended (public vs private) is related to levels of total cholesterol ($p = .002$) and triglycerides ($p = .013$) and accounts for between 10% and 23% of the variance. Father's educational level is related to HDL cholesterol ($p = .005$) and LDL cholesterol ($p = .004$) and accounts for 9% to 12% of the variance. No other variable was a significant predictor of serum lipids.

Food patterns

Table 5 shows the frequency of intake of different types of food by the children. A higher percentage of private schoolchildren than public schoolchildren consumed fruits, vegetables, and carbonated beverages three or more times per week ($p < .01$). Likewise, a higher percentage of private schoolchildren ($p < .05$) ate fast foods one to two times per week. The intake of junk food (chocolate bars, candies, biscuits, potato chips, and cornflour snacks) tended to be higher, but not significantly so, among public schoolchildren. Palm oil was consumed significantly more often by public schoolchildren than by private schoolchildren (30% and 5%, respectively; $p = .000$). The reverse was found for consumption of soya oil (90% and 66%, respectively; $p = .000$).

TABLE 5. Frequency of consumption of selected food groups by urban Costa Rican children in public and private schools

Food and frequency of consumption	Public school ($n = 358$)	Private school ($n = 325$)	p
Fruit			
Never or 1/mo	13.8	6.8	.004
1–2/wk	42.8	31.0	.002
≥ 3/wk	43.4	62.2	.000
Vegetables			
Never or 1/mo	26.2	20.3	NS[a]
1–2/wk	45.9	42.2	NS
≥ 3/wk	27.9	37.5	.009
Pulses			
Never or 1/mo	11.4	16.1	NS
1–2/wk	22.3	35.0	.000
≥ 3/wk	66.3	48.9	.000
Meat (beef and poultry) and fish			
Never or 1/mo	38.4	33.6	NS
1–2/wk	46.0	35.0	NS
≥ 3/wk	15.6	48.9	NS
Sausage			
Never or 1/mo	21.3	33.5	.000
1–2/wk	51.1	48.3	NS
≥ 3/wk	19.8	19.8	NS
Eggs			
Never or 1/mo	22.4	25.5	NS
1–2/wk	55.5	54.7	NS
≥ 3/wk	22.1	19.7	NS
Carbonated beverages			
Never or 1/mo	25.7	20.0	NS
1–2/wk	49.5	41.8	NS
≥ 3/wk	24.8	38.2	.000
Fast foods			
Never or 1/mo	50.5	32.7	.000
1–2/wk	36.5	53.5	.000
≥ 3/wk	13.0	13.8	NS
Junk foods[b]			
Never or 1/mo	24.8	31.7	NS
1–2/wk	41.9	40.0	NS
≥ 3/wk	33.3	28.3	NS

a. Not significant ($p > .05$, χ^2 test).
b. Chocolate bars, candies, biscuits, potato chips, and cornflour snacks.

Discussion

The presence of risk factors for coronary artery disease, previously identified in older subjects, is also related to the extent of lesions at an early age [5, 11]. The Bogalusa Heart Study suggested that more than 70% of the children with an adverse lipid profile tend to remain that way as young adults. This tracking phenomenon is important, because it allows the possibility of early identification of individuals at high risk for coronary artery disease. In this regard, the tendency observed in the lipid profile of Costa Rican schoolchildren is worrisome. It appears particularly important in Costa Rica, where coronary artery disease is the main cause of death [9].

More than 40% of the schoolchildren had LDL cholesterol levels above 2.86 mmol/L. LDL cholesterol levels have been linked to early lesions of the aorta and coronary arteries [13], and the measurement in young people is a powerful predictor of coronary artery disease in middle-aged people [6, 7]. The high prevalence of borderline and high levels of LDL cholesterol observed in this study suggests the progression of atherosclerosis and a greater risk of coronary artery disease. Stary has shown that coronary artery fatty streaks occur in more than half of children aged 10 to 14 years, and 8% have more advanced lesions [4, 5].

Furthermore, over 60% of the children had HDL cholesterol levels below 1.17 mmol/L, and around 30% simultaneously had HDL cholesterol levels below 1.17 mmol/L and LDL cholesterol levels above 2.86 mmol/L. HDL cholesterol is strongly protective at high levels [14], but low levels of this lipoprotein represent a marker for increased levels of atherogenic lipoproteins, such as very low density lipoprotein (VLDL), intermediate density lipoprotein (IDL), and small, dense LDL cholesterol [14, 15]. VLDL and IDL are atherogenic and cytotoxic [16, 17], and the LDL subfractions are independently associated with increased coronary risk [18, 19]. They have been associated with a three times higher risk of myocardial infarction [18]. Also, low levels of HDL cholesterol in the presence of high levels of LDL cholesterol have been identified as an important risk factor for coronary artery disease [14].

Around 30% of the children had triglyceride levels above 1.02 mmol/L together with HDL cholesterol levels below 1.17 mmol/L. This is alarming, because the combination of high triglyceride levels and low HDL cholesterol levels has been identified as an important indicator of high coronary risk [13, 15]. In addition, the high percentage of children (20%) with hypertriglyceridaemia (triglyceride levels above 1.47 mmol/L) is worrisome, because 50% of these children are considered at risk of overweight (BMI at least in the 85th percentile but below the 95th percentile). Overweight is the main risk factor for the development of insulin resistance [20].

Cross-sectional and longitudinal data from the Bogalusa Heart Study revealed a positive correlation between various indices of obesity and serum VLDL cholesterol and LDL cholesterol, and showed a negative correlation with HDL cholesterol [21]. A similar relation between BMI and lipid levels was found in this study. This is important, since 30% of the children in this study were at risk of overweight. If the weight continues to increase, the risk of disorders in lipid and carbohydrate metabolism will also increase, together with the risk of coronary artery disease.

Data from the National Health and Nutrition Examination Survey (NHANES) II and NHANES III and the Bogalusa Heart Study indicate a substantial increase in obesity but not in total energy intake among children. These results suggest that the increased prevalence of overweight in children is partly the result of increased leisure time spent in non-physical activities [22]. According to Gortmaker et al., more than 60% of the incidence of overweight in children aged 10 to 15 years can be attributed to television viewing [23].

A decrease in television viewing time to the levels recommended by the American Academy of Pediatrics (no more than two hours per day) [24] could help prevent the increase in the prevalence of overweight in Costa Rican elementary schoolchildren and improve their lipid profiles. Multiple evidence suggests that exercise may favourably affect the levels of triglycerides, HDL cholesterol, apolipoprotein A, and apolipoprotein B and the size and density of HDL particles [25–27]. Given these facts, prompt attention to our results is required, because only 22% of the schoolchildren in this study follow this recommendation, indicating that most children are at a greater risk of becoming obese if they continue with the same pattern of physical activity. This problem is even more alarming in private schoolchildren, since more than 32% of them watch television for five or more hours per day (table 6).

Changes in security, parental work habits, school schedules, and other cultural and environmental aspects may result in a further increase in the time spent watching television. It is important to promote lifestyle changes to reduce the time children spend watching television. Some studies have shown that television viewing is strongly related to the onset of new cases of obesity and to the lack of remission among obese children [28, 29]. This is important if we consider that our findings showed that BMI was the main predictor of triglyceride levels in children.

TABLE 6. Use of leisure time by urban Costa Rican children in public and private schools

Time spent (h/day)	% of children			p
	All children	Public school ($n = 358$)	Private school ($n = 325$)	
Watching television				
≤2	24	25	24	NS[a]
3–4	51	52	43	.023
5–6	23	23	32	.011
≥ 7	1	0	1	NS
Physical activity				
0	23	14	32	.000
1	14	7	21	.000
2–3	48	60	36	.000
≥4	15	19	11	.005

a. Not significant ($p > .05$, χ^2 test).

Overall, the average time spent in physical activity (approximately two hours a day) is adequate in both groups of children, considering that Pate et al. suggested that at least 30 minutes per day of moderate physical activity benefits health and fitness [30]. Nevertheless, more than 20% of the children reported that they did not engage in any physical activity during the week, and approximately 15% said they did it for less than one hour per day. This finding was more frequent among private schoolchildren (p = .000, table 6). The finding should be analysed closely to determine the factors that condition this behavioural pattern, since, at least theoretically, children in private schools have better access to recreational centres. However, in the Alameda County Study, Kaplan et al. found a monotonic inverse relation between the decline in leisure time physical activity and the level of either education or income [31].

SES acts as a powerful influence on the adoption of food habits or behaviours, such as physical activity [32]. It has been proposed that more educated parents are better informed about proper health behaviours and adopt them [33], which in turn influences their children's risk factor status. However, this cannot be generalized in Costa Rica, because no extensive local or national cardiovascular health promotion campaign has been implemented to improve the knowledge of risk-reduction factors. Instead, it has been observed that with increasing income decile in Costa Rican families, there is an increase in the consumption of saturated fats [34].

People with higher incomes can spend a larger percentage of it on food [32], but this does not imply healthier dietary choices. Private schoolchildren eat fruits and vegetables more frequently than public schoolchildren, which reflects a higher purchasing power, since they are more expensive [35, 36]. However, they also eat more junk foods and fast foods, which are rich in energy and saturated fats, and carbonated beverages, which contain large quantities of simple carbohydrates. Wolfe and Campbell demonstrated that children whose mothers were employed outside the home tended to eat a less diverse diet and consumed more snack foods than those with mothers at home [37].

Private schoolchildren tend to be more sedentary and tend to have a more atherogenic diet than public schoolchildren. This explains, at least partially, why the lipid profile of these children is more adverse than that of public schoolchildren. These results do not coincide with the documented relationship between SES and coronary artery disease. An inverse relationship between educational level and cardiovascular disease risk factors has been fairly well established [38]. However, Kaplan and Keil, in a review of the literature on the association between SES and coronary artery disease, argued that the evidence for a relationship between cholesterol level and SES is not consistent. They indicated that this relation has to do mainly with hypertension, cigarette smoking, obesity, fibrinogen, and diabetes mellitus [32].

Given the high prevalence of children with an adverse lipid profile, primary prevention programmes are required to decrease the prevalence of cardiovascular risk factors and to improve food habits and the pattern of physical activity. These programmes should include the children's school and family environment, so that adults reinforce and promote knowledge, attitudes, and practices tending to decrease coronary artery disease risk factors. Parents and educators should be good models of healthy behaviour.

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Prevalence of iron deficiency, anaemia, and iron-deficiency anaemia in high-school students in Jolfa, East Azerbaijan

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Abstract

Iron deficiency is the most prevalent nutritional problem in the world. We determined the prevalence of iron deficiency, anaemia, and iron-deficiency anaemia in 652 high-school students (340 girls and 312 boys) who were selected by stepwise random sampling from 16 high schools in Jolfa, East Azerbaijan. Iron deficiency was defined as having transferrin saturation and/or serum ferritin values below normal. Anaemia was defined as having haemoglobin levels below normal. Iron-deficiency anaemia was taken to be the combination of both. The prevalences of iron deficiency, anaemia, and iron-deficiency anaemia were 60.7%, 12.6%, and 11.5%, respectively. The respective prevalences of these conditions were 66.5%, 13.6%, and 13% in girls and 54.5%, 11.6%, and 10.3% in boys. The prevalences of these conditions were higher among 15- and 16-year-old boys than among girls. Among boys, age was inversely related to the prevalence of iron deficiency ($r = -0.88$, $p < .05$) and anaemia ($r = -0.79$, $p < .07$). Among girls, age was directly related to the prevalence of anaemia ($r = 0.96$, $p<.001$) and iron-deficiency anaemia ($r = 0.99$, $p < .001$).

Introduction

Iron deficiency is the most prevalent nutritional problem in the world. About two billion people suffer from iron deficiency, half of whom have clinical signs of anaemia [1, 2]. Iron deficiency and iron-deficiency anaemia adversely affect physical and intellectual performance, the immune system, and body temperature regulation [3, 4]. It is well known that adolescents are at risk for iron deficiency and iron-deficiency anaemia [2]. Limited data exist in Iran on the prevalence of iron deficiency, anaemia, and iron-deficiency anaemia in adolescent girls, and virtually no information is available on adolescent boys [5–8]. We looked at the prevalence of iron deficiency, anaemia, and iron-deficiency anaemia in 14- to 20-year-old high-school students in Jolfa, East Azerbaijan. This district is north of Azerbaijan Province, 120 km from Tabriz and 750 metres above sea level [9].

Materials and methods

High-school students (340 girls and 312 boys) were selected by stepwise random sampling from 16 high schools in Jolfa. The sample size was based on an estimated 11.5% prevalence of anaemia in East Azerbaijan, 95% confidence interval, and 2.5% error [10]. The proposal was approved by the Research Council of the National Nutrition Institute, and written consent was secured from the subjects' parents. Students who had hepatic or neural chronic diseases, had received blood transfusions, or had been blood donors within the previous two weeks were excluded, because these conditions change iron status indicators in the body [3]. About 10 ml of fasting venous blood was taken from each subject, 2 ml for haemoglobin and the remainder for serum tests. Serum was separated by a standard method in a reference health-care centre of Jolfa. The tubes were sealed with parafilm, and the samples were kept at 4° to 5°C and sent to Imam Khomeini Hospital in Tabriz. Haemoglobin was measured the same day with a SYS mex-K 9000 cell counter. Serum samples were stored at –20°C. Serum iron (SI) and total iron-binding capacity (TIBC) were measured with manual kits (Zeist) by spectrophotometry, and serum ferritin was assayed by IRMA kit (Kavoshyar) on a gamma counter. The transferrin saturation (TS) percentage was calculated as follows:

$$\%\,\mathrm{TS} = \frac{\mathrm{SI}}{\mathrm{TIBC}} \times 100$$

Iron deficiency was defined as serum ferritin below

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15 μg/L and/or transferrin saturation below 16% in both boys and girls. Anaemia was defined as haemoglobin values below 11.5 g/dl in girls under 15 years of age and below 12 g/dl in girls 15 years of age and older, as well as for boys under 15 years of age. In boys over 15 years of age, the cut-off point was 13 g/dl. Iron-deficiency anaemia was defined as the occurrence of iron deficiency together with anaemia [11–15]. About 10% of the tests were done in duplicate.

Results

The mean ages were 16.9 ± 1.3 years for girls and 17 ± 1.4 years for boys. In 25 students (24 girls and 1 boy), haemoglobin could not be tested because of sample coagulation and haemolysis. The age and sex distribution of the students surveyed in Jolfa are shown in table 1. Table 2 shows the distribution of iron deficiency, anaemia, and iron-deficiency anaemia.

Among girls, the 95% confidence intervals were 61.5% to 71.5% for the prevalence of iron deficiency, 9.8% to 17.4% for the prevalence of anaemia, and 9.3% to 16.7% for the prevalence of iron-deficiency anaemia. Among boys, the respective confidence intervals were 49% to 60%, 8% to 15.2%, and 6.9% to 13.7%. The age distributions of iron deficiency, anaemia, and iron-deficiency anaemia are shown in figs. 1, 2, and 3.

TABLE 1. Age and sex distribution of the subjects, Jolfa, 1997

Age (yr)	Female	Male
14	30	24
15	67	50
16	86	93
17	82	78
18	56	38
19	19	29
Total	340	312

Discussion

Our study showed that three out of every five girls and half of the boys were iron deficient. Studies in Islamabad and Karachi, Pakistan [16, 17]; Colombo, Sri Lanka [18]; Chartsworth, South Africa [19]; and Sligo, Ireland [20] showed a prevalence of iron deficiency of 30% to 59%. Measurements of serum iron, total iron-binding capacity, and transferrin saturation and assay of serum ferritin concentration are sometimes useful in distinguishing iron deficiency, except when conditions such as inflammatory disorders or malignancies and chronic diseases coexist. We excluded these conditions. At present, measurement of serum ferritin concentration appears to be the most sensitive, specific, and practical test for the diagnosis of uncomplicated iron deficiency [3].

Studies in other areas of Iran showed a 27% to 39% prevalence of iron deficiency in 14- to 20-year-old girls [5, 6, 8]. The difference is due to the different cut-off points used. Because there is no information on parasitic infection and dietary assessment in our study area, the real causes need to be determined in

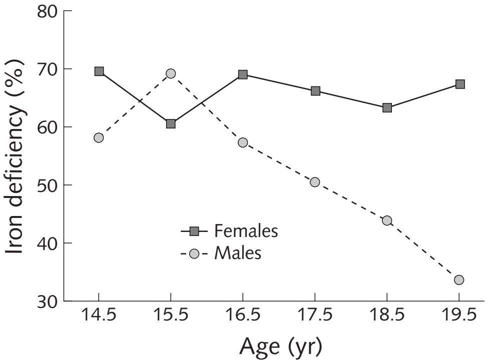

FIG. 1. Age distribution of iron deficiency in 652 students, Jolfa, 1997. In boys there was an inverse relationship between age and the prevalence of iron deficiency ($r = -0.88$, $p < .05$). In girls this relationship was not seen

TABLE 2. Distribution of iron deficiency, anaemia, and iron-deficiency anaemia in the subjects, Jolfa 1997

Sex	Iron deficiency[a] no. (%)		Anaemia[b] no. (%)		Iron-deficiency anaemia[c] no. (%)		% of anaemia due to iron-deficiency anaemia
	Present	Absent	Present	Absent	Present	Absent	
Female	226 (66.5)	114 (33.5)	43 (13.6)	273 (86.4)	41 (13.0)	275 (87.0)	95.3
Male	170 (54.5)	142 (45.5)	36 (11.6)	275 (88.4)	32 (10.3)	279 (89.7)	88.8
Total	396 (60.7)	256 (39.3)	79 (12.6)	548 (87.4)	71 (11.6)	554 (88.4)	89.9

a. Iron deficiency in both sexes is defined as serum ferritin below 15 μg/L and/or transferrin saturation below 16%.

b. Anaemia is defined as haemoglobin values below 11.5 g/dl in girls under 15 years of age and below 12 g/dl in girls 15 years of age and older, as well as for boys under 15 years of age. In boys over 15 years of age, the cut-off point is 13 g/dl.

c. Iron-deficiency anaemia is a combination of the above two conditions.

