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Commentaries

Results of primary health care in Matlab, Bangladesh

The authors believe that iron supplementation was the major factor responsible for the observed improvement in iron status that was found in the Matlab population surveys [1]. However, they do not prove it, because there was no true control group and other interventions were also occurring. Nevertheless, the data illustrate that the Matlab primary health-care programme, which included iron supplementation, was effective, and this should be an additional stimulus to the development of similar programmes in other countries. Another paper recently published in *Lancet* describes a decline in maternal mortality in the same population but cautions that the intervention programmes rely, at the very least, on the functioning of the entire health-care system and on effective referral and communication strategies to promote specific behaviours. It was noted that "One indicator will not be sufficient to elucidate the complex nature of such programmes, and various assessment techniques and indicators are required" [2]. Even if iron supplementation alone were sufficient to achieve the specific goal of correcting iron deficiency, it would not be a substitute for the other health measures in the Matlab programme.

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Prevention of anaemia in women of child-bearing age

The paper by Brabin et al. [1] in this issue of the *Food and Nutrition Bulletin*, consisting of an epidemiological cross-sectional study of women attending health posts and post-partum centres in Mumbai, India, points out very clearly several important and commonly observed facts regarding the haematological status of women of child-bearing age, particularly but not exclusively in the developing world. The following points are noteworthy from the policy point of view.

The prevalence of anaemia among both pregnant and non-pregnant women is extremely high (80% and 82%, respectively). Anaemia was defined on the basis of the World Health Organization proposed cut-off points of 110 g/L haemoglobin for women in early pregnancy (<15 weeks gestation) and 120 g/L for non-pregnant women. The fact that even with a cut-off 10 g/L lower for early pregnancy, the prevalence of anaemia is as high in this population as it is among non-pregnant women suggests either that gestational haemodilution occurs early or that even the small demands of erythropoietic nutrients early in pregnancy will produce anaemia.

The absence of severe anaemia (<80 g/L) is important to note, even when mean haemoglobin values ranged from 97 to 114 g/L. The distribution of haemoglobin values shown in figure 1 is skewed to the right, except for the post-partum group, which shows a very symmetrical distribution. In this group, the proportion of women with haemoglobin levels <90 g/L is lower than in non-pregnant women or women in early pregnancy. This finding would appear paradoxical, because post-partum women generally are more anaemic than non-pregnant women. A possible explanation for this finding could be that supplementation with iron and folate during pregnancy temporarily improved post-pregnancy haematological status. This interpretation may be supported by the apparently small effects of multiparity. On the other hand, pregnancy appears to have a long-term effect on haemoglobin levels, as evidenced by higher haemoglobin levels among women who have never been pregnant, women with "no live births," and women with "0 years since first pregnancy" than among the other three groups (table 1).

The results of multivariate analysis, including as independent variables women's education, socio-economic status, number of pregnancies and live births, and age at menarche, explain only 16% of the variance in haemoglobin levels, leaving a large proportion of unexplained variance according to this model. Unfortunately, there is no information on biochemical indicators that could point in the direction of possible causes of low haemoglobin, such as meal composition, cooking methods, overall dietary intakes, infection rates, or even approximate menstrual blood losses, that are expected to account for most of the rest of the variance. Even though the authors do not speculate on causality, their discussion and recommendations suggest that underlying the problem is poor diet, leading most probably to iron and vitamin A, and possibly to folate and/or vitamin B_{12} deficiencies. In spite of these limitations, education, reproductive history, and age at menarche (as a surrogate for general nutritional status before and during puberty) are significant.

From these salient facts, the authors suggest that policies directed to improve the health and education of girls and the survival of children, reduce the number of pregnancies, and provide iron + folate supplementation during pregnancy are important to reduce the high prevalence of anaemia in the women of Mumbai. However, they acknowledge that these measures may have only a limited impact, and go a step further in their recommendations: "Health promotion to improve the diet of girls and iron supplementation in adolescence are required to redress nutritional deficits and, in the longer term, to reduce anaemia in older women of reproductive age…governments are starting to draw up national policy guidelines to improve adolescent sexual and reproductive health. Nutritional information and supplementation should be included in these policies, and every effort should be made to link supplementation to other interventions reaching young girls."

Experimental animal, clinical, and population studies strongly suggest that *community-based, preventive* iron + folate supplementation, ideally combined with other nutrients deficient in the diet (e.g., vitamin A) should be targeted to vulnerable groups, in particular to small children and women of reproductive age (whether or not they are pregnant). This strategy could be implemented in the short term in areas where food-based approaches (i.e, food fortification and significant dietary improvement) cannot be achieved in the short or medium term. Focusing on fertile adolescents and adult women, the purpose of this strategy is to complement all other possible strategies, pertinently suggested by the paper by Brabin et al., but with the further aim that *all women enter pregnancy with adequate iron reserves and a superior folate nutritional status.*

The findings of the study of Brabin et al. suggest that iron + folate supplementation should start before pregnancy, and at least as early as possible during pregnancy. Providing 100 tablets of iron + folate late in pregnancy and without any mechanism that will promote their proper ingestion has proven, at most, only minimally effective. Effective preventive supplementation is most likely to occur through community action in coordination with the health posts and post-partum centres. Several trials in which schoolteachers provided weekly iron + folate tablets to schoolgirls (and boys in some cases) throughout the school year are demonstrating an improvement in iron nutrition, including the correction of moderate anaemia (as seen in Mumbai women) and, most importantly, a progressive and safe increment of iron reserves [2, 3] (B. Torun, personal communication, 1998; P. Winichagoon, personal communication, 1998).