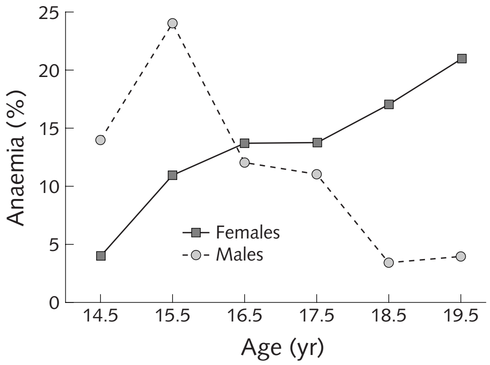

FIG. 2. Age distribution of anaemia in 627 students, Jolfa, 1997. There was a direct relationship in girls ($r = 0.96$, $p < .001$) and an inverse relationship in boys ($r = -0.79$, $p < .07$) between age and the prevalence of anaemia

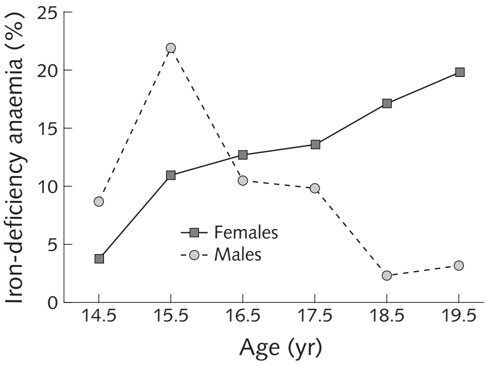

FIG 3. Age distribution of iron-deficiency anaemia in 627 students, Jolfa, 1997. In girls there was a direct relationship between age and the prevalence of iron-deficiency anaemia ($r = 0.96$, $p < .001$). In boys this relationship was not seen

future studies. Studies from Europe, North America, and Australia have reported a 2% to 38% prevalence of iron deficiency in male and female adolescents [13–15, 21–24]. Our study found that 13.6% of 14- to 20-year-old girls were anaemic, a figure comparable to those from Zahedan in southern Iran, Islamabad in Pakistan, and Adana in Turkey [6, 16, 25]. Studies in Georgia, USA, Sligo, Ireland, and Val-de-Marne, France, have found a 2.3% to 7% prevalence of anaemia in 14- to 20-year-old girls [14, 20, 23]. The prevalence of anaemia in boys in our study was less than that in Islamabad and Adana. In these studies, 15% to 17.5% of boys were anaemic [16, 25]. Iron-deficiency anaemia was found in 13% and 10.3% of girls and boys, respectively. In high-school girls, a direct relationship between age and the prevalence of anaemia and of iron-deficiency anaemia was observed, whereas in boys after puberty there was an inverse relationship between age and the prevalence of anaemia and of iron deficiency. Menstruation and puberty both increase body iron needs [3]. Thus, the prevalence of iron-deficiency anaemia increases more in adolescent girls.

Conclusions

The prevalence of anaemia and of iron-deficiency anaemia was in the range found in other studies in Iran (9%–16%), whereas the prevalence of iron deficiency was higher. The high prevalence of iron-deficiency anaemia and iron deficiency in 14- to 17-year-old male high-school students is notable. The high prevalence of iron deficiency and iron-deficiency anaemia in our study was similar to that in neighbouring countries and calls for the fortification of cereals, oral supplementation, and other public health interventions to combat it. These measures have been recently reviewed by a UNICEF/UNU/WHO/MI Technical Workshop [26]. Iron deficiency and iron-deficiency anaemia adversely affect behaviour and intellectual performance, body temperature regulation, immunity and resistance to infections, lead poisoning, and pregnancy outcome. In view of the prevalence of iron deficiency in adolescents and its adverse effects, it is essential to combat iron-deficiency anaemia and iron deficiency in school-age children in Iran.

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Physical fitness in relation to energy and iron status of female college students

Kiran Bains and S. K. Mann

Editorial note

The Bulletin *does not publish local surveys, except as short summaries, unless they have elements that make them useful to other groups. However, this paper was accepted because it describes the functional consequences of energy and iron deficiencies that are generalizable.*

Abstract

A nutritional survey was conducted on 150 female college students (75 boarders and 75 day scholars) aged 18 to 23 years at the Punjab Agricultural University in Ludhiana, India. The mean weight, mid-upper-arm circumference, and triceps skinfold thickness were below normal, but the mean height and body fat were in the normal range. The body mass index showed that 50% of the subjects were normal, 21% were low normal weight, and 21% had a mild energy deficiency. The average daily consumptions of energy and of iron were 1,776 ± 22 kcal and 14.5 ± 0.2 mg, respectively; both were inadequate. The daily total energy expenditure was 1,824 ± 9 kcal, yielding a negative energy balance of 48 ± 10 kcal/day. The average haemoglobin and serum ferritin levels were below normal, while serum iron was in the low normal range. Low iron intake and haemoglobin levels confirmed an unsatisfactory iron status of the subjects. The combined deficiency of energy and iron appeared to have a worse effect on physical fitness than energy or iron deficiency alone.

Introduction

Restricted energy intake and severe anaemia are claimed to reduce physical work capacity and therefore are important determinants of labour productivity. A good physical work capacity is a desirable attribute that depends on adequate intake of calories and iron [1].

Increasing population, demographic pressure, and the need for more food have put a heavy burden on the world's poor. Despite economic growth and increase in food production, the energy gap continues to be the major nutritional disorder that adversely affects work efficiency. Punjab state has a surplus of food grain production, which was 21.2 million tonnes in 1997–1998. It contributes 60% to 70% of its wheat and 40% to 45% of its rice to the central food grain pool of the country [2]. There is also an abundant production of green leafy vegetables in the winter.

In spite of adequate food production, energy and iron deficiencies continue to be the major nutritional disorders adversely affecting work efficiency. Nutritionally deprived persons have smaller body size as well as weight, and they expend energy only in proportion to their body weight. Thus, short stature and reduced body size due to undernutrition will mean lower levels of productivity for sustained moderate to heavy physical work [3–5]. Work efficiency is also directly correlated with energy consumption. Restricted energy intake leads to reduction in energy expenditure, which may limit work capacity [6].

Iron plays both a direct and an indirect role in sustaining the physiologic and metabolic processes involved in physical activity and exercise [7, 8]. Globally, 2,170 million people suffer from iron-deficiency anaemia [9], of whom 90% are in developing countries [10], and over the years this picture has not changed. Iron-deficiency anaemia is a major concern in most of the developing countries, especially among women in the reproductive age group. Severe anaemia may impair work capacity, learning ability, and immune function [11]. In India anaemia appears to be caused mainly by lower dietary intake and poor absorption of iron from cereal-based vegetarian diets, which leads to nutritional anaemia in more than 80% of women because of excessive body needs. Dietary inadequacy of energy, B-complex vitamins, and ascorbic acid has also been observed among young women [12].

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Serum ferritin values reflect liver iron stores. The total iron stores in the liver are normally about 1 g, mostly as ferritin. Low serum ferritin values, even among non-anaemic adolescent girls, indicate that they are iron deficient and at risk of becoming anaemic [13].

In recent years, there has been increasing concern about the poor nutritional status of many young women who are on the threshold of adulthood and constitute a segment of the vulnerable group. Undernutrition among young women limits the nation's productivity and social contribution to humanity. Thus, good nutritional status of young women can be considered an indicator of development. The Department of Foods and Nutrition, Punjab Agricultural University, Ludhiana, estimates the energy balance of adult women [14–16] and the effect of energy and iron supplementation on physical work capacity under controlled conditions [17, 18]. In order to formulate guidelines for the development of a scientifically sound and economically feasible nutrition strategy, a knowledge and understanding of the dietary energy and iron status of young women as it exists in the field and its relationship to physical fitness is essential.

Materials and methods

Subjects

Seventy-five young women residing in the Punjab Agricultural University hostel and an equal number of day scholars aged 18 to 23 years were selected to participate in the study. The volunteer subjects were not pregnant or lactating.

Anthropometric profile

Measurements included height, weight, mid-upper-arm circumference (MUAC), and skinfold thickness at four different sites—triceps, biceps, subscapular, and suprailiac—according to the methods of Jelliffe [19]. The percentage of body fat was calculated from the triceps, biceps, subscapular, and suprailiac measurements by using the equations given by Durnin and Womersley for 18- to 23-year-old women [20]. The body mass index (BMI) was calculated as weight/height^2, where weight is in kilograms and height is in metres. The BMI classification by Garrow [21] was followed to classify the subjects according to their energy status.

Dietary survey

A questionnaire was formulated to record the food intake of the subjects for three consecutive days during the summer and winter using the 24-hour-recall method. Time spent on different activities for three consecutive days was noted at the time of the dietary survey in both seasons.

Energy expenditure

Activity was classified as sleep or as light, moderate, or heavy activity. Energy expenditure was determined by the MSU Nutriguide computer programme adapted to the Indian population [22].

Biochemical analysis

Blood haemoglobin levels were determined by the cyanomethaemoglobin method [23] during the summer and winter. The anaemia classifications of WHO [9] and the National Institute of Nutrition [24] were followed. Serum iron was estimated by digesting the serum sample (1 ml), as described by Piper [25]. The concentration of iron in the sample was read in an atomic absorption spectrophotometer (Varian model). The method of Teitz [26] was used to measure total iron-binding capacity (TIBC). Unsaturated iron-binding capacity (UIBC) and percent transferrin saturation (TS) were calculated from the serum iron and TIBC values [26, 27]. Serum ferritin estimation was carried out in 34 subjects: 11 non-anaemic, 11 moderately anaemic, and 12 mildly anaemic. A UBI Marginal ferritin quantitative HP-601 kit, a solid-phase enzyme-linked immunosorbent assay (ELISA), was used for serum ferritin values: i.e., 1 μg/L serum ferritin is equivalent to 9 mg of liver iron stores [28].

Assessment of physical fitness

The Harvard Step Test [29] was administered to assess the physical fitness of the subjects. The total exercise time and the pulse between 1 and 1 1/2 minutes after the completion of exercise were recorded. The rapid fitness index (RFI) was then calculated as [(duration of exercise in seconds)/(5.5 × pulse count)] × 100.

Statistical analysis

Statistical analysis was performed with the computer programme package CPCS 1 [30].

Results

The anthropometric profile of the subjects is shown in table 1. The average height of the subjects was 160.4 ± 0.7 cm and their average weight was 52.6 ± 0.7 kg. The average weight-for-height was below the Life Insurance Corporation of India [31] standards for Indian women.

The measurements of MUAC and triceps skinfold thickness were 85.6% and 85.5% of the reference

TABLE 1. Anthropometric measurements of the subjects

Measurement	Range	Mean ± SE	Reference standards
Height (cm)	146.1–176.5	160.4 ± 0.7	—
Weight (kg)	38.0–76.8	52.6 ± 0.7	53.0–59.0 [31]
Mid-upper-arm circumference (cm)	18.8–33.2	24.4 ± 0.2	28.5 [19]
Triceps skinfold thickness (mm)	9.1–25.8	14.1 ± 0.2	16.5 [19]
Body-mass index (kg/m^2)	15.0–31.3	20.21 ± 0.24	20–25 [21]
Body fat (%)	21.4–34.0	26.22 ± 16	10–54 [20]

standards, respectively. The mean BMI of the subjects was in the normal range of 20 to 24 kg/m^2. The mean body fat was 26.22 ± 16%.

On the basis of BMI classification [21], 50% of the subjects were considered normal, whereas 21% were of low normal weight and an equal percentage were mildly energy deficient. Severe and moderate energy deficiency was observed in a very small number of subjects, and the number of obese subjects was also negligible (fig. 1).

The percent adequacy of the nutrients is shown in fig. 2. The mean daily energy consumption was 1,776 ± 22 kcal, which was below the recommended dietary allowance (RDA) of 1,915 kcal [32]. The total energy expenditure was 1,824 ± 9 kcal; thus, a negative energy balance of 48 kcal was observed (table 2). The protein intake of 48.6 ± 0.6 g/day was inadequate in comparison with the RDA of 51.5 g [32]. There were no significant differences in energy and protein intakes between boarders and day scholars or between summer and winter seasons.

The intake of thiamine and riboflavin per 1,000 kcal was adequate, whereas that of niacin, folic acid, and ascorbic acid was inadequate. Daily iron consumption was 13.4 ± 0.3 mg during the summer and 15.6 ± 0.3 mg during the winter, much below the RDA of 30 mg. The consumption of other minerals, i.e., copper, calcium, and phosphorus, was adequate, but that of zinc was inadequate when compared with the Indian RDA [32]. The consumption of minerals was significantly higher in the winter than in the summer ($p < .05$).

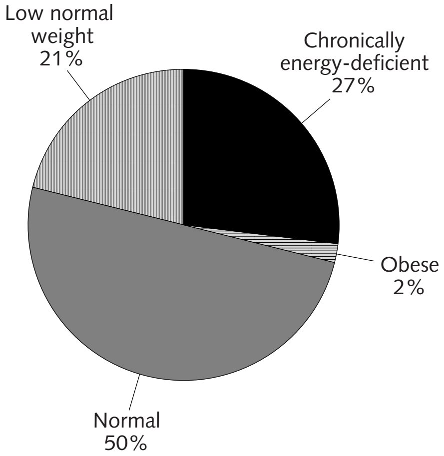

FIG. 1. Nutritional status of subjects based on BMI

The iron status indicators of the subjects are summarized in table 3. The mean blood haemoglobin level of 11.3 ± 0.11 g/dl was below the WHO standard [9], and 62% of the subjects were categorized as anaemic (Hb < 12.0 g/dl), of whom 27% were mildly anaemic (Hb 10.0–10.9 g/dl) and 14% were moderately anaemic (Hb 8.0–9.0 g/dl) (fig. 3). The values of serum iron, TS, and UIBC were in the normal range. The mean TIBC was above the normal range. The mean

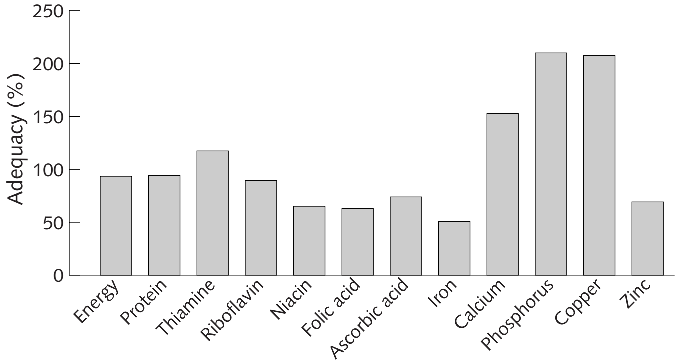

FIG. 2. Adequacy of intake of nutrients

TABLE 2. Total daily energy intake, expenditure, and balance of the subjects ($n = 150$)

Energy measurement (kcal/24 h)	Range	Mean ± SE
Intake	1,266 to 2,557	1,776 ± 22.1
Expenditure	1,582 to 2,122	1,824 ± 9.0
Balance	−452 to 635	−48 ± 10

serum ferritin level was 12.4 ± 0.9 µg/dl, and the mean liver iron, calculated from serum ferritin values of selected subjects, was 115 ± 7.8 mg.

The exercise time, pulse rate, and rapid fitness index (RFI) were 186 seconds, 103 beats per minute, and 31.0, respectively. On the basis of the RFI, 87% of the subjects had poor physical fitness. Energy-adequate subjects had significantly higher exercise times and RFI values and lower pulse rates than energy-deficient subjects ($p < .01$). Moderately anaemic subjects had significantly shorter exercise times, lower RFI values, and higher pulse rates than non-anaemic, marginally anaemic, and mildly anaemic subjects ($p < .05$)(fig. 4).

Table 4 presents the combined effect of energy and iron deficiency on the physical fitness of the subjects. Non-anaemic, energy-deficient subjects had significantly higher RFI values than anaemic, energy-deficient subjects ($p < .01$) The RFI values of the non-anaemic, energy-deficient group and the anaemic but energy-adequate group were lower than that of the non-anaemic, energy-adequate group, but the differences were not significant.

Discussion

The average height of the subjects was above the normal range for Indian women (150.7 to 153.3 cm) [32]. The above-normal height of Punjabi women has been confirmed by Mann et al. [16]. The MUAC and triceps skinfold thickness of the subjects were 85.6% and 85.5% of the reference standards. Fifty percent of the subjects were classified as of normal weight and normal BMI, whereas 21% had low weight and BMI, and an equal percentage had mild energy deficiency, as judged by their BMI. Severe or moderate energy deficiency was observed in a very small number of subjects, and the number of obese subjects was negligible. Thus, the low body weight, MUAC, and triceps skinfold thickness indicated the low energy status of the subjects.

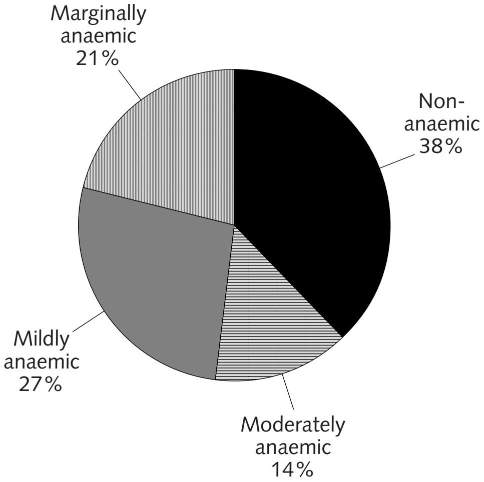

FIG. 3. Anaemia status of subjects based on haemoglobin levels

The daily intake of energy and protein was inadequate as compared with the Indian RDAs. A significant ($p < .01$) correlation between energy intake and anthropometric measurements, especially body weight and BMI, indicated that the low body weight and BMI were associated with low dietary energy intake. The energy expenditure of boarders and day scholars was also similar and did not vary significantly in the two seasons. The energy balance among the subjects was slightly negative, which, along with anthropometric measurements below the reference standards, confirmed their low energy status.