Similarly, in women of childbearing age, the results of ingestion of one tablet a week containing 60 mg of iron and 250 mg of folate in the course of seven months, for a total of 30 tablets, were as good as or better than the results of daily ingestion of tablets of the same composition but only for the first three months of the total seven-month trial (totaling 90 tablets) [4].

Equally important is the information and motivation of the whole community through mass media and the formation of community groups (e.g., based on educational, religious, industrial, and market activities), and especially women's groups, that can ensure the weekly ingestion of tablets by any woman who may become pregnant, and to double the dose as soon as pregnancy occurs (not waiting until the second or the last trimester of pregnancy). Coverage of the vulnerable population can also be increased in this fashion.

Several studies of pregnant women clearly indicate that initial haemoglobin concentration is the most important determinant of haemoglobin concentration at term, and that the duration of supplementation is more

important than the dose of iron. Thus, the better the pre-pregnancy iron nutritional status, the more effective iron + folate supplementation during pregnancy can be. Ideally, women should enter pregnancy with 300 mg of iron reserves. Very few women in the developing world and almost half the women in industrial countries do not have these reserve levels. Currently, if women are already clearly anaemic during pregnancy (haemoglobin <90 g/L), they are treated by daily administration of iron. This practice should be continued and carefully evaluated, especially when haemoglobin levels are lower than 80 g/L. However, several studies suggest that supervised weekly iron supplementation with proper doses covering at least 15 weeks during pregnancy can be almost as efficacious as daily supplementation [4–8].

In conclusion, this paper provides strong support for targeting interventions for the prevention of anaemia in the community as a whole and especially in pubertal, adolescent, and mature fertile women and not concentrating iron + folate supplementation strategies only on pregnant women during the second or third gestational trimesters. In most developing country settings, iron + folate supplementation restricted to or starting during the last half of pregnancy has proven ineffective [9–11].

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Stability of potassium iodate as an additive to salt

The research by L. L. Diosady, J. O. Alberti, M. G. Venkatesh Mannar, and S. FitzGerald published in this issue of the *Food and Nutrition Bulletin* [1] and the earlier paper on the same topic published in the *Bulletin* [2] merit comment. The investigators invested a great deal of effort in the technical aspects of the research, including the laboratory procedures and careful control of artificial environmental conditions. Nevertheless, the narrow scope of the experimental plan, which considers only two climatic conditions (40°C at 100% relative humidity and 40°C at 60% relative humidity) severely limits the usefulness and potential application of the research findings.

Extensive areas in many developing countries with less drastic conditions of environmental temperature and humidity are heavily populated by people suffering from iodine-deficiency disorders. It would have been a valuable additional effort not only to use samples of

salt from many countries, but also to include climatic conditions simulating medium and highland climates in countries such as Ecuador, Peru, Bolivia, Guatemala, Colombia, Nepal, and many others. It is my concern that this failure also to test stability under less extreme environmental conditions results in an unduly exaggerated view of the problem of iodate iodine instability. Readers not fully familiar with the variety of climatic situations in developing countries mentioned above may wrongly infer that most of the salts produced and consumed in developing countries are stored under the conditions of temperature and humidity tested in the study in question and therefore would require special low-density polyethylene bags. In actual practice worldwide, this special packaging requirement has not proved necessary in the many areas with milder climates.

As a historical footnote, it is appropriate to recall the original stability trial carried out in Guatemala in the 1950s [3]. Crude sea salt produced by solar evaporation was iodized in a plant at a production site by adding a premix containing one part of potassium iodate and nine parts of calcium carbonate. The amount added was adjusted to give a final product with approximately 1 mg of iodine per 10 g of salt. A 50-kg sample was then stored in a hemp fibre sack in an open room from January through August 1954 in the humid tropical lowlands. This period included four months of the dry season and four months of the rainy season, with an average humidity of 70% and 84%, respectively. The environmental temperature averaged around 25°C, ranging from 20° to 32°C.

The initial moisture content of the samples was 4.1%, and the final values in August, a rainy month, were 4.6% for the top layer, 4.9% for the middle, and 5.8% for the bottom of the sack. Only 3.5% of the iodine was lost during the eight months. No significant redistribution of the added iodate among the layers was observed. The authors concluded that their observations were of practical public health significance to those countries in which iodine deficiency is a problem, and iodization of salt by conventional methods is impractical for environmental reasons and protective packaging is economically or culturally unacceptable.

On the basis of these findings, the Institute of Nutrition of Central America and Panama (INCAP) successfully promoted the addition of potassium iodate to all salt for human consumption. In 45 years the prevalence of endemic goitre among children in Guatemala dropped from 38% to 5% [4]. The addition of potassium iodate has become the standard means of adding iodine to salt throughout the developing world and is widely promoted by the World Health Organization and UNICEF in their successful campaign to prevent iodine-deficiency disorders. No problems have been reported due to excessive loss of iodine, but a problem arose in Zimbabwe for the opposite reason. In determining the level of iodate to add to the salt, potential losses were severely overestimated. As a result, some subjects received too much iodine and experienced symptoms of thyrotoxicosis [5, 6]. It is unfortunate that the results of the above INCAP study and two other studies cited in the first of the two papers by Diosady et al. showing losses of 6% to 10% in 12 months were not taken into consideration [7, 8].

It should be very clear that with the ambient conditions prevailing in most countries, the loss of potassium iodate, even from crude moist salt without moisture-proof packaging, is so small that it has been no obstacle to the use of potassium iodate for salt fortification in developing countries worldwide.