Dietary iron intake was only 48% of the Indian RDA. A significant ($p < .01$) correlation was also observed between iron intake and haemoglobin level, indicating that low haemoglobin was usually due to low dietary iron intake. The average consumption of folic acid and ascorbic acid was 62% and 71% of the

TABLE 3. Blood iron status indices of the subjects

Index	n	Range	Mean ± SE	Normal values
Haemoglobin (g/dl)	150	8.0–13.0	11.3 ± 0.11	≥12 [9, 24]
Serum iron (µg/dl)	150	54–188	88 ± 2	63–202 [33]
TIBC (µg/dl)	150	272–672	429 ± 9	250–416 [34]
Transferrin saturation (%)	150	9.0–53.0	24.8 ± 1.0	16–37 [27]
UIBC (µg/dl)	150	144–604	331 ± 1.1	0–500 [26]
Serum ferritin (µg/dl)	34	2.0–42.5	12.4 ± 0.9	≥12 [28]

TIBC, Total iron-binding capacity; UIBC, unsaturated iron-binding capacity.

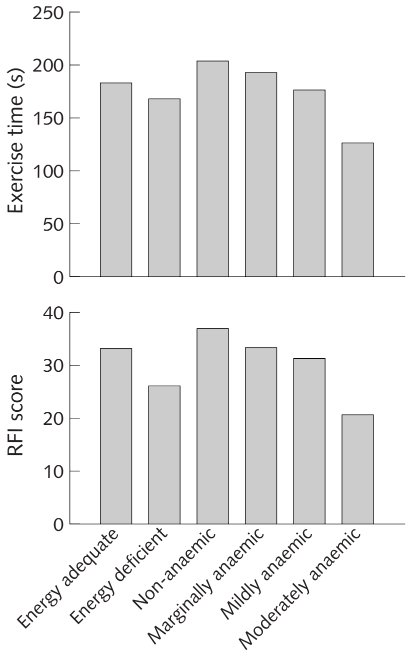

FIG. 4. Exercise time and rapid fitness index (RFI)

Indian RDAs, respectively. Adequate dietary folate is vital for haemoglobin synthesis and prevention of birth defects in early pregnancy. Ascorbic acid enhances the absorption of dietary iron from vegetable sources. The average daily intake of ascorbic acid was insufficient to meet the Indian RDA of 40 mg/day, which assumes that 50% of the vitamin is lost during storage and cooking of vegetables. Because the subjects consumed some fresh fruits and salads, the losses may not be as much as 50%, and they may actually be meeting the daily requirements of ascorbic acid.

The majority of the subjects (62%) were anaemic. In iron-deficiency anaemia, very low serum ferritin levels indicated an exhaustion of iron stores in 34 selected subjects. Serum iron also showed a consistent and progressive fall with negative iron balance. TIBC and UIBC, on the other hand, showed corresponding increases. The physical fitness of moderately anaemic subjects was significantly ($p < .01$) lower than that of non-anaemic, marginally, and mildly anaemic subjects, and the gap was greater between non-anaemic and moderately anaemic subjects. Physical work performance was reduced with a moderate degree of anaemia [17, 18].

A longer exercise time, lower pulse rate, and higher RFI in energy-adequate subjects compared with energy-deficient subjects indicated a positive effect of adequate energy status on physical fitness. The results indicate that anaemia had a greater effect on work performance than did energy deficiency, as reported by Bhatia and Seshadri [35]. Subjects with both iron and energy deficiency had significantly lower work performance than those with normal energy and iron status ($p < .01$), indicating that combined energy and iron deficiency had the most adverse effect on physical fitness, as was also reported by Satinderjit [18].

TABLE 4. Combined effects of anaemia and energy deficiency on physical fitness

Group	*n*	Mean ± SEM	
		Exercise time (s)	Rapid fitness index
Non-anaemic, energy-adequate	44	196 ± 13	39.8 ± 2.0
Non-anaemic, energy-deficient	14	171±8	28.9 ± 1.3
Anaemic, energy-adequate	73	172 ± 7	29.3 ±1.1
Anaemic, energy-deficient	19	142 ± 12	24.6 ± 2.0
F-ratio		10.0[a]	14.6[b]

a. $p < .05$.
b. $p < .01$.

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Inadequate salt iodization and poor knowledge, attitudes, and practices regarding iodine-deficiency disorders in an area of endemic goitre in south-eastern Nigeria

E. O. Umenwanne and I. O. Akinyele

Abstract

Focus group discussions and interviewer-administered questionnaires assessed the knowledge, attitudes, and practices of rural dwellers relating to iodine-deficiency disorders. The iodine content of salt was measured at the household and retail levels, and the iodine nutritional status of school-aged children (6–12 years) was assessed by measuring urinary iodine concentrations. The analyses showed a high level of ignorance about the causes and consequences of iodine deficiency, iodine as a nutrient, and iodized salt and its purpose. In a goitre endemic area of south-eastern Nigeria, only 47% of the household samples and 48% of the retail salt samples were iodized to a level above 30 ppm, whereas 34% of the household samples and 19% of the retail samples had no iodine. These findings could be attributable to the methods of salt handling and storage in the area. Among children, 90% had moderate to severe iodine deficiency, 10% were mildly iodine deficient, and none had normal iodine levels according to urinary iodine excretion. The findings suggest a high level of iodine deficiency and the urgent need for information, education, and communication in the study area.

Introduction

The clinical and subclinical manifestations of iodine deficiency are collectively included in the term iodine-deficiency disorders. Iodine-deficiency disorders include goitre at all ages; endemic cretinism, characterized commonly by mental deficiency, deaf-mutism, and spastic diplegia; and impaired mental function in children and adults. In pregnancy, iodine deficiency may cause spontaneous abortions, stillbirths, impaired foetal brain development, and infant deaths. In Nigeria, a survey of goitre in schoolchildren found a national prevalence of 20%. On a regional basis, the south-east had the highest prevalence (37%), the south-west had a prevalence of 29%, and the north-west and north-east each had a prevalence of 13%. On a state basis, the prevalence was highest in Benue (48%), followed by Enugu and Taraba (35%), Kogi (34%), Ondo (30%), Oyo (26%), Edo (25%), Osun (24%), and Plateau (17%), with other states having prevalences less than 17% [1]. In addition, the following areas were mapped out as goitre belts: Akoko-Edo local government area (LGA) in Edo State; Igboetiti and Uzo-uwani LGAs in Enugu State; Bassa in Plateau State; Obudu and Abalinku in Cross Rivers State; Okpokwu, Ankpa, Idah, and Oturkpo in Benue State; and Ifedapo in Oyo State [2, 3].

Iodine deficiency is a nutritional problem of public health concern that requires individual, organizational, and national initiative and support. Fortification of salt with iodine has proved to be the best way to prevent iodine-deficiency disorders [4]. A 1994 survey reported that 97% of edible salt in Nigeria was iodized and more than 95% of households consumed salt iodized to the level of 50 ppm [5].

This study was undertaken because of the hazards posed by iodine deficiency and the dearth of documented information about the current iodine content of salt and knowledge, attitudes, and practices (KAP) related to iodization in the goitre-endemic Uzo-wani LGA. It evaluated the iodine levels in salt at both the household and the retail levels, determined the iodine status of schoolchildren by measuring urinary iodine concentrations, and assessed KAP relating to iodine and goitre. Appropriate nutrition intervention programmes are recommended based on the findings.

Materials and methods

The study was carried out in Uzo-uwani LGA of Enugu State from March 1996 to May 1997.

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Distribution of questionnaire

Each of the four zones of Uzo-uwani LGA served as a cluster from which a community was selected randomly. The population of men and women 18 to 45 years of age (24,387) was obtained from the Community Health office and was divided by the population of the entire LGA (94,632) to obtain the proportion of the study group in the area. The proportion obtained was substituted in the formula for calculating the appropriate sample size for a dichotomous variable with 95% confidence interval and 5% precision level. Three hundred adult men and women from randomly selected households representing each of the four communities were interviewed.

Section A of the questionnaire dealt with personal and socio-economic characteristics such as age, sex, and occupation. Section B sought information on food consumption patterns. Section C dealt with knowledge and practices about iodized salt. Section D contained questions concerning the respondent's knowledge and practices related to iodine and iodine-deficiency disorders.

Collection of salt samples

Salt samples were randomly collected from 25 households that were interviewed in each of the four communities, giving a total of 100 household salt samples.

A total of 21 samples of salt sold in four markets in the selected communities were collected. In addition, rapid rural appraisal interviews [6] and focus group discussions (FGDs) [7] were conducted with retailers in the four markets and housewives to elicit information on the distribution, storage, and handling of salt, place of purchase, type of salt sold, and KAP related to iodized salt and iodine-deficiency disorders.

Collection of urine samples

Eighty subjects of both sexes were systematically selected from 6- to 12-year-old schoolchildren in four primary schools randomly selected from each of the four zones in Uzo-uwani LGA. From each subject, a casual urine sample was collected under the supervision of the researcher, using screw-cap containers with a drop of toluene as a preservative.

Analysis of salt samples

The level of iodine in the salt samples was determined with two simple field test kits developed by MBI Chemicals (India). One of the kits was used for iodated salt and the other for iodized salt. The kits were collected from the Ibacan UNICEF zonal office. The components of the simple field kit included an ampule, enclosed in a plastic container, containing starch solution. A colour gradation chart on the external flat surface of the plastic container showed the number of parts per million of iodine against certain colours. The colour chart was used to determine the concentration of iodine in iodized salt of unknown concentration by simply comparing the colour produced by the tested salt and the colour on the chart. The procedure involved spreading a spoonful of the salt to be tested on a white paper and discharging a drop of the test solution on the surface of the salt sample. The colour change depends on the iodine content. After analysis, the salt samples were classified according to their iodine levels, and their frequencies and percentages were calculated.

Urine analysis

The urine samples were taken to the laboratory where they were stored at –20°C before laboratory analysis. The iodine concentration of the urine was assayed by the Zak method [8]. The principle of this method is that iodine is oxidized to iodate by chloric acid digestion in the presence of sodium chromate. After digestion, the amount of iodate is estimated by its catalytic action on the cleric-arsenite system. Frequencies, percentages, and mean urinary iodine concentrations were calculated for the different age groups. Student's *t* test was used to test for significant differences between the mean urinary iodine concentrations of boys and girls.

Data analysis

The Statistical Package for Social Sciences (SPSS) was used to analyse the questionnaire data. Frequency distributions and percentages for all the variables were computed, and relationships between variables were tested by the chi-square distribution. A value of $p \leq .05$ was considered statistically significant.

Results

Almost all the respondents (table 1) had knowledge of goitre and had seen cases of goitre in the area, but almost 80% of them had no knowledge of the causes of goitre. Some attributed it to sociocultural factors (table 2). A majority of the respondents (59.7%) indicated that goitre is not contagious and that goitrous subjects do not have to be isolated, but 4.7% thought

TABLE 1. Knowledge of goitre

Response	Frequency	%
Yes	295	98.3
No	5	1.7

that goitre was infectious or a manifestation of evil. Recommended therapy for goitre included treatment in a hospital (67.3%), traditional healers (6.3%), and self-medication (1.7%) with pharmaceutical products or herbs (table 3). Some of the respondents (7.3%) thought that goitre was incurable and that only females had goitre.

Most of the respondents (76.3%) did not know that iodine was essential for body function (table 4). Although 21.3% claimed to know dietary sources of iodine, most of them (78.3%) could not name any. Most of the respondents (86.7%) and nearly all of the salt retailers (97%) were not aware of iodized salt or of its purpose (table 5). FGDs revealed that the retailers purchased salt in bags from wholesalers in a more developed town in a neighbouring LGA, and there was no source of salt in the local area. Some of the retailers sold salt in its pure crystalline form, whereas others heated or baked it before taking it to the market for sale. Salt was purchased mainly in cups or as baked salt (table 6).

Twenty-one salt samples were collected from the markets. Tables 7 and 8 show the levels of iodine in the market and household salt samples, respectively. At both the household and the retail levels, less than 50% of the salt samples contained more than 30 ppm of iodine. Almost 20% of the retail samples and 34% of the household samples contained no iodine.

The urinary iodine concentrations of 80 schoolchildren were determined (table 9).

Discussion

The KAP of Uzo-uwani residents about iodine-deficiency disorders and iodized salt reflects their low socio-economic status and lack of education. To most of the subjects, it was ridiculous to discuss the presence of iodine in salt and food consumed by human beings. Their perception of iodine was that it is a medical formulation or drug used externally on wounds, and therefore they questioned the rationale for its oral consumption.

The prevalence of knowledge about goitre from this study notwithstanding, perception of the causes was very poor. Less than 15% of the respondents could link goitre to iodine deficiency. Some respondents attributed goitre to natural causes, poison from one's enemy,

TABLE 2. Opinions about causes of goitre

Cause	Frequency	%
Heredity	6	2.0
Natural causes	10	3.3
Unclean food or water	2	0.7
Lack of balanced diet	2	0.7
Lack of iodine	32	10.7
Supernatural forces	10	3.3
Talking too much	1	0.3
Carrying heavy loads	1	0.3
Deep noise while sleeping	1	0.3
No answer	235	78.3

TABLE 3. Opinions about management of goitre

Mode of treatment	Frequency	%
Hospital (surgery)	202	67.3
Self-medication	5	1.7
Traditional healers	19	6.3
Iodized salt	0	0
No idea	74	24.7

TABLE 4. Knowledge of iodine as an essential nutrient

Response	Frequency	%
Yes	64	21.3
No	229	76.3
Not sure	7	2.4

TABLE 5. Knowledge of iodized salt

Response	Frequency	%
Yes	40	13.3
No	260	86.7

TABLE 6. Mode of purchase of salt

Mode of purchase	Frequency	%
Cups	165	55.0
Packets	0	0
Bags	32	10.7
Baked	103	34.3

TABLE 7. Iodine content of salt samples at the retail level

Iodine content (ppm)	Frequency	%
>30	10	47.6
15	4	19.1
7	3	14.3
0	4	19.0

TABLE 8. Iodine content of salt samples at the household level

Iodine content (ppm)	Frequency	%
>30	47	47.0
15	15	15.0
7	4	4.0
0	34	34.0

TABLE 9. Classification of severity of iodine deficiency among schoolchildren based on urinary iodine excretion[a]

Age (yr)	n	No. of children (mean iodine concentration)		
		Mild deficiency	Moderate deficiency	Severe deficiency
6	16	5	7 (35.1)	4
7	15	—	10 (24.1)	5
8	12	1	7 (30.0)	4
9	9	1	4 (24.0)	4
10	10	1	2	7 (18.2)
11	7	—	2	5 (18.9)
12	11	—	4	7 (19.5)
All ages	80	8	36	36
%		10	45	45

a. Mild deficiency, 50–99 µg/L; moderate deficiency, 20–49 µg/L; severe deficiency, <20 µg/L. No children had normal values (≥100 µg/L). Based on epidemiological criteria for assessing severity of micronutrient deficiency set by WHO at its 45th World Health Assembly in 1992.

heredity, or supernatural forces. Others believed that it was caused by snoring, carrying heavy loads, talking too much, and consuming unclean food and water (table 2). Similar opinions and perceptions about goitre and its causes were also reported in Ghana [9]. Most respondents believed that goitre could be treated either in the hospital through surgery or by traditional healers using plants and roots.

The findings in Uzo-uwani are not consistent with those of the 1994 study reporting that 97% of edible salt in Nigeria was iodized and more than 95% of the households consumed salt iodized to a level of 50 ppm [5]. In our study less than 50% of the households consumed salt iodized to a level of 30 ppm, and these households consumed salt in its pure crystalline form. Thirty-four percent of the households consumed salt that had no iodine.

There were no local sources of salt in the study area, and all the salt consumed in the area came from outside the area in pure crystalline form. Every sample of crystalline salt contained iodine at a level of 30 ppm. Consumption of salt without iodine in the area was found to stem mainly from a poor and unhygienic method of handling and storage. Some retailers moisturize and bake the pure crystalline salt before offering it for sale or consumption. The 34% of households who consumed salt that had no iodine used baked salt. Exposure of iodized salt to heat, light, and moisture reduces or depletes its iodine content [10]. The people buy and use baked salt because of age-old practices. The method of storage could also contribute to depletion of iodine in the salt. In addition to being baked, the salt is broken into small pieces and stored in uncovered containers over the fire. These practices contribute to the low levels of urinary iodine found in schoolchildren in the study area.

Iodine in the urine provides a good index of iodine intake [11, 12]. It is also known that schoolchildren are representatives of the current state of iodine deficiency in an area and are a major priority for prompt correction of iodine deficiency [13]. None of the children studied had normal urinary iodine levels of 100 µg/L and above. Ninety percent of the children had severe to moderate forms of iodine deficiency, and 10% had mild deficiency (table 9).

Iodine deficiency is characteristically associated with goitre, and the rate increases with age, reaching a maximum in adolescent girls [14]. This is consistent with the study findings, which showed that the mean urinary iodine concentration of the children decreased with age (table 9), although not significantly ($p > .05$).

The low urinary iodine levels found in the study area confirm that, despite the programme of salt iodization, Uzo-uwani remains an iodine-deficient area [2, 3]. Data from other studies indicate that children from iodine-deficient areas have poorer school performance and lower intelligence quotients than children from non-iodine-deficient populations [15]. The urinary iodine levels found in this study indicate that schoolchildren in the area are at risk of impaired cognitive performance.