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Plausible evidence of effectiveness of an iron-supplementation programme for pregnant and post-partum women in rural Bangladesh

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Abstract

Since 1978 iron and folic acid pills have been distributed, along with other family-planning and health services, to women in Matlab subdistrict, Bangladesh, through fortnightly visits of community health workers. In 1986 the iron dose was set at three pills daily (198 mg of iron) during pregnancy and two pills daily for 6 months post-partum. Haemoglobin concentrations were determined in a representative sample of 218 women who gave birth from June through August 1994 and who were followed prospectively from 0.5 to 9 months post-partum. At 0.5 months post-partum, 88% of women reported that they had taken iron pills on the previous day. The prevalence of anaemia declined from 36% at 0.5 months to 9% at 9 months post-partum, with an overall average prevalence of 23% in this period. To estimate the impact of the programme, these results were compared to anaemia results from representative samples of non-pregnant women in Matlab in 1975 and 1976 and in three other rural communities in Bangladesh in 1996. The estimated reduction in the prevalence of anaemia resulting from the programme ranged from 48% to 70%, and the estimated increase in haemoglobin concentration ranged from 0.9 to 2.1 g/dl. This evidence suggests that the Matlab programme has been highly effective in controlling anaemia.

Introduction

Iron-deficiency anaemia is the most prevalent form of malnutrition, affecting around 50% of pregnant women worldwide [1]. Iron supplements are inexpensive, widely available, and efficacious, and iron-supplementation programmes have been carried out in many places throughout the world over the last two decades. Still, the prevalence of iron-deficiency anaemia does not appear to be declining [2, 3]. Although most large-scale programmes have not been evaluated, several evaluations have found programmes to be ineffective [4], with no significant decrease in the prevalence of anaemia in the population. To our knowledge, there have been no published reports providing evidence of the effectiveness of a sustained, large-scale iron-supplementation programme.

Although iron-deficiency anaemia is prevalent in many parts of the world, the burden of anaemia in women is highest in South Asia, including Pakistan, India, Nepal, and Bangladesh. Worldwide there are around 420 million anaemic women, of whom 335 million (80%) live in Asia and 160 million (38%) live in South Asia [1]. Clearly, to make substantial progress against the global burden of anaemia in women, effective programmes are needed in South Asia.

We present evidence suggesting that a community-based health-care programme that delivers iron supplements to women during pregnancy and the post-partum period in rural Bangladesh has been highly effective in reducing anaemia in women. Haemoglobin and supplemental iron consumption data were collected as part of a study of vitamin A supplementation and breastfeeding. This provided an opportunity to estimate the impact of an iron-supplementation programme that has been operating for two decades without any evaluation. Because these data were not collected with the intent of evaluating the iron-supplementation programme, the need for additional evaluation data from this programme is highlighted. The elements of the programme that might be keys to its success are discussed.

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Methods

Description of the Matlab iron-supplementation programme

This iron-supplementation programme is part of the community-based Maternal Child Health Family Planning Project (MCH-FP) of the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B). Since 1966 ICDDR,B has operated a demographic surveillance system in Matlab thana (subdistrict). The surveillance system provides continuous recording of all births, deaths, migrations, and changes in marital status in a population of 210,000. In 1977 the MCH-FP programme was implemented in half of the surveillance area. In the other half, the health services were provided by the regular government programme. The focus of the MCH-FP programme was initially family planning, but in 1986 it was expanded to include interventions more clearly directed at maternal and child health.

Matlab thana is located 45 km south-east of Dhaka, in a wet and fertile delta area that is interlaced with small rivers and irrigation canals. Rice, jute, and fish are the main agricultural products. The majority of the population are Muslim, but a significant minority (12%) are Hindu. Even though current governmental policies have improved female literacy, most women are functionally illiterate, and about half of adult women have never attended school.

The health services provided by ICDDR,B consist of a central clinic and four subcentre clinics that provide basic medical care. Through the MCH-FP programme, there has also been a system of community health workers who provide primary health-care and basic family-planning services at the household level. All households with a married woman of child-bearing age are visited fortnightly by one of 80 community health workers. These women provide family-planning services, immunizations, breastfeeding promotion, oral rehydration salts for diarrhoea, vitamin A capsules for children under five years of age, and prenatal care, including iron supplements and safe delivery kits, and they are trained to screen people for a variety of health conditions and refer them to health-care facilities. As part of the demographic surveillance system, these health workers also ascertain reproductive status and vital events at each visit.

The community health workers are educated young housewives recruited from the community where they are assigned to work. They are paid staff of the ICDDR,B. After recruitment they are given one month of training, followed by supervisory meetings every two weeks. These meetings focus on the problems the community health workers face daily. An experienced group of paramedical staff conduct training, supervise the work, and provide necessary backup to the community health workers.

The provision of iron supplements to pregnant women by community health workers began in 1978 and has been ongoing ever since with no formal evaluation [5]. The iron tablets are brown-coloured and contain 200 mg of ferrous fumarate (66 mg elemental iron) and 200 g of folic acid. The tablets are procured from local sources at a cost of US$5 per thousand tablets. Beginning in 1978, women were instructed to take one tablet daily from the time a pregnancy was detected by the health worker until six months post-partum. In 1986 the dose was increased to three tablets daily during pregnancy and two tablets daily post-partum. When a pregnancy is detected, the health worker gives the woman a one-month supply of tablets. At subsequent visits, the health worker reviews that the woman is taking the tablets correctly, but reported compliance or occurrence of side effects is not recorded. Initially, acceptance of the tablets was low, and women were suspicious of taking them and complained of side effects. Over time, the tablets gained popularity. The most commonly reported side effects are black stool, nausea, and constipation.

Data collection

Matlab 1994–95 data

Recent maternal haemoglobin data (hereafter called Matlab 1994–95) were collected as part of a randomized trial of vitamin A supplementation and β-carotene supplementation to women in the Matlab MCH-FP intervention area, the RETIBETA study. The details of the main study have been reported elsewhere [6], but the salient points are also described here. We attempted to enroll in the study all women who delivered infants in the MCH-FP area between June 14 and August 29, 1994, and who could be assessed with their live infants at two weeks post-partum. The age distribution, education, and religion of the 218 women enrolled in the study were very similar to those of all women in the MCH-FP area who delivered infants around that time.

Beginning at two weeks post-partum, women in the study were randomly allocated to receive one of three interventions until nine months post-partum: one 200,000 IU vitamin A capsule, followed by daily placebo capsules; daily 7.5 mg β-carotene capsules; or daily placebo capsules. At 0.5, 3, 6, and 9 months post-partum, a random 50% subsample of the enrolled women was brought to the hospital for a health assessment; 93% of enrolled women completed the nine months of follow-up. Haemoglobin concentration was determined from a venous sample of blood using the HemoCue system (Angelholm, Sweden). A control cuvette was checked daily, and no problems were encountered with the instrument. The women's vitamin A status was also assessed at these times. Vitamin A status improved with vitamin A supplementation, but haemoglobin concentrations and anaemia prevalence rates did not differ

between treatment groups, and there was no evidence of any interactions among either form of vitamin A supplementation, iron supplementation, and haemoglobin concentration (data not shown). Therefore, the three treatment groups are combined in these analyses.

The women's reported consumption of iron tablets was ascertained during a dietary interview that included questions on intakes of all types of supplements. Neither the interviewers nor the mothers were aware of any special interest in the iron-supplementation programme. The interviewers were independent of the community health workers who distributed the tablets. Before starting the 24-hour recall in the dietary interview, the women were asked, "Other than the RETIBETA capsule, did you take any vitamin capsule, pill, or liquid yesterday?" Women who responded yes were then asked, "What kind of capsule, pill, or liquid did you take?" MCH-FP iron-folate tablets were recorded as one possible response to this question. Women were not prompted to recall any specific type of vitamin preparation.

All women gave their informed consent to participate in the study, which was reviewed and approved by the Committee on Human Research of Johns Hopkins University and the Ethical Review Committee of ICDDR,B.

Comparison data

To estimate the impact of the iron-supplementation programme on haemoglobin concentrations of the Matlab study sample, non-intervention data were needed for comparison. Two types of comparison data are presented. A survey of haematocrit values of non-pregnant women in Matlab was used as a historical comparison (hereafter called Matlab 1975–76 data). These data were collected in 1975–76 from a representative sample of 2,445 married women below the age of 50 years [7]. These data allow a pre-post-intervention estimate of programme impact, as the iron-supplementation programme did not begin until 1978.

The second type of comparison data consists of other contemporary data from Bangladesh. These data are from a haemoglobin survey conducted by the International Food Policy Research Institute in 1996 in three rural areas of Bangladesh apart from Matlab (hereafter called IFPRI 1996). In these surveys, haemoglobin concentrations of all women in survey households were determined in a representative sample of households, using the HemoCue method and capillary blood samples. The Manikganj site (Saturia thana) is 90 minutes by car from Dhaka, off the main road running west from Dhaka to Jessore. It is a vegetable-growing region, with intensive agriculture for the markets of Manikganj and Dhaka. The Mymensingh study area (Pakundia, Kishoreganj, and Gaffargaon thanas) is a traditional rice-growing area two hours north of Dhaka. The Jessore site is eight hours south-west of Dhaka, near the Indian border. The economy consists of subsistence agriculture and an active labour market based on fruit trees, date juice, rickshaw pulling, and embroidery. In all three study sites, there is no regular programme to provide iron supplements to pregnant women. However, iron tablets have replaced the "placebo" pills in monthly cycles of oral contraceptives used by 20% of women in these survey areas. Out of 28 pills per packet, 7 pills contain 75 mg of iron as ferrous fumarate. Therefore, this comparison population does not represent a non-intervened population, but one in which iron supplementation reaches many fewer women overall and none during pregnancy, is intermittent (seven days per month), and is of lower dose than the Matlab programme. The efficacy of this one week per month supplementation strategy has not been measured; however, iron supplementation one day per week improved iron status in non-pregnant women in Indonesia [8] and the United States [9].

Data analysis

To compare the Matlab 1994–95 data with those from other studies, we needed a summary figure of haemoglobin concentration in the study sample over the post-partum study period. Because the majority of women contributed two haemoglobin measurements, we took the average of all available haemoglobin measurements for each woman and used this value to obtain overall mean haemoglobin concentration and anaemia prevalence. The two haemoglobin measurements for each woman were taken at random intervals post-partum. Thus this overall average value represents a theoretical midpoint of the period from 0.5 to 9 months post-partum.

The Matlab 1975–76 data consisted of haematocrit rather than haemoglobin values. So that these data could be directly compared with the contemporary haemoglobin data, mean and SD haematocrit values were converted to estimated haemoglobin values using a factor of 0.33 [1]. The criterion for anaemia in non-pregnant women is 12 g/dl haemoglobin or 36% haematocrit [10]. The prevalence of anaemia according to this cut-off was not reported by Huffman et al. [7]. We derived an estimated prevalence of haematocrit values less than 36%, based on the reported mean and SD, assuming a normal distribution of values.

The IFPRI 1996 survey included all women in survey households. Two samples were constructed, designed to be comparable to the Matlab 1975–76 and Matlab 1994–95 samples, respectively. The first sample included all married women below 50 years of age, the sample definition in the Matlab 1975–76 study. For this sample definition, haemoglobin and anaemia values are reported separately for each of the three survey communities, to reveal the variability in anaemia between communities. The second sample included all women who re-

ported having given birth within the past nine months. This sample definition approximates the Matlab 1994–95 sample. For this sample, haemoglobin and anaemia values are reported for all three communities combined, as the total number of women meeting this definition was only 62.