Conclusions and recommendations

In Nigeria, given the 1994 report [5] that 97% of edible salt was iodized and more than 95% of the households were consuming salt iodized at a level of 50 ppm, the present findings are discouraging. The finding that in 1996–1997 in the Uzo-uwani LGA of Enugu State, less than 50% of salt samples, at both the retail and the household levels, contained more than 30 ppm iodine is alarming. This is especially true when almost 20% of retail samples and 35% of household samples contain no detectable iodine. Given these findings, the risk of decreased cognitive performance of infants born of iodine-deficient mothers requires urgent preventive measures.

Further confirmation of the seriousness of the problem comes from the finding that 90% of the children examined had moderate to severe iodine deficiency, as judged by urinary iodine excretion, and none had normal iodine excretion levels. The lack of understanding of the causes and consequences of iodine deficiency revealed by the KAP survey, the poor handling and storage of salt, and especially the custom of using baked salt are formidable obstacles to the prevention of iodine-deficient disorders in this population. Surveys to determine the extent to which this situation is characteristic of other populations in Enugo State and other parts of Nigeria should have a high priority. For the population studied, there is need for an intensive effort at education of retailers and consumers regarding the consequences of iodine deficiency, the importance of using and properly storing crystalline salt, and the danger of consuming baked salt. Effective monitoring to ensure an appropriate iodine content of crystalline salt is an essential public health responsibility.

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Use of mango mesocarp flour to enrich the provitamin A content of a complementary food blend of maize and soya bean flours for porridge

G. I. O. Badifu, J. C. Ilochi, J. V. Dutse, and M. A. Akpapunam

Abstract

This study used locally available raw materials to enrich the contents of provitamin A (β-carotene) and other nutrients in a maize-based traditional complementary food for infants and pre-school children in Benue State, Nigeria. Fermented maize, dehulled soya bean, and sliced mango mesocarp were dried in a mobile wooden solar cabinet dryer (65°–70°C) to a moisture level of 8% to 10%. The dried products were milled separately. Blends containing different proportions of the flours were prepared to determine the most appropriate blend for preparing porridge, which was tested by sensory evaluation. The most appropriate blend consisted of 55% maize, 25% soya bean, and 20% mango flour (blend B). Its β-carotene content was 233 μg/100 g. The β-carotene contents of other blends were 199 μg/100g for 60% maize, 25% soya bean, and 15% mango (blend C), and 158 μg/100 g for 70% maize and 30% soya bean (blend A), whereas that of traditional maize akamu *was 67 μg/100 g. The provitamin A retention percentages were 89% for blend A, 92% for blend B, 91% for blend C, and 88% for akamu. A healthy, well-fed infant 6 to 11 months of age is expected to consume 200 to 300 ml of the porridge, which provides 13 to 20 μg of retinol activity, compared with 1 to 2 μg of retinol activity expected from akamu. The porridge prepared with blend B was organoleptically acceptable. Detailed nutrient composition, including essential amino acids, was determined.*

Introduction

Maize plays a very important role in the diets of most people of Nigeria. It is used in different consumable forms, among which is the fermented food product called *akamu* (Ibo and Hausa) or *ogi* (Yoruba). It is widely used as a complementary food for infants. Unfortunately, maize is not a good source of protein, and the traditional methods of processing it to make akamu deplete it of nutrients, such as the already meagre proteins and micronutrients. This problem stimulated work by several authors on methods of reducing these losses [1–9]. Akinrele and Edwards [10] enriched ogi with soya bean to form a product known as *soy-ogi*, which has wide acceptability in Nigeria. It is a good source of protein because of the added soya bean, and consequently is used as a complementary food for breastfed infants. In spite of these efforts, however, the problem of low micronutrient levels, particularly vitamin A, in the product has not been given research attention. Vitamin A deficiency is the most important cause of childhood blindness in developing countries. It also contributes to morbidity and mortality from common childhood infections. WHO [11] estimated that vitamin A deficiency, including clinical and subclinical forms of severe and moderate degrees of public health significance, exists in 60 countries, and it is likely to be a problem in at least another 13 countries. At least 254 million children of pre-school age are at risk in terms of their health and survival. In Nigeria vitamin A deficiency affects 9.2% to 17% of children and 7.2% to 15% of mothers [12], depending on the area.

Vitamin A deficiency is more prevalent in the northern part of the country, including Benue State, than the south. Most of the intervention strategies that are being applied are expensive, do not adequately reach the target population, and have low sustainability in rural settings. Consequently, enriching the vitamin A content of any widely consumed traditional food using readily available food commodities and adaptive processing methods would help to reduce the prevalence of vitamin A deficiency in infants, the most vulnerable group. The mesocarp of mango fruit is a good source of provitamin A, with reported concentrations of 2,400 mg/100 g [13]. A wide variety of processed products derived from mango fruits include

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canned whole or sliced mango pulp in brine or in syrup, mango juice, nectar, jam, sauce, chutney, and pickle [14, 15]. Mango trees grow in home gardens, roadsides, and forests all over Nigeria. During the fruiting season, there is always spoilage because of lack of adequate storage facilities. Drying the mesocarp would help to reduce the in-season wastage of the fruit and diversify its uses in food. Incorporation of mango mesocarp flour into a blend of maize and soya bean flours might enrich the provitamin A content of the complementary food in comparison with the traditional akamu and soy-ogi. The purposes of this study were to develop a complementary food blend rich in provitamin A and other micronutrients and to evaluate the chemical and organoleptic qualities of the product.

Materials and methods

Collection of raw materials

Maize (*Zea mays* L.), soya bean (*Glycine max* Merr.), and mango (*Mangifera indica* L.) were purchased from local markets in Benue State. The mangoes were bought during the April 1998 fruiting season.

Preparation of flours

Maize grains were cleaned and submerged in cold tap water at 34 ± 2°C and allowed to ferment naturally for 48 hours. The water was changed every 24 hours. After fermentation, the water was drained off and the grains were spread on metal trays.

Soya bean grains were cleaned and blanched in hot water (96 ± 3°C) for 30 minutes. This was followed by washing in cold tap water to remove the hulls. The water with the hulls was discarded, and the dehulled soya beans were drained for 45 minutes in a basket and then spread on metal trays.

Mangoes were peeled with a sharp kitchen knife, and the mesocarp was sliced off the hard nut. The slices were trimmed to 5 × 2 × 0.3 cm and spread on metal trays to a depth of about 0.6 cm.

The blanched soya beans, fermented maize, and mango mesocarp slices spread on trays were put into the dryer through a vent in the lid at the lower part of the back wall of the dryer. The dryer was kept in the sun, and at the end of each drying session (usually when the dryer temperature dropped below 65°C), when the sun had set, the food items were removed and put separately into cans with lids and stored in a freezer at –18°C, while the dryer was kept in the processing laboratory. This process of drying was continued, and samples were taken at 2½-hour intervals for determination of β-carotene and moisture, until they dried to the desired moisture content (8%–10%). The operating temperature of the dryer was in the range of 65° to 70°C. The maize, soya bean, and mango were dried for 2, 5, and 10 days, respectively, for five hours every sunny day.

During the drying process, the materials were occasionally turned to enhance even drying. The dried materials (maize, soya bean, and mango mesocarp) were then separately milled and sieved into flours through a muslin cloth and packaged in low-density polyethylene bags and stored in covered tins in a freezer at –18°C, from which samples were taken for β-carotene determination and subsequent use.

Preparation of akamu

Our method of preparing akamu was similar to the traditional method, except that the period of fermentation was longer in our study (72 hours), the fermented grains were wet-milled, and the final product was in paste form.

Formulation and storage of the blends

Blends with different proportions of maize, soya bean, and mango mesocarp flours were prepared. A blend with no mango flour was used as the control. An electronic top-loading digital weighing balance and a Kenwood Cheff mixer were used for weighing and mixing the flours. Blends of the developed product and akamu were packaged in low-density polyethylene bags in packs of 200 g each and stored at a temperature of 30° to 34°C, simulating local market conditions, for a period of five months (April–September, 1998). Initially samples for β-carotene determination were taken every two weeks, but later they were taken once a month.

Analysis of the blends and of akamu

Moisture, protein (N% × 6.25), fat, fibre, ash, and β-carotene (provitamin A) were determined by the methods of the AOAC (Association of Official Analytical Chemists) [16]. Carbohydrate was calculated by difference. The ash samples were made into solutions, as described by Buchanan-Smith et al. [17], and the minerals were determined by an atomic absorption spectrophotometer. The energy value was estimated from Atwater factors (protein × 4, carbohydrate × 4, fat × 9). The pH was determined as described by Pearson [18]. The method of Mosha and Svanberg [19], slightly modified, was used to determine viscosity. A porridge was prepared by heating a slurry containing 17% of each flour blended with water to a cooking temperature of 96°C for five minutes with continuous stirring. The porridge was transferred to a water bath at 40°C, and the viscosity was measured with a Brookfield Synchro-Electric Viscometer (Model LV8, Chington UK).

Amino acids

The amino acid compositions of the blends and of akamu were determined according to the procedure described by Spackman et al. [20]. The hydrolysate was injected into the Technicon Sequential Multisample (TSM) Amino Acid Analyzer. Norleucine was used as internal standard with other reference amino acid standards. The column operating conditions were as follows: flow rate, 0.50 ml/min; temperature, 60°C; resin bed, 23.0–23.5 cm (acid-neutral column) and 45–5.0 cm (basic column); sensitivity, 25 nm; wavelength, 440 nm for proline and 570 nm for other amino acids.

Sensory evaluation and statistical analysis

Porridge samples made from each blend and from akamu, prepared as previously described, were served warm (40°C) to an untrained 10-member taste panel composed of both staff and students (including nursing mothers) of the university community who were familiar with the products. The judges were instructed to evaluate the samples for texture, colour, flavour, and general acceptability using a 9-point hedonic scale where 9 indicated “like extremely” and 1 indicated “dislike extremely.” Two panel sessions were conducted. The average scores obtained were subjected to analysis of variance [21], the means were separated by the Duncan multiple-range test [22], and Tukey’s test [23] was used to determine the degree of difference between samples.

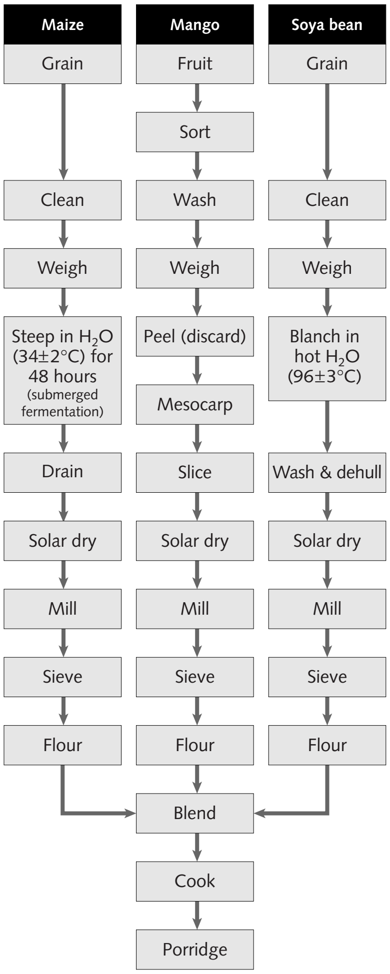

FIG 1. Flow chart for the production of maize, soya bean, and mango mesocarp flours, blend, and porridge

Results and discussion

Appearance of flours, blend, and akamu paste

Figures 1 and 2 show the steps involved in the preparation of the flours and of akamu paste, respectively. The drying was done in a solar cabinet dryer. The processing conditions for the flours were controlled, quite unlike the steps in simulated traditional preparation of akamu paste, where fermentation was continuous and was terminated only during the making of porridge. This had quality implications, such as lack of consistency in the product and, perhaps, loss of organoleptic values as well as some nutrients. There was a slight change in the colour of the paste from white to creamy white. The colours of the maize, soya bean, and mango mesocarp flours were white, cream-white, and light-yellow, respectively.

The proportion of the flours in each blend is presented in table 1. The colour of the blends ranged from cream-white to light-brown. However, the colour differences were not significant ($p > .05$). The control blend of maize and soya bean flours (blend A) did not differ from the others in appearance. This implied that the blends did not deviate physically from the product the assessors were familiar with. The blends were free-flowing because of their dried state.

Chemical characteristics and viscosity

The chemical characteristics and viscosity of the blends and of akamu are presented in table 2. The moisture content of the blends ranged from 8.7% to 9.5%, suggesting that the blends could be shelf-stable. This would be an advantage to the target population, which might not have access to storage facilities, such as refrigerators. In contrast, the moisture content of the akamu paste was 19.8%. The blend of 70% maize and 30% soya beans (blend A) had a relatively high protein content (18.7%), and the rest of the blends had 17.4% to 17.6% protein. The content of fat ranged from 8.5% to 8.9%, that of ash from 2.3% to 2.6%, that of

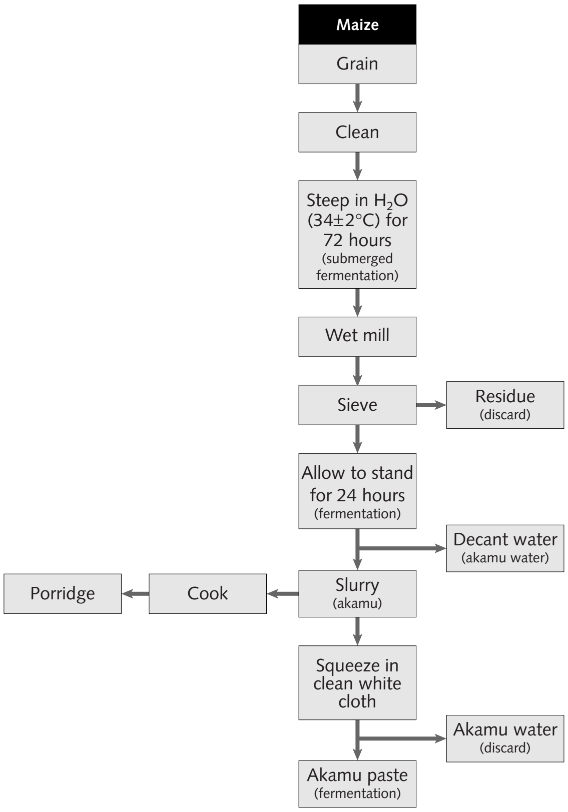

FIG 2. Flow chart showing laboratory simulation of the traditional method of preparing maize akamu paste and porridge

TABLE 1. Composition of blends (%)

Blend code	Maize	Soya bean	Mango mesocarp
A (control)	70	30	0
B	55	25	20
C	60	25	15

carbohydrate from 58.6% to 60.3%, and that of fibre from 2.0% to 2.3%. The energy values agree with the guidelines for commercial complementary food [24]. Akinrele and Edwards reported contents of 20.3% protein, 6.3% fat, 4.7% moisture, and 4 kcal/g for soy-ogi [10].

The β-carotene contents of the mango mesocarp, soya bean, and maize grains were 2671.4, 1468.6, and 670.1 μg/100 g, respectively. However, when the foods were processed into flour, the β-carotene levels were reduced to 2396.1 in mango, 1024.8 in soya bean, and 418.7 μg/100 g in maize. The losses were greater in soya bean (30.2%) and maize (37.5%) than in mango (10.3%) flours. The reductions could be due to thermal damage, leaching, oxidation, and enzymatic degradation of the β-carotene during processing. The addition of mango mesocarp flour increased the provitamin A (β-carotene) content of the blends. The blend with 20% mango flour was highest in β-carotene (233 μg/100 g), whereas the maize and soya bean blend was the lowest (158 μg/100 g). After five months of storage, the β-carotene contents were reduced to 140.8, 214.6, and 180.3 μg/100 g in blends composed of 70% maize and 30% soya bean (blend A); 55% maize, 25% soya bean, and 20% mango (blend B); and 60% maize, 25% soya bean, and 15% mango (blend C), respectively, whereas that of akamu was 58.7 mg/100 g. The content of β-carotene retained in the blends after five months of storage at ambient conditions was 89.1% in blend A, 92.0% in blend B, 90.5% in blend C, and 87.6% in akamu. The losses were minimal in the blends and in akamu. This suggested that the product could be suitable for community use.

According to FAO/WHO [25], the estimated basal requirement of vitamin A (mg RE) is 180 μg/day, or 40 to 20 μg/kg, for children 0 to 1 year old and 200 μg/day, or 13 μg/kg, for children 1 to 6 years old. The

TABLE 2. Characteristics of blends and of maize akamu[a]

Characteristic	Akamu	Blend A	Blend B	Blend C
Moisture (%)	19.8	9.5	8.7	9.3
Protein (N × 6.25)(%)	5.7	18.7	17.4	17.6
Fat (%)	3.9	8.9	8.7	8.5
Ash (%)	0.3	2.3	2.6	2.4
Fibre (%)	1.2	2.0	2.3	2.3
Carbohydrate (%)[b]	78.9	58.6	60.3	59.9
β-Carotene (μg/100 g)	67.0	158.0	233.2	199.2
Energy (kcal/100 g)	373.5	389.3	389.1	386.5
pH	3.7	4.9	4.7	4.7
Viscosity (cp)	3,436	2,350	2,208	2,217

a. Values are means of three determinations.
b. Calculated by the difference method.

safe intake levels are 350 μg/day, or 78 to 39 μg/kg, for children 0 to 1 year old and 400 μg/day, or 26 μg/kg, for children 1 to 6 years old. For planning purposes, the basal vitamin A requirement is 250 μg/day and the recommended safe intake level is 550 μg/day [11]. The complementary food we developed contained 233 μg of provitamin A per 100 g, which translates to 38.8 μg of retinol activity per 100 g. A healthy, well-fed infant 6 to 11 months of age is expected to consume 200 to 300 ml of the porridge at a meal, and this quantity was estimated to provide 13 to 20 μg of retinol activity. This value was significant ($p < .05$) when compared with 1 to 2 μg retinol activity expected from porridge prepared with akamu. This is expected to contribute appreciably to the basal requirements in infants and pre-school children fed with the blend. The addition of mango flour slightly increased the ash, fibre, and carbohydrate contents of the blend. There was a slight drop in pH (4.9–4.7) with the addition of mango flour. However, the pH of akamu paste was 3.7 because of the uncontrolled fermentation that apparently continued.