To make comparisons between study samples, we calculated 95% confidence intervals around the mean haemoglobin values and the prevalences of anaemia [11]. The programme impact was estimated as the percent reduction in anaemia prevalence in the Matlab 1994–95 sample as compared with either the historical (Matlab 1975–76) or contemporary (IFPRI 1996) samples.

Results

Matlab 1994–95 sample

At all times during the post-partum period, the average haemoglobin concentration was above 12 g/dl (table 1). The haemoglobin concentration improved dramatically from the first six months to the ninth month post-partum, reaching a high of greater than 14 g/dl. The prevalence of moderate anaemia, defined as haemoglobin concentration less than 10 g/dl, was 4.7% in the first month post-partum but declined to nil by nine months post-partum. The percentage of women who reported that they consumed iron tablets was 88% immediately post-partum but declined markedly after six months post-partum, the time at which the community health workers were scheduled to stop distributing the tablets.

Comparability of population samples

A potential flaw in the use of historical control data that span a 20-year interval is the effect of secular trends. In particular, the family-planning programme and other health interventions that have been carried out in Matlab might have led to an improvement in women's nutritional status that is independent of the iron-supplementation programme. However, the differences in heights and weights of women in the Matlab 1994–95 and 1975–76 samples were small (table 2). Although the women in the 1994–95 sample were on the average 1.6 cm taller, the weights of the women in the two samples were nearly identical (0.5 kg difference).

A noteworthy difference between the samples is the age of the women, with the 1975–76 sample including a much greater proportion of women over the age of 30. This difference is explained by the fact that the 1975–76 sample was a representative sample of all non-pregnant women of reproductive age, whereas the 1994–95 sample was a representative sample of all women who had recently delivered an infant. The probability of delivering an infant is higher in women 20 to 30 years old than in older women.

The heights and weights of the women in the IFPRI 1996 sample of women of reproductive age were slightly greater than those of the women in the Matlab 1994–95 sample. The IFPRI 1996 post-partum subsample was similar to the Matlab 1994–95 sample in weight (0.7 kg heavier), height (1.5 cm taller), and percentage of women above 30 years of age (4% difference).

Estimates of programme impact

The average haemoglobin values for women in the Matlab 1994–95 data yielded a population prevalence of 23% for anaemia, whereas the prevalence of anaemia in the Matlab 1975–76 sample was 60% (table 3). In the IFPRI 1996 samples, the prevalence of anaemia was 44% to 59% in non-pregnant married women, and 76% in women in the first nine months post-partum. The estimated impact of the Matlab programme in 1994–95 was a 62% reduction in the prevalence of anaemia, as compared with the historical Matlab data. The estimated impact was a 48% to 61% reduction in the preva-

TABLE 1. Haemoglobin concentration, prevalence of anaemia, and self-reported consumption of iron tablets in Matlab, 1994–95, according to time post-partum

Time post-partum (mo)	N^a	% Prevalence of iron tablet consumption	Hb[b] concentration (g/dl)	% Prevalence of anaemia	
				Hb <12.0 g/dl	Hb <10.0 g/dl
0.5	106	87.7	12.5 ± 1.8[c]	35.8	4.7
3	105	75.2	12.4 ± 1.4	42.9	3.8
6	104	22.1	12.7 ± 1.3	30.8	1.0
9	98	14.3	14.1 ± 1.4	9.2	0

a. Haemoglobin concentration was measured in 218 women; for most women measurements were made at two different times post-partum.
b. Hb, Haemoglobin.
c. Plus-minus values are means ± SD.

TABLE 2. Anthropometric and age characteristics of population samples

Study	*N*	Mean weight—kg (95% CI)	Mean height—cm (95% CI)	Age > 30 yr—%
Matlab 1994–95	218	40.9 (40.3 to 41.5)	149.5 (148.8 to 150.2)	23
Matlab 1975–76[a]	2,445	40.4 (40.2 to 40.6)	147.9 (147.7 to 148.1)	59
IFPRI 1996 (non-pregnant married women <50 yr)				
Manikganj	278	41.6 (40.8 to 42.3)	149.9 (149.2 to 150.5)	58
Mymensingh	234	41.5 (40.6 to 42.4)	149.7 (149.0 to 150.3)	59
Jessore	277	42.8 (42.0 to 43.5)	150.3 (149.6 to 150.9)	55
IFPRI 1996 (women <9 mo post-partum)				
All communities	62	41.6 (40.4 to 42.8)	151.0 (149.7 to 152.2)	27

Abbreviations: CI, confidence interval; IFPRI, International Food Policy Research Institute.
a. From Huffman et al. [7].

lence of anaemia as compared with contemporary non-pregnant women of reproductive age, and a 70% reduction as compared with contemporary women in the first nine months post-partum. The programme impact on average haemoglobin concentration was an increase of 0.9 to 2.1 g/dl.

Discussion

We have documented a low prevalence of anaemia in women in Matlab during the post-partum period, accompanied by a high self-reported consumption of iron supplements. Both figures are remarkable, given the consistent reports in the literature of prevalent and severe anaemia in South Asian women [1, 3] and the poor coverage of iron supplementation documented in other programmes [4]. The obvious question is, "Can the low rates of anaemia in this population be attributed to the iron-supplementation programme?" Because an evaluation was not designed into the programme, we constructed comparison data from existing anaemia surveys and tried to assess the extent and direction of bias that is inherent in non-randomly allocated comparison groups. We draw the following conclusions from these analyses:

» The current prevalence of anaemia is substantially lower in Matlab today than it was before iron supple-

TABLE 3. Haemoglobin concentration and prevalence of anaemia in non-pregnant women in Matlab 1994–95, Matlab 1975–76, and IFPRI 1996 surveys

Study	*N*	Hb—g/dl (95% CI)	% Prevalence of anaemia[a] (95% CI)	% Impact of Matlab programme on anaemia[b]
Matlab 1994–95[c]	218	12.9 (12.7 to 13.1)	23 (21 to 25)	
Matlab 1975–76[d]	2,445	11.7 (11.7 to 11.8)	60 (58 to 62)	–62
IFPRI 1996 (non-pregnant married women <50 yr)[e]				
Manikganj	278	12.0 (11.8 to 12.1)	47 (41 to 53)	–51
Mymensingh	234	11.3 (11.1 to 11.5)	59 (52 to 65)	–61
Jessore	277	11.9 (11.8 to 12.1)	44 (38 to 50)	–48
IFPRI 1996 (women <9 mo post-partum)				
All communities	62	10.8 (10.4 to 11.2)	76 (63 to 85)	–70

Abbreviations: CI, confidence interval; Hb, haemoglobin; IFPRI, International Food Policy Research Institute.
a. Defined as Hb<12.0 g/dl.
b. Defined as the ratio of the prevalence of anaemia in Matlab 1994–95 to the prevalence in the comparison sample, subtracted from 100%.
c. Calculated from the average of the haemoglobin values available for each woman, usually two values.
d. Estimated from haematocrit values of Huffman et al. [7]. No iron supplements were provided in the study area.
e. Twenty percent of women reported taking oral contraceptive pills in which 7 of the 28 pills contained 75 mg of iron per pill.

mentation began, and it is substantially lower than in similar samples of women in three other rural Bangladeshi communities today.
» Women in the comparison samples consumed no supplemental iron, or much less supplemental iron than contemporary women in Matlab were reported to consume.
» The difference in the prevalence of anaemia between the samples is not attributable to differences in age or in general nutritional status of the women, as reflected by their weights and heights.
» The most plausible explanation at hand is that the low rates of anaemia in Matlab are related to the high consumption of supplemental iron provided by the MCH-FP programme. However, this inference is ad hoc and merits a more rigorous investigation.

Our best estimates of programme impact from these data are a 62% reduction in anaemia based on historical Matlab data and a 70% reduction based on a contemporary sample of women at a similar stage post-partum. To our knowledge, this is the first evidence in the published literature of substantial impact from a long-standing health-care programme that delivers iron supplements to pregnant and post-partum women.

What are the major threats to the validity of these conclusions? To begin with, we have identified two possible sources of bias in the comparisons between these data sets. First are the assumptions we made in estimating the prevalence of anaemia from the Matlab 1975–76 data. We used a conversion factor of 0.33 between haematocrit and haemoglobin. This factor depends on the mean cell haemoglobin concentration [12], which will vary among individuals in any study sample. On a population basis, anaemia prevalence rates based on haematocrit tend to be lower than those based on haemoglobin when "equivalent" cut-offs for the two indicators are based on this factor [13]. This bias would cause us to underestimate programme impact. We also assumed a normal distribution of haematocrit values. Examination of numerous haemoglobin distributions from a variety of iron-deficient populations shows that in general the assumption of normality is a reasonable one [14]. When distributions are not normal, they are skewed to low values. If the Matlab 1975–76 data were skewed to low values, this also would bias downward our estimate of the prevalence of anaemia and cause us to underestimate the programme impact.

Second, the Matlab 1994–95 sample consisted of women in the post-partum period, whereas the Matlab 1975–76 sample consisted of all non-pregnant married women below the age of 50 years. Because of these different sampling strategies, the women in the Matlab 1994–95 sample were younger and earlier in the post-partum period than those in the historical comparison sample. The effect of these biases on comparison of the two Matlab samples is illustrated in the comparison of the two IFPRI 1996 samples (table 2). Women in the post-partum period had significantly lower haemoglobin values than all women of reproductive age, even though they were younger. This is almost certainly because women shortly post-partum are still recovering from the substantial iron costs of pregnancy. In summary, these biases would tend to lead us to underestimate programme impact. No bias that we have identified could spuriously create the greater than 50% reduction in the prevalence of anaemia that we observed.

The preceding discussion relates to biases we can identify in the variables we measured. However, the most important threat to validity lies in differences in the samples that we did not measure and therefore cannot account for. Unmeasured differences between the historical and contemporary Matlab samples might include general socio-economic improvements, such as greater mobility of women, changes in infectious disease patterns, and changes in reproductive patterns, with contemporary women having fewer babies and starting at a later age. Despite economic development, however, there is no evidence that dietary intake has improved over the last three decades in rural Bangladesh. Food-intake data collected by the government of Bangladesh show a decline in food availability per capita, which they attribute to the fact that the rate of population growth is outpacing the rate of increase in food production [15]. This may explain the lack of improvement in women's weights between the Matlab 1975–76 and Matlab 1994–95 samples. Unmeasured differences between the contemporary IFPRI and Matlab samples might include differences in reproductive patterns and safe motherhood practices that could have reduced blood loss at delivery in Matlab. We cannot rule out the influences of these variables, and a more rigorous evaluation should account for them.

Evidence of programme impact would be stronger if it could be demonstrated that the haemoglobin concentrations of women who consumed many pills were higher than those of women who consumed few or no pills. Iron-supplementation trials of pregnant women have shown clearly that the impact on haemoglobin is directly related to the duration of supplementation [16]. According to our 24-hour-recall information, women who reported consuming a pill on the previous day at three, six, and nine months post-partum had anaemia rates 25% to 50% lower than women who did not report consumption, but these differences were not statistically significant. The strength of this evidence is limited by our small sample size. Furthermore, we assessed consumption on only four days in the post-partum period (i.e., the day before each clinic visit), although women received supplements throughout most of pregnancy and up to six months post-partum. Prospective information on pill consumption in larger samples of women should be ascertained in future evaluations of this programme.