Fermented food products have some antimicrobial activity [26], which could improve their stability. The porridge made from the blends was easy to swallow, with viscosity in the range of 2,208 to 2,350 cp. The addition of mango flour decreased the viscosity of the porridge by about 6%. A liquid consistency of 1,000 to 3,000 cp is expected for complementary foods [27] for tropical climates.

Table 3 presents the mineral composition of the blends and of akamu. Calcium, magnesium, phosphorus, and potassium were present in relatively high quantities, which were higher in the blends containing mango. Iron, zinc, and sodium were present in reasonable amounts. Calcium is required for the development of bone mass in infants. However, genetic background, hormonal changes, physical activity, and nutrition may influence bone mass [28]. Milk and milk products are good sources of calcium, but they are expensive, and hence the developed complementary food (blend B) could make a reasonable contribution to the consumer, particularly the target group. The bioavailability of iron and zinc is enhanced by certain amino acids, such as cysteine, lysine, and especially methionine. Zinc deficiency occurs in many populations in developing countries and is increasingly recognized as an important public health problem [29]. Zinc deficiency may contribute significantly to growth stunting in young children [30], delayed maturation, poor appetite, and impaired immune function. It may also contribute to the major causes of morbidity in young children [31] and increased mortality in mothers and their babies [32]. The quantities of all the minerals were relatively low in akamu paste.

Amino acid composition

The blends and akamu contained essential and nonessential amino acids, with akamu having very low values of amino acids (table 4). The 70% maize and 30% soya bean blend (blend A) had higher levels of amino acids than the other blends. This was expected because this blend has more soya bean than the other blends; akamu contains no soya bean. In general, the levels of amino acids decreased as the amount of mango flour increased. However, in the blend containing 55% maize, 25% soya bean, and 20% mango mesocarp (blend B), the histidine, isoleucine, and phenylalanine concentrations were comparable to the values of 4.0 g/16 g N for isoleucine [33], 2.4 g/16 g N for histidine, and 2.8 g/16 g N for phenylalanine [34] that are reported for standard proteins. Lysine (3.3 g/16 g N), leucine (3.1 g/16 g N), glutamic acid (5.4 g/16 g N), aspartic acid (2.3 g/16 g N), and tyrosine (2.3 g/16 g N) were present in reasonable quantities in the blend, whereas methionine was relatively low. The quality of a protein is determined by its amino acid composition. The quantity of protein obtained from a diet depends on the amount of food consumed and the protein content of the food. Foods with a low protein content may provide useful amounts of protein if consumed in sufficient quantity. The amino acid composition of the developed complementary food (blend B) suggests that it would be a good dietary product for infants and pre-school children.

TABLE 3. Mineral composition of blends and of maize akamu[a]

Characteristic	Akamu	Blend A	Blend B	Blend C
Iron (mg/100 g)	2	10	12	11
Zinc (mg/100 g)	4	13	15	14
Magnesium (mg/100 g)	3	19	26	20
Sodium (mg/100 g)	2	21	14	13
Calcium (mg/100 g)	6	36	39	37
Potassium (mg/100 g)	10	24	31	29
Phosphorus (mg/100 g)	110	380	270	269
Iodine (μg/kg)	1	3	10	4

a. Values are means of three determinations.

TABLE 4. Amino acid composition of blends and of maize akamu[a]

Amino acid (g/16 g N)	Akamu	Blend A	Blend B	Blend C
Essential				
Arginine	0.48	3.23	1.72	0.99
Lysine	1.50	4.05	3.29	2.40
Histidine	0.72	2.87	2.39	1.74
Threonine	0.56	3.17	1.21	0.99
Valine	0.27	1.54	0.48	0.66
Methionine	0.15	1.33	0.39	0.39
Isoleucine	1.04	4.58	3.52	2.61
Leucine	1.10	5.10	3.08	2.16
Phenylalanine	0.93	5.40	2.53	1.40
Non-essential				
Aspartic	1.33	6.79	2.30	2.48
Serine	0.97	3.71	1.39	1.37
Glutamic	4.24	8.00	5.40	5.95
Proline	0.21	1.59	0.62	0.46
Glycine	0.86	5.63	1.22	1.91
Alanine	0.94	4.95	1.53	1.78
Cystine	0.42	2.25	0.60	0.94
Tyrosine	0.98	5.82	2.29	1.29

[a] Values are means of two determinations.

Sensory evaluation

There were no significant differences among the three blends in sensory attributes except for flavour (table 5). The flavour of the porridge prepared from the blend of 55% maize, 25% soya bean, and 20% mango mesocarp flour (blend B) was most preferred ($p < .05$). There were no significant differences in the general acceptability of the blends, but the blends were significantly more acceptable than akamu.

Conclusions

An acceptable complementary food blend of 55% maize, 25% soya bean, and 20% mango mesocarp flours with enhanced provitamin A content was developed by using technology that is very easy to adapt to rural settings. The chemical composition of the blend suggests that it could meet the nutritional requirements of infants and pre-school children. Further studies are in progress in our laboratory on the complementary food.

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TABLE 5. Sensory characteristics of porridge prepared with blends and with maize akamu[a]

Porridge	Texture	Colour	Flavour	General acceptability
Akamu	3.5^b	3.7^b	3.1^b	3.8^b
Blend A	4.1^c	3.9^c	4.4^c	4.6^c
Blend B	4.9^c	4.8^c	5.3^d	4.9^c
Blend C	4.8^c	4.7^c	4.8^c	4.7^c

[a] Means within columns with different superscripts are significantly different ($p < .05$). Sensory scale: 9 = like extremely, 1 = dislike extremely.

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Effects of salt fortified with iron and iodine on the haemoglobin levels and productivity of tea pickers

S. Rajagopalan and Malavika Vinodkumar

Abstract

*To determine if double-fortified salt improved the haemoglobin levels and productivity of tea pickers, a double-blind, randomized, placebo-controlled trial was conducted on 793 tea pickers. The subjects in the experimental households (*n = 385*) received salt fortified with iron and iodine, and the subjects in the control households (*n = 408*) received common unfortified salt. Fingerprick blood analysis for haemoglobin by the cyanmethaemoglobin method was performed three times during a period of one year. The productivity data were also analysed for 450 tea pickers. At the end of the year, their average haemoglobin level had increased from 8.9 to 10.2 g/dl and their corresponding picking average had increased from 24.8 kg to 26.2 kg, which could increase annual tea production by 330 tonnes.*

Introduction

It is well known that anaemia affects the productivity of workers [1–5] and that productivity improves when anaemia is reduced. In fact, anaemia is associated with reduced production of women workers even in less physically strenuous tasks, as seen in jute factory workers [6]. Tea estates provide a valuable opportunity to measure the productivity of the workers, because the work done by an individual is quantifiable as kilograms of tea leaves picked per day. These results are similar to those of Edgerton et al. [7], who found a decrease in work performance capacity in iron-deficient male tea pickers with anaemia. The present study provides additional evidence for the link between anaemia and the productivity of plantation workers.

Development

Sundar Chemicals developed and introduced Nutrisalt, a common cooking salt fortified with both iron and iodine to alleviate iron and iodine deficiencies in developing third world countries. Earlier this company was a pioneer in developing and marketing iron-fortified salt in India. Several problems had to be overcome during the development of both iron-fortified salt and double-fortified salt. Normally iron compounds that are used in fortification tend to discolour food during cooking. It took several years of research to develop a suitable iron product that would not discolour the salt during the process of fortification or discolour any foods during cooking, and that would be stable on storage and bioavailable. Stabilizing chemicals were used that enhanced the bioabsorption of iron, not only from the salt, but also from the food consumed.

In the development of double-fortified salt, there were problems related to the stability of iodine. It is well known that iodine is stable in an alkaline pH, whereas iron requires an acidic pH. Intensive research led to the development of a product in which both iron and iodine were stable for more than a year. There was no development of colour when it was used in cooking, nor was there any change in the taste of the food.

Study design

The study was conducted jointly by Sundar Chemicals, Parry Agro Group, and United Planters Association of South India. The CWS tea estate of the Parry Agro Group, in the hilly region of Valparai in South India, was chosen as the area for the study. On the basis of the terrain, the tea estate is divided into lower Sheikalmudi and Upper Sheikalmudi regions. Both regions were considered for the trial. The study was designed by Dr. S. Rajagopalan. Dr. P. Shankar of Parry Agro, the director of the hospital attached to the tea estate, acted as the project leader and took responsibility for conducting the trial. Ms. Savithri of the United

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Planters Association of South India acted as a project coordinator and helped to create nutritional awareness in the labour community.

This tea estate was chosen for the study for several reasons. It is isolated and far from the city in the remote interior hilly region. Therefore easy access to salt other than the fortified salt is not possible. Such a closed community can be easily monitored. Blood for analysis can be taken from the workers when they report for work in the tea plantation. Since the workers are paid according to the quantity of tea leaves they pick, their productivity can be measured, and the effect on productivity of a reduction in anaemia can be quantified.

The workers live in rows of houses called lines. Each line is a building containing eight to ten households. A number of such lines constitutes a cluster. There are several clusters spread throughout the plantation. By using a map of the entire plantation, the area was divided into 20 clusters. Care was taken to see that all the clusters had approximately the same number of lines and houses to insure a uniform sample size in every cluster. With the use of a table of random numbers, every cluster was assigned to either an experimental or a control cluster. The study was a double-blind, randomized, placebo-controlled trial. Only the project leader knew which were the experimental and which were the control households.

There were 2,659 people living in 671 houses on the tea estate, 1,327 people in the experimental area and 1,332 in the control area. These numbers include the entire population, adults and children. Although 2,659 people consumed Nutrisalt, blood analysis was done on only 1,320 adult labourers. Of these 1,320, 1,096 were permanent workers and the rest were casual workers. Only 793 of the 1,096 permanent labourers came for all three rounds of haemoglobin analysis, and only this sample was considered for final statistical analysis. Of the 793 labourers, 408 were in the control group and 385 were in the experimental group.

Baseline studies and education before the beginning of the experiment

The plantation was equipped with good hospital facilities on the premises. CWS Parry Agro Company keeps detailed morbidity reports on all their workers. Baseline studies included a study of the nutritional pattern of the workers. The quantity of vegetables, dhal (lentils), and rice consumed by the families on a weekly basis was monitored to give information on dietary intake. From the hospital records, it was noted that amoebic and hookworm infestations were rampant and dietary intakes of iron and protein were low. All these factors contributed to the anaemia prevailing in the area.

The experimental salt was in powdered form, but the plantation workers were used to crystal salt. Before the start of the trial, the project coordinator gave talks and cooking demonstrations on how to use the powdered salt. The population was instructed that iron- and iodine-fortified experimental salt had nutritional benefits and that they could use it as they used crystal salt. Through cooking demonstrations, they observed that the fortified salt did not change the colour, taste, or appearance of the food. These demonstrations helped them to overcome their fears about the salt, and they enthusiastically began using it.

For the first three months, unfortified powdered salt was supplied to the entire population to get them accustomed to using powdered instead of crystal salt. After the powdered salt had been accepted by the population, the unfortified salt in the experimental areas was replaced with double-fortified salt.

Before the start of the programme, the first fingerprick blood samples were collected and analysed for haemoglobin. Deworming and treatment with iron and folic acid tablets were also stopped. After three months, when the population had become accustomed to the powdered salt, another fingerprick blood sample for haemoglobin analysis was taken.

Comparison of haemoglobin levels in these two samples showed that there was a marked increase in anaemia in those three months. It was believed that this marked increase in anaemia was caused by stopping deworming. It was therefore decided to deworm half the population in both the experimental and control areas and then administer the iron- and iodine-fortified salt in the experimental area and unfortified salt in the control area. This would eliminate the anaemia caused by worm infestation and facilitate determining whether further administration of iron- and iodine-fortified would help to reduce anaemia.

Blood collection, determination of haemoglobin, and quality control

Fingerprick blood samples were taken for haemoglobin analysis at the beginning, middle, and end of the study. Each permanent worker on the CWS estate is given a provident fund number. When the workers assembled at the fields to pick tea, the fingerprick blood samples were taken, accurately measured in a 0.02-ml (20-µl) micro pipette, and transferred immediately into vials containing 5 ml of Drabkins solution labeled with the PF number of the worker. The vials were packed in ice and immediately taken to the laboratory for analysis.

Haemoglobin was determined by the cyanmethaemoglobin method using Drabkins solution for colour development. The developed colour was read on a photoelectric colourimeter. The optical density was compared with the optical density of the standard. To avoid errors in preparation of the standard, a commercial standard was used.

Validation of the blood samples

For 10% of the population, blood samples were collected again soon after the first prick and transferred into separate vials. Each vial was then independently analysed by two different technicians.

Production and coding of double-fortified salt

The double-fortified salt was produced by Sundar Chemicals and packed in 1-kg bags. Fifty of the 1-kg bags were placed in a larger bag. A sheet containing the code for iron- and iodine-fortified salt was placed in the bag, and the bag was stitched. The code was also printed on the outside. Unfortified salt was similarly packaged and identified by code. The bags were then despatched to the project leader, Dr. P. Shankar, who was the only one who knew the codes.

Salt distribution

A register was maintained from the beginning of the trial to determine the quantity of salt required by the households. The project leader, after decoding the bags, despatched the appropriate quantity of salt needed for the trials to the project workers, who delivered the required quantity of the salt to the individual households. A detailed register contained data on the quantity of salt delivered during each visit, and their requirement of salt was recorded. The project workers did not know whether the salt they were distributing was iron- and iodine-fortified or unfortified.

Checks to ensure that only Nutrisalt was used

Project workers made periodic surprise visits to the houses of the workers and collected salt samples from their kitchens for analysis. These checks proved that the population was using only Nutrisalt.

Stability of iron and iodine in Nutrisalt

Sundar Chemicals retained control samples of every batch of salt. The iron and iodine contents were periodically monitored in their laboratory. Samples collected from the kitchens of the workers were also sent to the Sundar Chemicals laboratory in Madras for determination of the stability of the micronutrients at the end user level. Sundar Chemicals had previously noted that both iron and iodine were stable in these samples for more than a year.

Measurement of productivity

Productivity data were gathered for about 450 permanent employees whose blood was analysed for haemoglobin. The Parry Agro group maintains detailed records of the tea leaves picked by an individual each day. At the end of every month, data are transferred into another register that contains data such as the total quantity of tea leaves picked by an individual as well as the total number of days worked for the entire month. The total quantity of leaves picked by an individual for a month divided by the total number of days worked gives the average daily quantity of tea leaves picked by the individual. Two-criteria analysis of variance was performed with the productivity data for the first six months and again for the second six months. The picking average for the first six months was averaged for every individual, and these numbers were subjected to two-criteria analysis of variance. The data for the second six months were analysed in the same way. The two criteria for analysis of variance were experimental versus control group and deworming versus no deworming. Half the subjects in each group, experimental and control, were dewormed. The scheme and design of the analysis are represented in tables 1 and 2.

TABLE 1. Two-criterion analysis of variance of picking average for first six months

Dewormed	Experimental (fortified salt)	Control (unfortified salt)
No	N_1 (no. of samples in this block) = 118 M_1 (mean of samples in this block) = 21.79 A_1 (sum of samples in this block) = 2,571.27	N_2 (no. of samples in this block) = 114 M_2 (mean of samples in this block) = 21.80 A_2 (sum of samples in this block) = 2,485.05
Yes	N_3 (no. of samples in this block) = 103 M_3 (mean of samples in this block) = 24.84 B_1 (sum of samples in this block) = 2,558.22	N_4 (no. of samples in this block) = 119 M_4 (mean of samples in this block) = 24.69 B_2 (sum of samples in this block) = 2,937.80

M_a (mean for row 1 [not dewormed]) = $(A_1 + A_2)/(N_1 + N_2) = 21.79$.
M_b (mean for row 2 [dewormed]) = $(B_1 + B_2)/(N_3 + N_4) = 25.76$.
M_{A1B1} (mean for experimental column) = $(A_1 + B_1)/(N_1 + N_3) = 23.21$.
M_{A2B2} (mean for control column) = $(A_2 + B_2)/(N_2 + N_4) = 23.27$.
Overall mean = $(A_1 + A_2 + B_1 + B_2)/(N_1 + N_2 + N_3 + N_4) = 23.24$.

TABLE 2. Two-criterion analysis of variance of picking average for second six months

Dewormed	Experimental (fortified salt)	Control (unfortified salt)
No	N_1 (no. of samples in this block) = 114 M_1 (mean of samples in this block) = 23.29 A_1 (sum of samples in this block) = 2,655.18	N_2 (no. of samples in this block) = 112 M_2 (mean of samples in this block) = 24.16 A_2 (sum of samples in this block) = 2,706.18
Yes	N_3 (no. of samples in this block) = 101 M_3 (mean of samples in this block) = 26.15 B_1 (sum of samples in this block) = 2,641.35	N_4 (no. of samples in this block) = 117 M_4 (mean of samples in this block) = 25.06 B_2 (sum of samples in this block) = 2,931.72

M_a (mean for row 1 [not dewormed]) = $(A_1 + A_2)/(N_1 + N_2) = 23.72$.
M_b (mean for row 2 [dewormed]) = $(B_1 + B_2)/(N_3 + N_4) = 25.56$.
M_{A1B1} (mean for experimental column) = $(A_1 + B_1)/(N_1 + N_3) = 24.64$.
M_{A2B2} (mean for control column) = $(A_2 + B_2)/(N_2 + N_4) = 24.62$.
Overall mean = $(A_1 + A_2 + B_1 + B_2)/(N_1 + N_2 + N_3 + N_4) = 24.63$.

Results

Haemoglobin analysis

At the beginning of the study, the mean haemoglobin level of the control group was higher than that of the experimental group that received the iron- and iodine-fortified salt. However, at the end of the trial, the mean haemoglobin level of the experimental group had increased significantly (table 3). Table 4 shows the haemoglobin levels according to age and sex at the end of the study. For men in the experimental group, the mean haemoglobin level was higher than that of the control group among those aged 18 to 30 and over 45. For women in the experimental group, the mean haemoglobin level was higher than that of the control group among those aged 18 to 30 and 31 to 45.

The average increase in the haemoglobin level in the experimental group was 1.27 g/dl, 65% greater than the average increase of 0.77 g/dl in the control group (Z = .77; $p < .05$). At the end of the trial, the increase in the mean haemoglobin level in the dewormed experimental group compared with that in the non-dewormed group was nearly three times (0.31 g/dl) greater than

TABLE 3. Mean ± SD haemoglobin levels (g/dl)

Sex of subjects and stage of study	Experimental (fortified salt)	Control	*p*
Male	(*n* = 155)	(*n* = 158)	NS[a] (Z = 1.08)
Baseline	9.57 ± 0.140	9.71 ± 0.137	
Middle	9.63 ± 0.135	9.75 ± 0.120	
End	10.42 ± 0.153	10.30 ± 0.146	
Female	(*n* = 230)	(*n* = 250)	< .05 (Z = 2.55)
Baseline	8.48 ± 0.132	8.92 ± 0.159	
Middle	8.61 ± 0.099	8.68 ± 0.093	
End	10.031 ± 0.134	9.75 ± 0.132	

a. Not significant.

TABLE 4. Haemoglobin levels (mean ± SD g/dl) according to sex and age group at the end of the study

	Experimental (fortified salt)		Control			
Sex and age group (yr)	*n*	Haemoglobin	*n*	Haemoglobin	Z	*p*
Male						
18–30	46	10.20 ± 0.263	44[a]	9.96 ± 0.271	1.15	NS[b]
31–45	81	10.58 ± 0.222	83	10.59 ± 0.188	0.11	NS
> 45	28	10.33 ± 0.344	30	9.98 ± 0.415	1.34	NS
Female						
18–30	84[a]	9.72 ± 0.207	92	9.50 ± 0.208	1.43	NS
31–45	116	10.27 ± 0.199	95	9.78 ± 0.203	3.53	<.05
> 45	29	10.02 ± 0.345	63	10.27 ± 0.286	1.09	NS

a. Included one subject less than 18 years of age.
b. Not significant.

the increase in haemoglobin in the control group (0.08 g/dl). Deworming further enhanced the effect of double fortification, as seen in table 5.

The reduction in severe anaemia (defined as haemoglobin level less than 8 g/dl) was greater in the experimental group than in the control group among both dewormed and non-dewormed subjects. The increase in the proportion of non-anaemic subjects in the dewormed group was more than twice the increase in the non-dewormed experimental group (table 6).

Productivity data

The interaction effect between deworming and iron supplementation on the picking average was not seen in the first six months of the trial, whereas the deworming and non-deworming component gave a value at 95% (table 7). In the second six months, the interaction of iron supplementation with deworming had significant effects on the picking average at a level of 95% (table 8). This may mean that it takes about six months for the

TABLE 5. Combined effect of deworming and of salt fortified with iodine and iron on mean haemoglobin levels (g/dl)

	Control				Experimental (fortified salt)				
Dewormed	*n*	Baseline	End	Change	*n*	Baseline	End	Change	*p*
Yes	198	9.14	10.04	0.90	185	8.87	10.35	1.48	<.05
No	210	9.30	9.95	0.65	200	8.96	10.04	1.08	NS[a]
Combined groups	408	9.22	9.99	0.77	385	8.92	10.19	1.27	<.05

a. Not significant.

TABLE 6. Combined effect of deworming and of salt fortified with iodine and iron on changes in incidence (%) of anaemia

	Control		Experimental (fortified salt)	
Anaemia status[a]	Dewormed	Not dewormed	Dewormed	Not dewormed
Severe anaemia	–15.64	–9.04	–22.5	–15.50
No anaemia	+7.57	+5.72	+18.37	+9.00

a. Hemoglobin concentrations: severe anaemia, <8 g/dl; no anaemia, >12 g/dl.

TABLE 7. Analysis of variance of productivity: picking averages for the first six months[a]

Source of variation	SS	df	MSS	*F* ratio	*p*
Variable: dewormed vs not dewormed	995.54	1	995.54	68.23	.05
Variable: fortified salt vs control	0.46	1	0.46	0.0315	NS
Variable: interaction of fortified salt and deworming	2.69	1	2.69	0.1845	NS
Error	6,566.54	450	14.59		
Total variation	7,565.23	453	16.70		

a. *SS*, Sum of squares; df, degrees of freedom; MSS, mean square; NS, not significant.

TABLE 8. Analysis of variance of productivity: picking averages for the second six months[a]

Source of variation	SS	df	MSS	*F* ratio	*p*
Variable: dewormed vs not dewormed	376.35	1	376.35	14.05	<.05
Variable: fortified salt vs control	0.0262	1	0.026	0.00098	NS
Variable: interaction of fortified salt and deworming	107.54	1	107.54	4.0155	<.05
Error	11,784.23	440	26.7823		
Total variation	12,268.14	443	27.69		

a. *SS*, Sum of squares; df, degrees of freedom; MSS, mean square; NS, not significant.

increase in haemoglobin levels to translate into an increase in the picking average. In any community with a high incidence of worm infestation, iron supplementation at the level of daily requirements may not have any effect, because iron absorption is limited when parasitic worm infestation is high. For the purpose of the experiment, we allowed deworming in 50% of those in both the experimental and control groups. This also gave us an insight into the interaction effect of iron supplementation with deworming on the picking average, which we would have missed otherwise.

The impact of iron supplementation on the dewormed sample and its effect on the picking average in both periods, taking into account the *t* ratio between the two mean values, are shown in tables 9 and 10.

At the end of the second six months, the mean picking average of the experimental dewormed group was significantly higher than that of the control dewormed group. The picking average for the first six months did not significantly differ in the experimental and control groups. This establishes the significant impact of iron supplementation by the use of double-fortified salt on the productivity of tea pickers. These results are similar to those of other studies [8] and of the Chinese studies [9] in which iron supplementation enabled cotton mill workers in Beijing to do the same work at a lower energy expenditure when anaemia was alleviated.

Effect of reducing anaemia on absenteeism

The number of days worked by the whole group for the one-year control period before the start of the trial was 96,034 person-days. The same group worked for 97,602 person-days during the one-year experimental period. This was an increase of 1,568 person-days compared with the previous year. The tea pickers also reported a feeling of well-being and were less irritable and less fatigued at the end of the one-year period during which they consumed Nutrisalt. This is probably due to the improvement in their haemoglobin levels. The increase in the number of days worked during the trial period also reflects the decrease in absenteeism due to fatigue. These results are similar to those of the Sri Lankan study on tea pickers, in which the quantity of tea leaves picked increased when anaemia was alleviated [10].

Cost-benefit ratio

Each person consumes 10 g of salt per day. Thus 450 people would consume 4.5 kg of salt per day or 1,620 kg per year. At the rate of Rs. 4.50 per kilogram, the cost of double-fortified salt for 450 people would be Rs. 7,290 per year (US$215).

From the statistical analysis, it is seen that during the second six months of the trial, the experimental dewormed group picked 1.1 kg more tea leaves per day than the control dewormed group (26.2 and 25.1 kg, respectively). If these data can be extrapolated to 1,000 workers, these 1,000 workers could pick 1,000 × 1.1 kg more tea leaves per day (27.5 tonnes more per month and 330 more tonnes per year). Therefore, for an expenditure of Rs. 7,290 per year (US $215), an additional 300 tonnes of extra tea leaves could be picked. This demonstrates that a small sum of money spent in eliminating micronutrient deficiencies would increase productivity.

Conclusions

Nutrisalt is a double-fortified salt enriched with iron (1,000 ppm) and iodine (30 ppm) in which the two micronutrients are stable for more than a year. There was no change in the colour, taste, or smell of the food when Nutrisalt was used in cooking. Statistical analysis

TABLE 9. Dewormed sample: first six months picking average

Value	Control	Experimental (fortified salt)
Mean	24.68739 kg	24.83706 kg
Variance	12.50529	14.07773
Observations	119	103
Hypothesized mean difference	0	
Degrees of freedom	211	
t statistic	–0.304376	
$p\ (T \leq t)$ one-tail	0.380571	
t critical one-tail	1.652106	
$p\ (T \leq t)$ two-tail	0.761141	
t critical two-tail	1.971271	

Difference in picking average not significant ($p = < .05$) by *t* test for two samples assuming unequal variances.

TABLE 10. Dewormed sample: second six months picking average

Value	Control	Experimental (fortified salt)
Mean	26.15198 kg	25.05741 kg
Variance	14.02874	15.32912
Observations	101	117
Hypothesized mean difference	0	
Degrees of freedom	214	
t statistic	2.106832	
$p\ (T < = t)$ one-tail	.018148	
t critical one-tail	1.652006	
$p\ (T < = t)$ two-tail	.036297	
t critical two-tail	1.971111	

Difference in picking average significant ($p = < .05$) by *t* test for two samples assuming unequal variances.

using the Z test showed that at the end of the trial, the average haemoglobin level in the group receiving the iron- and iodine-fortified salt was significantly higher than that of the control group for both men and women. The mean increase in haemoglobin levels in the experimental group compared with the controls was slightly higher in women. The reduction in severe anaemia (haemoglobin < 8 g/dl) was 53% greater in the experimental group than in the control group. The increase in the proportion of non-anaemic subjects in the dewormed group was more than twice that in the non-dewormed experimental group. At the end of one year, the average haemoglobin level in the experimental group had increased from 8.9 to 10.2 g/dl and their tea- picking yield had increased from 24.8 kg to 26.2 kg, equivalent to an annual 330-tonne increase in tea production for the group receiving the iron- and iodine-fortified salt. Double-fortified salt was well accepted by the community and would be purchased if marketed.

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The computer programme "MSU Nutriguide: Asian Indian Foods" is effective in assessing nutrient intakes of Indian populations

Kiran Bains, S. K. Mann, and W. O. Song

Abstract

A nutritional study was conducted on 150 female college students aged 18 to 23 at the Punjab Agricultural University, Ludhiana, India, to evaluate the effectiveness of "MSU Nutriguide: Asian Indian Foods," a computer programme for assessing nutrient intakes and total energy expenditure (TEE) of the Indian population. A non-significant difference between analysed and calculated values for energy, protein, iron, and ascorbic acid revealed that the intake of the nutrients calculated with the MSU Nutriguide was a correct assessment in most of the subjects. TEE estimation by MSU Nutriguide gives values based on age, height, weight, and four levels of physical activity (sleeping and light, moderate, and heavy activity), whereas prediction equations are based on the body weight of each subject and a single level of activity. Therefore, MSU Nutriguide can be efficiently used to assess the TEE of people in India.

Introduction

"MSU Nutriguide: Asian Indian Foods" is a computer programme designed to assess nutrient adequacy and provide nutrition education based on actual intake and body requirements [1]. Although most Indian raw foods have been analysed for nutrient composition and the values have been published in texts, it is only recently that software has been prepared for analysis of Indian diets. This has become possible through the efforts of several Indian scholars who went to Michigan State University in the United States under UNDP (United Nations Development Programme) fellow training. They provided the nutritional values of cooked Indian foods and developed a computer programme. To evaluate its effectiveness in assessing nutrient intake and energy expenditure of Indian populations, a study was conducted on young college women at Punjab Agricultural University in Ludhiana, India.

Materials and methods

One hundred fifty women, aged 18 to 23 years, attending the Punjab Agricultural University were selected to participate in the study. The heights and weights of the subjects were measured [2]. Food intake was recorded by the 24-hour-recall method for three consecutive days in summer and winter. Nutrient intake was calculated by the MSU Nutriguide computer programme. For 20% of the subjects, consumed foods were weighed for three consecutive days and analysed for energy, protein, iron, and ascorbic acid by standard methods. The gross energy content was determined with a ballistic bomb calorimeter, Gallankamp, using the Association of Official Analytical Chemists (AOAC) procedures [3]. Protein was estimated by the AOAC method [4], and ascorbic acid content was estimated by the method of Caraway [5]. Iron was determined by an atomic absorption spectrophotometer (Varian method) after digestion of the food samples [6].

Total energy expenditure (TEE) was estimated by using MSU Nutriguide as well as the prediction equation of FAO/WHO/UNU [7] and the Indian Council of Medical Research (ICMR) [8] during the summer and winter seasons for three consecutive days along with the dietary survey. In the MSU Nutriguide method, age, sex, height in centimetres, and weight in kilograms are entered into the computer. Information regarding episodes of any serious disease was also recorded. The number of sleep hours and time spent on light, moderate, and heavy activities were then noted. Basal metabolic rate (BMR), energy expended on light, moderate, and heavy activities, and TEE were obtained

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for each of the subjects individually from the computer. The BMR of the subjects was calculated by using the FAO/WHO/UNU [7] and ICMR [8] prediction equations for adult Indian women:

$$\text{BMR [7]} = 14.7 \times \text{body weight (kg)} + 496$$
$$\text{BMR [8]} = 14.0 \times \text{body weight (kg)} + 471$$

TEE was calculated by using the BMR factors of 1.56 according to FAO/WHO/UNU [7] and 1.6 according to ICMR [8] for adult Indian women engaged in sedentary activity. The data were statistically analysed by the computer programme package CPCS I [9].

Results

The average height of the subjects was 160.2 ± 0.5 cm. The average weight was 51.9 ± 0.6 kg, which was below the 53.5-kg standard of the Life Insurance Corporation of India [10]. The average nutrient intake, as calculated by the MSU Nutriguide, is given in table 1. The respective intakes of energy, protein, iron, and ascorbic acid were 93%, 94%, 48%, and 71% of the recommended dietary allowances (RDA) according to ICMR [8].

Representative food samples for 20% of the subjects chosen at random were analysed, and the values were compared with calculated values for energy, protein, iron, and ascorbic acid (table 2). The differences between the analysed and calculated values of dietary energy, protein, and iron were non-significant. However, a significant ($p \leq .05$) difference was observed in the values of dietary ascorbic acid obtained by the two methods.

The BMR values calculated by the MSU Nutriguide, FAO/WHO/UNU, and ICMR equation methods were 55, 52, and 50 kcal/h, respectively. There were significant differences in the values of BMR and TEE calculated by the three different methods ($p \leq .05$)(tables 3 and 4). The MSU Nutriguide yielded a daily TEE value 7.5% lower than that calculated by the FAO/WHO/UNU method and 4.7% lower than that calculated by the ICMR equation.

TABLE 1. Average daily dietary nutrient intake (mean ± SE) calculated by the MSU Nutriguide ($n = 150$)

Nutrient intake	Summer	Winter	Average	RDA[a]
Energy (kcal)	1,757 ± 24.0	1,794 ± 25.4	1,776 ± 22.1	1,915
Protein (g)	48.1 ± 0.7	49.1 ± 0.7	48.6 ± 0.6	51.5
Iron (mg)	13.4 ± 0.3	15.6 ± 0.3	14.5 ± 0.2	30
Ascorbic acid (mg)	27.7 ± 0.9	29.2 ± 0.8	28.5 ± 0.7	40

a. RDA values for energy and protein are based on body weight [8].

TABLE 2. Calculated and analysed values (mean ± SE) for dietary nutrients of the selected subjects ($n = 30$)

	Summer		Winter		
Nutrient intake	Analysed	Calculated	Analysed	Calculated	*F* ratio
Energy (kcal)	1,623 ± 35.6	1,680 ± 43.6	1,684 ± 29.2	1,749 ± 29.7	2.86 NS[a]
Protein (g)	50.4 ± 1.1	47.5 ± 1.8	52.0 ± 1.6	51.1 ± 1.6	2.99 NS
Iron (mg)	14.3 ± 1.0	13.3 ± 0.8	16.9 ± 1.0	16.1 ± 0.9	2.04 NS
Ascorbic acid (mg)	22.9 ± 0.9	29.0 ± 1.6	23.4 ± 0.9	32.7 ± 1.5	3.09[b]

a. Not significant.
b. Significant at 5% level.

TABLE 3. Basal metabolic rate and total energy expenditure (kcal/24 h) of the subjects measured by three methods ($n = 150$)[a]

	Basal metabolic rate		Total energy	
Method	Range	Mean ± SE	Range	Mean ± SE
MSU Nutriguide	1,118–1,520	1,322 ± 5	1,582–2,122	1,824 ± 9
FAO/WHO/UNU equation	1,051–1,099	1,253 ± 8	1,645–2,390	1,961 ± 16
ICMR equation	1,003–1,543	1,196 ± 7	1,580–2,473	1,910 ± 11

a. Values are average of summer and winter.

An overall negative energy balance of the subjects was found by the three different methods (table 5). However, the energy gap was less according to the MSU Nutriguide than according to the equation methods.

Discussion

The non-significant differences between analysed and calculated values indicated that the nutrient intakes calculated with the MSU Nutriguide were correct assessments, except for the intake of ascorbic acid. The low ascorbic acid content measured during analysis of food samples, in comparison with the calculated values for ascorbic acid in raw foods, was probably due to cooking losses

Lower values of daily TEE were observed by using the MSU Nutriguide than were suggested by the prediction equations of ICMR and FAO/WHO/UNU. These equations are based on body weight, whereas the MSU Nutriguide gives values based on age, height, weight, and four levels of physical activity (sleep and light, moderate, and heavy activity). The energy balance was negative by all three methods, but a wider gap between energy intake and expenditure was observed when the FAO/WHO/UNU prediction equations were used. Since the average daily intake of the subjects was marginally below the RDA (93% of RDA) and their body weight showed slightly low energy status, the MSU Nutriguide and ICMR methods gave a more realistic picture of TEE.