The low prevalence of anaemia in Matlab at nine

months post-partum (9.2% with haemoglobin levels below 12.0 g/dl, and none with levels below 10.0 g/dl) is particularly noteworthy in a rural South Asian population. The substantial improvement in haemoglobin concentrations of Matlab women during the post-partum period probably reflects the effect of continued iron supplementation during a period that is physiologically favourable to iron status. This is because iron contained in the additional red cell mass needed during pregnancy is made available, and iron requirements are relatively low because menses are suppressed during full lactation and the iron content of breastmilk is low [17]. Furthermore, women have low iron stores following pregnancy, and this facilitates the absorption of iron. Thus women tend to be in positive iron balance (i.e., a state of improving iron status) during the post-partum period, especially when consuming supplements.

Some characteristics of the MCH-FP iron-supplementation programme that might account for its apparent success are generalizable lessons. A review of six large-scale iron-supplementation programmes carried out in 1991 identified several major constraints to programme success. These included "low accessibility and utilization of antenatal care, inefficient supply and distribution of supplement…inadequate training and motivation of first line health workers, insufficient and inappropriate counselling of mothers, and failure of effective screening and referral procedures" [4]. It was revealing that the major constraints highlighted in the review had much more to do with the health-care system and health-care providers than with non-compliant behaviour by the recipients. The system of community health workers in Matlab overcomes these constraints. In the context of this well-functioning distribution system, the compliance with and effectiveness of daily iron supplementation with 198 mg of iron as ferrous fumarate appear to be very high. Nevertheless, even if compliance can be achieved at higher doses of iron, we should not give women three iron pills daily if less iron would be equally effective, since reducing the dose would reduce side effects and increase efficiency by reducing costs and logistical difficulties.

Some aspects of the MCH-FP programme are unique. The health-care system in Matlab coordinates with governmental services, but the system of community health workers is sustained with a high level of donor support and with the supervision of an international research centre. The Matlab programme represents one example of an effective iron-supplementation programme. It remains to be demonstrated under what conditions governmental or non-governmental programmes can achieve similar success.

Several questions are unanswered by this evaluation and should be addressed in a further investigation. How many pills do women in Matlab typically consume during pregnancy and the post-partum period? Do women who take fewer pills have lower haemoglobin concentrations? What is the prevalence of anaemia in a representative sample of non-pregnant women and in pregnant women? What benefits do women and community health workers perceive from the iron-supplementation programme?

In 1986, when the Matlab regimen was revised to three pills daily, the iron dose given in the Matlab programme exceeded the international recommendation, which was 120 mg of iron daily during pregnancy, when anaemia is prevalent [18]. The dose given in Matlab is more than triple the current recommendation of 60 mg [10, 19]. This provides a unique opportunity to evaluate the new recommendation in a programmatic context. Could the observed low rates of mild anaemia be sustained if the dose of iron were reduced to around 60 mg (one pill) daily?

As compared with other forms of micronutrient malnutrition, global progress against iron-deficiency anaemia has been slow, if not invisible. This has led to numerous discussions of what we are doing wrong and what innovations can spur progress [4, 20–22]. To substantially reduce anaemia of pregnancy on a global scale, it is likely that prenatal iron supplementation must be combined with interventions that improve women's iron stores before pregnancy [9]. Nonetheless, the high coverage and apparent effectiveness of the Matlab pre- and post-natal iron-supplementation programme sound a timely note of optimism and a reminder to strive to implement better what we know *can* work, while also striving to discover new and complementary approaches.

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High prevalence of anaemia among women in Mumbai, India

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Abstract

*Iron-deficiency anaemia is highly prevalent among women of reproductive age in South-East Asia. In this study, the haemoglobin levels of 2,813 women living in inner-city Mumbai, India, were measured as part of a reproductive health study. Women were recruited over a two-year period at three health facilities providing pregnancy and post-partum services. Five reproductive groups were studied, and the haemoglobin values differed significantly among the groups. Infertile women and women without living children had the highest haemoglobin values (*p *<.01). However, a least-squares regression analysis of factors affecting haemoglobin status accounted for only 16% of the variability observed. The study concludes that nutritional interventions that focus on reducing fertility or iron supplementation during pregnancy are beneficial, but many women remain iron deficient. Action is needed to improve nutritional status before pregnancy—a policy that is feasible given the current interest in adolescent sexual and reproductive health programmes.*

Introduction

Iron-deficiency anaemia is the most common form of malnutrition in the world and is the eighth leading cause of disease in girls and women in developing countries [1]. Its estimated prevalence in South-East Asia is 50% to 70% [2, 3]. Whereas severe anaemia is closely related to risk of mortality, even mild anaemia carries health risks and reduces the capacity to work [4]. Supplementation of pregnant women remains the cornerstone policy for reducing anaemia among women of reproductive age, because the demands of child-bearing, high fertility rates, and breastfeeding are associated with undernutrition and maternal depletion [5, 6]. Little progress has been made in reducing iron-deficiency anaemia among women in developing countries, in spite of the introduction of iron-supplementation programmes in many of them. In Indonesia, for example, iron supplementation for pregnant women was started some 10 years ago, but the prevalence of anaemia among pregnant women still remains at 63.5% [7].

As part of a study to determine the prevalence of reproductive tract infections and gynaecological morbidity among young women living in inner wards of the city of Mumbai, India, haemoglobin measurements were collected from a large sample of pregnant and non-pregnant women attending health-care centres [8]. In Mumbai a large majority of pregnant women attend centres for antenatal care, and iron and folic acid tablets are provided for daily prophylaxis against nutritional anaemia as an integral part of maternal and child health activities in the Indian Family Welfare Programme [9]. It is recommended that women take 100 tablets of iron and folic acid during pregnancy, and health workers are instructed accordingly. Many of the women were attending for tubal ligations, and we hypothesized that the prevalence of anaemia might be lower among women who were limiting their family size.