Conclusions

The analysed nutritional values and those calculated by the MSU Nutriguide were not significantly different, and TEE estimated by the MSU Nutriguide was closer to that obtained by the ICMR equation method than to that obtained by the FAO/WHO/UNU method. The MSU Nutriguide can be considered more realistic, because it gives values based on age, height, weight, and four levels of activity, whereas prediction equations are based on body weight and a single level of activity. Moreover, the MSU Nutriguide is a very quick method of estimating nutrient intake as well as nutrient adequacy. Other countries can use this software for assessing the nutrient adequacy of their population by making any necessary adjustments in its food-composition database.

TABLE 4. Difference between basal metabolic rate and total energy expenditure (kcal/24 h) of the subjects measured by three methods[a]

Methods	Basal metabolic rate	Total energy
Nutriguide[b] and FAO/WHO/UNU equation	69 (5.3)	–137 (7.5)
Nutriguide[b] and ICMR equation	126 (9.5)	–86 (4.7)

a. Figures in parentheses are percent differences.
b. Taken as basis.

TABLE 5. Energy balance (kcal/24 h) of the subjects measured by three methods

Method	Range	Mean ± SE
MSU Nutriguide	–452 to 635	–48 ± 10
FAO/WHO/UNU equation	–544 to 659	–186 ± 14
ICMR equation	-493 to 561	–134 ± 13

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Condensed survey report

Prevalence and potential determinants of protein–energy malnutrition in Upper Egypt

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Abstract

The present community-based study of 2,700 children in three governorates of Upper Egypt revealed that stunting was present among 35.7% of the total sample. It was more prevalent in Menia (39.4%), followed by Assiut (38%), and Sohag (29.9%) governorates. Underweight was observed in 30.4% of all pre-schoolers (Menia 28.6%, Sohag 27.1%, and Assiut 25.7%). The prevalence of wasting in the whole sample was 9.2% (Assiut 10.8%, Sohag 9.3%, and Menia 7.6%). Protein–energy malnutrition (PEM) was usually higher in rural than in urban sites and higher in girls than in boys, with the second year of life showing the highest prevalence. Low socio-economic level and high morbidity load were associated with increased risk of all PEM indicators. Integrated programmes are needed to improve socio-economic conditions and infant-feeding practices.

Introduction

Three of the six governorates in Upper Egypt—Menia, Assiut, and Sohag—were chosen to represent middle, upper, and lower Upper Egypt. Nine hundred children were selected from each of these for determination of the prevalence of protein–energy malnutrition (PEM), dietary intake, morbidity, and, in a 20% sample, haemoglobin and intestinal parasites.

Materials and methods

The study was carried out on 2,700 children 6 to 71 months of age in late 1997. A two-stage cluster-sampling technique was used, with probability proportionate to the size of the population at the first stage and a constant number of subjects per cluster at the second stage. In the first stage, a total of 30 clusters (urban and rural communities) was selected from the different districts of each governorate. In the second stage, 30 children were selected from each cluster to form the target population of the study. Of the 2,700 children selected for the study, 2,670 (1,560 boys and 1,110 girls) completed the study. The data collected included family characteristics, socio-economic score [1], morbidity profile in the last two weeks, and, from a 20% subsample, dietary characteristics, including breastfeeding and quantitative food consumption pattern, using the 24-hour recall method [2].

Length/height and weight measurements were obtained according to WHO/UNICEF guidelines and cut-off points [3]. Urine analysis was performed on subsamples by the sedimentation centrifugation technique [4], and stool analysis was performed by the Merthiolate iodine formaldehyde technique [5].

Data management

Data were analysed by Epi Info Version 6.0. Dietary intake data were processed and analysed by using the Egyptian food-composition tables [6]. Nutrient intake was compared with the US National Research Council's recommended dietary allowances [7] to estimate the adequacy of intakes of the selected nutrients. The prevalence of PEM was estimated on the basis of anthropometric indicators of height-for-age (stunting), weight-for-age (underweight), and weight-for-height (wasting) compared with WHO/NCHS (National Center for Health Statistics) reference standards.

Univariate and bivariate analysis and multiple linear regression were used to evaluate the relation between

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PEM indicators and child and family characteristics. Stepwise regression selected the most significant predictors of PEM, and a correlation matrix evaluated the relationship between different PEM indicators.

Sample characteristics

The mean age of the children was 30.4 ± 17.9 months, and that of the mothers was 28.2 ± 6.3 years. More than two-thirds of the mothers (70.1%) and about half of the fathers (48.3%) were illiterate. Sohag governorate had a higher rate of illiteracy and lower education levels for both mothers and fathers. Most of the studied families (87%) belonged to low and very low socio-economic levels, with a significant difference between governorates.

Results

Morbidity pattern

The frequencies of infections in the last two weeks of the study are given in table 1, as well as the parasites in faecal samples taken from 20% of the study population.

Breastfeeding status

Very few (3.3%) of the children had never been breastfed; almost two-thirds (64.1%) were not being breastfed at the time of the study (table 2). The majority (65.3%) were weaned at 12 to 24 months of age, with a significant difference among governorates in the duration of breastfeeding.

TABLE 1. Morbidity and parasitic status of pre-school children in Menia, Assiut, and Sohag governorates, 1997

Variable	Menia	Assiut	Sohag	Total	
Morbidity[a]	*n* = 880–891 %	*n* = 883–884 %	*n* = 895–898 %	*n* = 2,660–2,673 %	*p*
Diarrhoea	55.8	35.5	30.1	40.4	<.01
Vomiting	15.8	10.6	6.7	11.0	.01
Cough	22.3	15.0	10.9	16.1	.01
Fever	33.3	44.5	25.1	42.4	.01
Measles	2.3	1.5	1.6	1.8	NS
Parasitic status[b]	*n* = 158 no. (%)	*n* = 165 no. (%)	*n* = 175 no. (%)	*n* = 498 no. (%)	
Negative	110 (69.6)	126 (76.4)	84 (48.0)	320 (64.3)	
Protozoa					
Giardia lamblia	9 (5.7)	7 (4.2)	46 (26.3)	62 (12.4)	
Entamoeba histolytica	33 (20.9)	24 (14.5)	43 (24.6)	100 (20.1)	
Helminthes					
Endolimax nana	6 (3.8)	6 (3.6)	12 (6.9)	24 (4.8)	
Enterobius vermicularis	2 (1.3)	4 (2.4)	11 (6.3)	17 (3.4)	
Ascaris lumbricoides	3 (1.9)	2 (1.2)	1 (6.0)	6 (1.2)	
Schistosoma mansoni	3 (1.9)	0 (0.0)	0 (0.0)	3 (1.9)	
Schistosoma haematobium	5 (3.4)	1 (0.6)	2 (1.2)	8 (1.6)	
No. of parasites					
1	41 (85.4)	35 (89.7)	70 (76.9)	146 (82.0)	
≥2	7 (14.6)	4 (10.3)	21 (23.1)	32 (18.0)	

a. Morbidity was determined during the last two weeks of the study, except for measles, which was determined during the last six weeks.

b. Thirty-three percent (189 cases) of the total sample were positive for enteropathogenic coli.

Nutrient intake

Daily intakes and percent adequacy of selected nutrients are given in table 3. The mean daily energy intake of pre-school children under and over four years of age covered only 82% and 64% of the recommended allowances, respectively. The total protein intake in both age groups exceeded the recommendations by 194% and 133% for those less than four years and those over four years of age, respectively. About one-third (31% and 28%, respectively) of the total protein came from animal sources.

Even without taking into account low bioavailability, the values for total iron intake satisfied only 67% and 79% of recommended allowances in younger and older children, respectively. The percentage of haem iron intake in relation to total iron intake was 18% and 11% in younger and older children, respectively.

TABLE 2. Distribution of sampled pre-school children according to breastfeeding status and age of cessation of breastfeeding in Menia, Assiut, and Sohag governorates, 1997

Variable	Menia—no. (%)	Assiut—no. (%)	Sohag—no. (%)	Total—no. (%)
Currently breastfeeding[a]				
No	533 (60.2)	573 (65.9)	590 (66.2)	1,696 (64.1)
Yes	352 (39.8)	296 (34.1)	301 (33.8)	949 (35.9)
Breastfeeding stopped (mo)[b]				
Never breastfed	22 (4.2)	20 (3.5)	13 (2.2)	55 (3.3)
<1	5 (0.9)	6 (1.0)	2 (0.3)	13 (0.8)
1–2	19 (3.6)	17 (3.0)	16 (2.7)	52 (3.0)
3–5	15 (2.8)	15 (2.6)	10 (1.7)	40 (2.4)
6–11	26 (4.9)	23 (4.0)	32 (5.4)	81 (4.8)
12–23	297 (56.3)	406 (71.0)	401 (68.0)	1,104 (65.3)
24+	144 (27.3)	85 (14.9)	116 (19.7)	345 (20.4)

a. No response in six mothers; $\chi^2 = 8.79$, $p = < .05$ for the difference among governorates.
b. $\chi^2 = 40.48$, $p < .01$ for the difference among governorates.

TABLE 3. Mean ± SD daily intake and percent adequacy of selected nutrients of pre-school children under four years old and four or more years old in Menia, Assiut, and Sohag governorates, 1997

Nutrient	Children < 4 yr $n = 238$	Children ≥ 4 yr $n = 121$
Energy (kcal)	1,039 ± 460	1,148 ± 436
Total protein (g)	30.9 ± 15.0	32.3 ± 16.0
Animal protein	9.4 ± 8.6	9.1 ± 10.1
Vegetable protein	21.5 ± 12.3	23.2 ± 10.7
Total iron (mg)	6.8 ± 4.3	7.9 ± 5.3
Haem iron	1.2 ± 1.8	0.9 ± 1.2
Non-haem iron	5.6 ± 3.8	7.0 ± 5.0
Total vitamin A (RE)	236 ± 268	305 ± 333
Retinol	130 ± 248	143 ± 347
β-Carotene	106 ± 176	162 ± 209
Vitamin C (mg)	60.8 ± 133	83 ± 143
% of total protein from animal protein	31	28
% of total iron from haem iron	18	11
% of retinol from total vitamin A	55	47
Adequacy (%)		
Energy	82	64
Protein	194	133
Iron	67	79
Vitamin A	59	62
Vitamin C	153	184

The total mean daily intake of vitamin A by preschoolers under four years of age satisfied only 59% of recommendations, whereas for those over four years of age it covered only 62% of recommendations. The intake adequacy of vitamin C was 153% and 184% of the recommended allowance in both age groups.

Prevalence of PEM

Figure 1 shows the anthropometric measurements. Stunting, wasting, and, with the exception of Sohag governorate, underweight were more prevalent in the rural sites. Indicators of PEM were consistently higher in the second year of life (12–24 mo) (fig. 2). There was no significant difference between boys and girls in the prevalence of PEM.

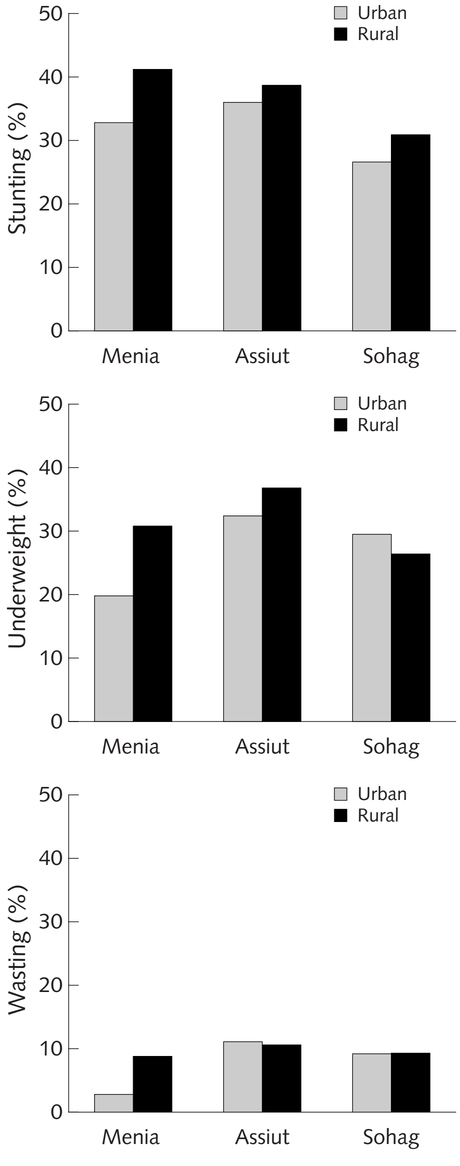

FIG. 1. Prevalence of indicators of protein–energy malnutrition in urban and rural areas of Menia, Assiut, and Sohag, 1997

Regression analyses

Stepwise multiple logistic regression (table 4) showed economic level and diarrhoea to be the most important determinants of stunting, and vomiting and diarrhoea were the most indicative of underweight. Age, economic level, persistent cough, vomiting, and fever were all significant determinants of wasting. Thus, infections were contributing or precipitating factors for all forms of PEM. Diarrhoeal disease, measles, respiratory infections, and other infections frequently result in negative protein and energy balance due to anorexia, vomiting, decreased absorption, and catabolic processes [8]. Residence in Assiut and Sohag governorates was associated with increased risk of wasting.

Simple logistic analysis (not shown) indicated that low iron intake was also associated with underweight (odds ratio, 0.91; $p < .01$), although it was not significantly associated with stunting or wasting. Illiteracy and limited education of both fathers and mothers contributed significantly to stunting and underweight ($p < .01$), but the relationship to wasting fell short of significance. Economic level, fever, vomiting, and diarrhoea were also associated ($p < .01$) with increased risk of all forms of PEM.

Discussion

The present study found that malnutrition is still a serious problem in Upper Egypt and revealed a high overall prevalence of all PEM indicators. We found a higher prevalence of stunting than the 31.4% reported from Upper Egypt by the DHS in 1998 [9]. Stunting due to a slowing in skeletal growth indicates long-term cumulative ill health and/or nutritional inadequacies.

The prevalence of underweight among pre-school children in the present study was 30.4%, a higher value than the 14.6% reported from Upper Egypt by the DHS [9] or the 16.8% reported by the Nutrition Institute national survey [10]. The 9.2% overall prevalence of wasting was slightly higher than the 7.8% reported for wasting in the Upper Egypt DHS survey [9], and much closer to the 9.7% recorded in the Nutrition Institute national survey for assessment of vitamin A deficiency [10].

Comparison of the figures for PEM prevalence with those estimated by DHS surveys in 1992, 1995, and 1997 revealed that wasting and underweight increased while stunting level remained relatively stable, in the range of 30% to 35%.

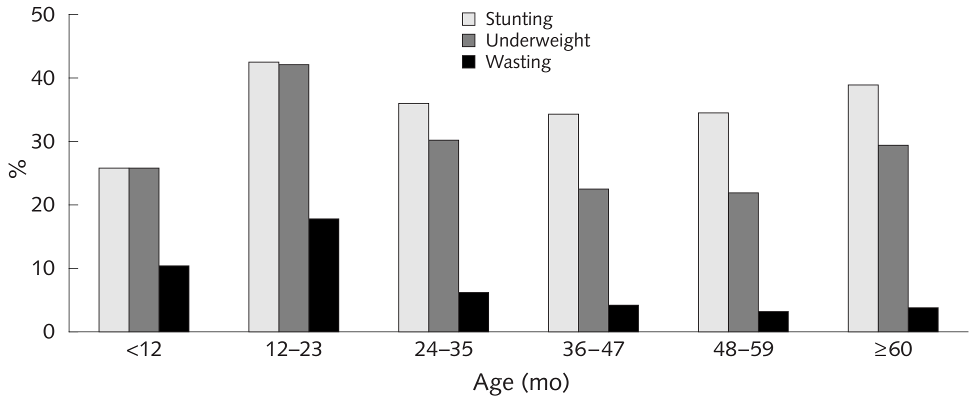

FIG. 2. Prevalence of indicators of protein–energy malnutrition in total sample according to age, 1997

Conclusions

The present findings reveal that PEM is still highly prevalent in Upper Egypt, especially in rural populations. Undernutrition indicated by wasting is increasing. The high prevalence of PEM was attributed to multiple factors, including insufficient energy intake, ingestion of foods of low protein quality, high rates of infection, prolonged breastfeeding with poor weaning practices, and low socio-economic status. Integrated programmes are needed to improve sanitary conditions, income, household food security, and education; control infections and parasitic diseases; and support exclusive breastfeeding for four to six months and timely and appropriate weaning practices.

Acknowledgements

This study was done in collaboration with UNICEF.

TABLE 4. Stepwise multiple logistic regression analysis of protein-energy malnutrition indicators

Independent variable	OR	95% CI	*p*
Stunting			< .01
Economic level	0.92	0.89–0.95	
Diarrhoea	1.30	1.09–1.55	
Mother's age	0.999	0.97–0.99	
Underweight			< .01
Total protein intake	0.96	0.94–0.89	
Vomiting	2.87	1.40–2.76	
Diarrhoea	1.78	1.02–3.14	
Wasting			< .01
Age	0.97	0.96–0.98	
Economic level	0.92	0.42–0.47	
Assiut	1.89	1.31–2.72	
Sohag	1.70	1.16–2.51	
Persistent cough	1.50	1.06–2.15	
Vomiting	1.46	1.01–2.16	
Fever	1.35	1.01–1.82	

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Books received

Erratum

In the **Books Received** section of the March 2000 issue of the *Bulletin* (volume 21, number 1, page 103) the price of the following book was inadvertently omitted:

Scaling up, scaling down. Overcoming malnutrition in developing countries. Edited by Thomas J. Marchione. Gordon and Breach Publishers, Amsterdam, The Netherlands, 1999. (90-5700-547-6) 292 pages, hardcover.

The prices given were for shipping only. The price of the book is US$50.00/£32.00 plus US$5.00/£3.00 shipping for the first copy and US$2.00/£1.00 for each additional copy.

Complementary feeding of infants and young children in developing countries: A review of current scientific knowledge. World Health Organization, Geneva, 1998. 228 pages, paperback. Sw fr 35.–/US$31.50 (in developing countries: Sw fr. 24.50).

This state-of-the-art review is intended primarily for health professionals and others concerned with the nutrition, health, and well-being of children, as child malnutrition remains a common problem in developing countries. The objective is to provide the background information that is necessary for the development of scientifically sound feeding recommendations and appropriate intervention programmes to enhance children's dietary intake and nutritional status. Although much of the information may be relevant for young children in industrialized countries, the review focuses on the particular needs of children in low-income settings, and the recommendations have been formulated with consideration for the economic and environmental constraints that are common in developing countries.

The book is organized into nine sections. An introductory chapter provides the rationale for the exercise and defines some of the terms used. Chapter 2 discusses the importance of breastfeeding and the appropriate age to introduce complementary foods and breastfeeding duration. Chapter 3 is devoted to technical information, including energy requirements at different ages, feeding frequency, energy density, and organoleptic characteristics of food, while chapter 4 discusses protein and micronutrients. Chapter 5 considers the role of caregivers, chapter 6 food processing and food safety, chapter 7 child feeding practices and children's dietary intake, and chapter 8 a range of programmatic interventions to promote improved child feeding. The last chapter summarizes current conclusions regarding appropriate child feeding and future research needs. Anyone involved with the scientific and programmatic aspects of complementary feeding will find this review useful.

Obesity and poverty: A new public health challenge. Edited by Manuel Peña and Jorge Bacallao. Pan American Health Organization, Washington, DC (Scientific Publication No. 576, 2000). (ISBN 92-7511576-1) 124 pages, paperback.

Also published in Spanish (2000) with the title **Obesidad y la pobreza: un nuevo reto para la salud pública**. Publicación de la OPS No. 576 (ISBN 9275-315766-0) Overweight and obesity have not only become epidemic in many industrialized countries but are also increasingly serious public health problems in developing countries. The global demographic and epidemiologic transition responsible still leaves behind a large number of malnourished children in the latter. There is evidence that the health consequences of obesity are more serious for persons who were poorly nourished as children. Thus, obesity and overweight in this and other developing regions differ from traditional risk factors seen in developed countries—the persistence or the increase of inequality and inequities in health.

This book describes the prevalence of overweight and obesity in Latin America and the Caribbean and their medium- and long-term consequences. It examines the socio-anthropological aspects of obesity in poverty, physical activity patterns in Central America, and the emerging problems of obesity among the poor. Chile, Cuba, and Brazil provide case studies. Methodological approaches to studying obesity are examined from a public health perspective. An important closing chapter reviews the evidence that nutritional and other insults during critical stages of foetal development in early childhood, followed by relative affluence, result in an increased risk of disease in later life. It concludes that a high priority should be given to effective strategies for dealing both with undernutrition and malnutrition during pregnancy and early childhood and with obesity, often beginning during adolescence and increasing in adults. This book provides valuable information for students, communicators, and policy makers concerned with public health as well as for researchers and health specialists.

Principles of health economics for developing countries. William Jack. World Bank, Washington, DC, 1999. (ISBN 0-8213-4571-0) 298 pages, paperback.

This book attempts to provide a suitable economic framework that will foster an understanding of the allocation of broadly defined health-care resources, and to aid the design and analysis of policies that affect health outcomes.

News and notes

Final Report to the ACC/SCN by the Commission on the Nutrition Challenges of the 21st Century

At its 24th session in Kathmandu, in 1997, the Administrative Committee on Coordination/Sub-Committee on Nutrition launched a Commission to identify the nutrition challenges of the 21st century and to examine the role of the UN in addressing them. The Commission was chaired by Professor Philip James and included six distinguished internationalists involved in nutrition. The Commission held hearings and collected evidence from many sources and from meetings in London, New York, and Madras. A first draft was presented to the SCN meeting in Oslo in 1998, and a much revised version was circulated for comments at the 1999 SCN meeting in Geneva. However, the report is that of an independent Commission, not of the SCN itself or any of its members.

The report is a rich source of new information and insights into the nutrition challenges that have persisted for some time, as well as new and emerging issues. The report should also serve to inspire partnerships and move the nutrition community towards accelerated and concerted action. Additional copies are available on the ACC/SCN web site: www.unsystem.org/accscn/. Copies can also be obtained without charge from the SCN secretariat:

UN ACC Sub-Committee on Nutrition
(ACC/SCN)
c/o World Health Organization
20, Avenue Appia
CH-1211 Geneva 27
Switzerland

International course on food and nutrition programme management

The International Agricultural Center (IAC), a training institute for mid-career professionals, will conduct an international course on food and nutrition programme management. This course is intended for the staff of governmental and non-governmental organizations at (sub-) national level, involved in policy making and/or planning or management of food and nutrition security programmes. The course focuses on issues related to management and decision making in the context of food security, nutrition, and health issues. The training is interactive and experience-based and provides participants with an opportunity to learn from the accumulated international knowledge and each other's experience. The course, which lasts for six weeks, will be conducted from 15 October to 25 November 2000 and from 20 October to 30 November 2001. The tuition fee is NLG 6,000. No scholarships are available for this course from the Netherlands Government or from IAC. For further information and application forms contact:

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The Netherlands
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Fax: + 31 317 495 395
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Home page: www.iac-agro.nl

IFPRI 2020 Vision Discussion Paper 30: Food, agriculture, and the environment

Overcoming child malnutrition in developing countries. Past achievements and future choices. Lisa C. Smith and Lawrence Haddad.

Today about one-third of the children under five years of age in developing countries—167 million children—are malnourished. These numbers are still rising in some regions. What are the key causes of child malnutrition, and what will it take to end this suffering? In this paper, Lisa C. Smith and Lawrence Haddad present the results of research on factors that have contributed to reducing child malnutrition in the developing world over the past quarter century. The most important finding is that improvements in women's education accounted for two-fifths of the reduction, owing to its strong influence on child nutrition. Increases in per capita food availability contributed to a quarter of the reduction, followed by improvements in health environments and women's status. The study also projects the prevalence and distribution of child malnutrition in three scenarios for 2020. Even under the most optimistic scenario, as many as 128 million children could be malnourished. To bring these numbers down, the authors recommend that efforts to improve women's education, raise food supplies, bolster women's status, and create healthy environments should be an integral part of strategies for reducing child malnutrition in the future. To support these efforts, continued economic growth and democratic decision-making processes are essential. Investment in all these areas should complement more direct nutrition interventions in feeding programmes.

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Micronutrient documents available on line

At its web site (http://www.micronutrient.org/publications) the Micronutrient Initiative has the following documents available for viewing or downloading. All documents are available in English unless otherwise specified:

Preventing iron deficiency in women and children: background and consensus on key technical issues and resources for advocacy, planning and implementing national programmes. UNICEF/UNU/WHO/MI Technical Workshop. Co-published by International Nutrition Foundation (INF) and Micronutrient Initiative (MI). View file in PDF format.

Global directory of commercial manufacturers of micronutrient premixes and supplements. 1st ed. December 1997. View directory.

Report of the UNICEF/WHO regional consultation on prevention and control of iron deficiency anaemia in women and children 3–5 February 1999 Geneva, Switzerland. View document in PDF format.

Community-based fortification of cereals. Report of a meeting held 1–2 June 1998, Ottawa, Canada. View document.

Expert consultation on anemia determinants and interventions. Micronutrient Initiative, 1998. Proceedings from a consultation held at the Micronutrient Initiative, Ottawa, in September 1997. Table of Contents/Executive Summary.

Food fortification to end micronutrient malnutrition: state-of-the-art. Proceedings of the IUNS satellite meeting held in Montreal, Canada, 2 August 1997. Micronutrient Initiative, Ottawa, 1998. Table of Contents.

Joining hands to end hidden hunger: a call to action. Micronutrient Initiative, Ottawa, 1996. Table of Contents.

Major issues in the control of iron deficiency. Micronutrient Initiative and UNICEF, 1998. Table of Contents/Summary and Conclusions.

Micronutrient fortification of foods: current practices, research and opportunities. Lotfi M, Mannar MGV, Merx RJHM, Naber-van den Heuvel P. Micronutrient Initiative, International Agricultural Centre, 1996. 108 pages. Table of Contents.

Monitoring universal salt iodization programmes. Sullivan KM, Houston R, Gorstein J, Cervinskas J, eds. UNICEF/PAMM/MI/ICCIDD/WHO, 1995. 101 pages. Table of Contents.

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Sharing risk and reward. Public-private collaboration to eliminate micronutrient malnutrition. Report of the Ottawa Forum on Food Fortification, 1996. Table of Contents.

Stability of iodine in iodized salt used for the correction of IDD. Diosady LL, Alberti JO, Mannar MGV, Stone TG. Food Nutr Bull 1997;18(4):388-396.

Vitamin A deficiency: key resources in its prevention and elimination. 2nd ed. Cervinskas J, Lotfi M, eds. Micronutrient Initiative, Ottawa, Canada, 1996. 59 pages. Full text.

All we expect. Nutrition: A basic human right. Micronutrient Initiative, 1995. English, French, and Spanish. (24-minute video).
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Tel: 1-613-236-6163
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E-mail: contact@micronutrient.org

Sugar fortification to end vitamin A deficiency in Southern and Eastern Africa

On 29–30 June 1999, participants in a regional workshop in Ezulwini, Swaziland, on "Sugar Fortification to End Vitamin A Deficiency in Southern and Eastern Africa" issued a declaration calling for universal fortification of sugar with vitamin A for household consumption in Southern Africa to permanently resolve the problem of vitamin A deficiency and its consequences. This is described in "Sugar fortification to end vitamin A deficiency in Southern and Eastern Africa. Report of a public-private dialogue." The report is available from:

Micronutrient Initiative
PO Box 8500
Ottawa ON K1g 3H9
Canada
E-mail: www.micronutrient.org

Nutrition and aging

The December 1999 issue of SCN News (no. 19) has a series of short authoritative articles on "Nutrition and Aging," as well as much else of equal interest to *Food and Nutrition Bulletin* readers. This issue and a continuing subscription are available without charge from:

ACC/SCN
c/o World Health Organization
20 Avenue Appia
CH-1211 Geneva 27
Switzerland
E-mail: ACC/SCN@who.ch

Capacity building

The International Union of Nutritional Sciences (IUNS) in collaboration with the United Nations University (UNU) is playing a leading role in capacity building—nutrition expertise and operational capacity—including strengthening the infrastructure for nutrition policies and implementing national strategies in developing countries. A workshop for that purpose was held in June 1999 in Cape Town, South Africa. The major part of the workshop was devoted to issues related to the types of professionals needed to implement the growing knowledge base available to the nutritional sciences. It also devoted some time to evaluating the supplementary role that short-term training plays in the recruitment and preparation of professionals for specific purposes or upgrading and/or broadening of skills. The enhancement of national and regional research capacities was also a part of the discussions. The anticipated outcome of the workshop is a regional plan including training, research, and establishing linkages between regional and global expertise and centres of excellence. The plan of action will provide a framework for investment by donor agencies. It is expected that participants will take stock of progress in developing human and institutional capacity for nutrition in Southern Africa. They will also examine the disciplinary and interdisciplinary competencies essential to meet specified regional needs. They will explore the possibilities for strong collaborative relationships among training and research institutions and policy and programme implementing agencies in the region, and discuss appropriate collaborative South–South and North–South relationships. A follow-up action group met to elaborate the plan at the 27th ACC/SCN meeting in Washington, DC, on 10–14 April 2000.

Note for contributors

The editors of the *Food and Nutrition Bulletin* welcome contributions of relevance to its concerns (see the statement of editorial policy on the inside of the front cover). Submission of an article does not guarantee publication—which depends on the judgement of the editors and reviewers as to its relevance and quality. All potentially acceptable manuscripts are peer-reviewed. Contributors should examine recent issues of the *Bulletin* for content and style.

Language. Contributions may be in English, French, or Spanish. If French or Spanish is used, the author should submit an abstract in English if possible.

Format. Manuscripts should be typed or printed on a word processor, **double-spaced**, and with ample margins. Only an original typed copy or a photocopy of equivalent quality should be submitted; photocopies on thin or shiny paper are not acceptable.

When the manuscript has been prepared on a word processor, a diskette, either 3½- or 5¼-inch, should be included with the manuscript, with an indication of the disk format and the word-processing program used.

Length. Ordinarily contributions should not exceed 4,000 words.

Abstract. An abstract of not more that 150 words should be included with the manuscript, stating the purposes of the study or investigation, basic procedures (study subjects or experimental animals and observational and analytical methods), main findings (give specific data and their statistical significance if possible), and the principal conclusions. Emphasize new and important aspects of the study or observations. Do *not* include any information that is not given in the body of the article. Do not cite references or use abbreviations or acronyms in the abstract.

Tables and Figures. Tables and figures should be on separate pages. Tables should be typed or printed out double-spaced. Submit only original figures, original line drawings in India ink, or glossy photographs. Labels on the figures should be typed or professionally lettered or printed, not handwritten.

Photographs. Ideally photographic materials should be submitted in the form of black and white negatives or black and white glossy prints. Photographs will not be returned unless a specific request is made.

Units of measurement. Preferably all measurements should be expressed in metric units. If other units are used, their metric equivalents should be indicated.

Abbreviations. Please explain any abbreviations used unless they are immediately obvious.

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Number references consecutively in the order in which they are first mentioned in the text. Identify references in the text and in tables and figure legends by arabic numerals enclosed in square brackets. References cited only in tables or figure legends should be numbered in accordance with the first mention of the relevant table or figure in the text. **Be sure references are complete.**

Reference citations should follow the format illustrated below.

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—*corporate author:*

2. Committee on Enzymes of the Scandinavian Society for Clinical Chemistry and Clinical Physiology. Recommended method for the determination of gammaglutamyltransferase in blood. Scand J Clin Lab Invest 1976;36:119–25.

Book or other monograph reference

—*personal author(s):*

3. Brozek J. Malnutrition and human behavior: experimental, clinical and community studies. New York: Van Nostrand Reinhold, 1985.

—*corporate author:*

4. American Medical Association, Department of Drugs. AMA drug evaluations. 3rd ed. Littleton, Mass, USA: Publishing Sciences Group, 1977.

—*editor, compiler, chairman as author:*

5. Medioni J, Boesinger E, eds. Mécanismes éthologiques de l'évolution. Paris: Masson, 1977.

—*chapter in book:*

6. Barnett HG. Compatibility and compartmentalization in cultural change. In: Desai AR, ed. Essays on modernization of underdeveloped societies. Bombay: Thacker, 1971:20–35.

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Note à l'intention des auteurs

La rédaction du *Food and Nutrition Bulletin* recherche des articles traitant de sujets correspondant à ses thèmes (voir au vérso de la couverture la politique éditoriale de cette revue). La remise d'un manuscrit ne signifie pas sa publication, qui dépend de l'opinion de la rédaction et des réviseurs sur son intérêt et sa qualité. Tous les manuscrits susceptibles d'être acceptés sent révisés par des pairs. Les auteurs sent invités à se pencher sur les récents numéros du *Bulletin* pour prendre connaissance de son contenu et de son style.

Langues. Les manuscrits peuvent être rédigés en anglais, en français ou en espagnol, et dans ces deux derniers cas, l'auteur ajoutera, si possible, un résumé en anglais.

Format. Les manuscrits doivent être dactylographiés ou imprimés sur une machine de traitement de texte, **en double interligne**, avec une marge suffisante. Ne doit être présenté qu'un exemplaire original dactylographié ou une photocopie de qualité équivalente.

Lorsque le manuscrit a été préparé sur une machine de traitement de texte, une disquette de 3,50 ou de 5,25 pouces devrait dans toute la mesure possible y être jointe en précisant son format et le programme utilisé.

Longueur. Les manuscrits ne doivent pas, normalement, dépasser 4000 mots.

Résumé: Un résumé de 150 mots maximum doit accompagner le manuscrit. Il devra donner les buts de l'étude ou des recherches, les procédures de base (sujets de l'étude ou animaux expérimentaux et méthodes d'observation et d'analyse), les principaux résultats (fournir des données spécifiques et indiquer dans la mesure du possible leur importance statistique) ainsi que les principales conclusions. Veuillez mettre en relief les aspects nouveaux et importants de l'étude ou des observations. Prière de *ne pas* inclure des informations qui ne figurent pas dans le corps de l'article. Dans le résumé, ne citez aucun ouvrage de référence et n'utilisez ni abréviations ni sigles.

Tableaux et figures. Ils doivent être reportés sur des feuillets séparés. Les tableaux doivent être dactylographiés ou imprimés en double interligne. Veuillez soumettre uniquement des figures originales, des dessins à l'encre de Chine ou des photographies tirées sur papier glacé. Les labels qui apparaissent sur les figures doivent être dactylographiés ou gravé ou imprimés de manière professionnelle et non pas écrits à la main.

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1. Alvarez ML, Mikasic D, Ottenberger A, Salazar ME. Caracteristicas de familias urbanas con lactante desnutrido: un análisis critico. Arch Latinoam Nutr 1979;29:220–30.

—*auteur d'une société:*

2. Committee on Enzymes of the Scandinavian Society for Clinical Chemistry and Clinical Physiology. Recommended method for the determination of gammaglutamyltransferase in blood. Scand J Clin Lab Invest 1976;36:119–25. Livre ou autre monographie

—*auteur(s) à titre personnel:*

3. Brozek J. Malnutrition and human behavior: experimental, clinical and community studies. New York: Van Nostrand Reinhold, 1985.

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4. American Medical Association, Department of Drugs. AMA drug evaluations. 3e éd. Littleton, Mass.
(E.-U.): Publishing Sciences Group, 1977.

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5. Medioni J, Boesinger E, éds. Mécanismes éthologiques de l'évolution. Paris: Masson, 1977.

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