Methods

Study population

A cross-sectional survey was conducted in Mumbai between October 1993 and December 1995 under the auspices of the Brihan Mumbai Municipal Corporation and with ethical approval from Lokmanya Tilak

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Teaching Hospital, where all laboratory investigations were undertaken. Since 1988 the Brihan Mumbai Municipal Corporation has extended family health services to all slum areas through the creation of Health Posts and Post-Partum Centres offering health education, preventive services, simple curative care, and family planning. Services are available free at municipal clinics and hospitals. Women aged 35 years or less attending these health facilities were recruited at three inner-city centres that served large slum areas of Mumbai. Women were classified into five groups on the basis of their reasons for inclusion in this study: women being investigated for infertility; women admitted with suspected pelvic inflammatory disease; fertile, non-pregnant women seeking tubal sterilization who had no symptoms of gynaecological disease; pregnant women seeking tubal ligation after early termination of pregnancy; and post-partum women seeking tubal ligation following delivery.

Investigations

Routine haematological tests (erythrocyte sedimentation rate, white blood cell count, and haemoglobin) were performed before laparoscopy or treatment at each clinical centre. Haemoglobin was estimated by the cyanmethaemoglobin method [10]. Anaemia was classified as a haemoglobin concentration less than 12 g/dl for non-pregnant women and less than 11 g/dl for pregnant women [11].

Data analysis

Univariate analysis was undertaken to detect differences in mean haemoglobin using analysis of variance or the Kruskall-Wallis test. The variable "number of years since first pregnancy" was used as an indicator of number of years of exposure to pregnancy. Other variables were age of menarche and socio-economic indicators. Multivariate analysis was performed using ordinary least-squares regression to assess which factors were independently associated with haemoglobin status. All analyses were performed with STATA version 4.1 software [12].

Results

The distribution of haemoglobin values for the five groups of women is shown in figure 1. A total of 2,813 women were studied; 287 were infertile, and 144 were suspected of having pelvic inflammatory disease. Among the remaining women, 588 were not currently pregnant, 908 were in the first trimester of pregnancy, and 886 were requesting sterilization in the post-partum period. There was significant variation among the five groups (p <.001). Whereas most women with a gynaecological problem (infertility or suspected pelvic inflammatory disease) had haemoglobin values of at least 10 g/dl, women who were in early pregnancy or not currently pregnant were more likely to have values less than 10 g/dl (p < .01). About half of post-partum women had values falling between 10.0 and 10.9 g/dl. The mean haemoglobin values (± SD) for the five groups were 11.4 ± 1.2 g/dl for women with infertility, 10.7 ± 1.3 g/dl for those with suspected pelvic inflammatory disease, 10.1 ± 1.5 g/dl for those not currently pregnant, 9.7 ± 1.3 g/dl for those in early pregnancy, and 10.4 ± 0.9 g/dl for post-partum women. Severe anaemia (<8.0 g/dl) was not observed.

A univariate analysis of factors likely to confound comparison of mean haemoglobin levels between groups was done. The results are shown in table 1. Of sociodemographic factors, only younger age and having at least 10 years of education were associated with higher mean haemoglobin values. For all the socio-economic categories, differences between the values were small. For the reproductive factors, all showed significant variance between the mean values. The mean age of menarche was 13.0 ± 1.1 years. The mean haemoglobin values were significantly higher for the 14.4% of women who had an early menarche (at 10–12 years of age) and the 11.8% who had a late menarche (at 15 years or more of age). All other significant differences reflected the gap between the high mean haemoglobin values of women who had never been pregnant or had a live birth, and fertile women.

Table 2 shows which reproductive factors remained independently associated with haemoglobin levels after regression analysis. Socio-economic variables are not shown, as only having at least 10 years of education remained significant. The mean haemoglobin concentrations for women in different reproductive categories were significantly different after adjustment for sociodemographic factors. Those who were pregnant or who had a surviving child were significantly more likely to have lower mean haemoglobin levels. The values for women with younger and older ages of menarche also remained significant. However, the regression model accounted for only 16% of the variability in observed haemoglobin status.

Discussion

This study showed a high prevalence of moderately severe anaemia (<10 g/dl haemoglobin) among young women of reproductive age attending health facilities. Haemoglobin values were measured routinely in each clinic and were not independently validated, so some range of error may be expected. The distribution of values shown in figure 1 is, nonetheless, what would be expected, with the lowest values in pregnant women. The values were highest among women with suspected

TABLE 1. Univariate analysis of possible factors confounding haemoglobin status

Variable	N^a	Mean haemoglobin (g/dl)	SD	*p*
Sociodemographic				
Age (yr)				
<25	577	10.5	1.3	<.01
25–29	1,282	10.2	1.3	
≥30	954	10.1	1.3	
Years of education				
<3	1,152	10.3	1.3	<.01
4–9	1,184	10.2	1.4	
≥10	475	10.4	1.4	
Religion				
Hindu	2,076	10.3	1.3	.11
Muslim	342	10.3	1.3	
Other	394	10.1	1.3	
Place of birth				
Bombay	1,139	10.2	1.3	.11
Other	1,669	10.3	1.3	
No. of household members				
≤6	1,983	10.2	1.3	.83
>6	830	10.2	1.3	
Monthly household income (rupees)				
<1,000	592	10.3	1.3	.16
1,000–3,000	1,648	10.2	1.3	
>3,000	573	10.3	1.4	
Reproductive				
Age at menarche (yr)				
10–12	399	10.5	1.2	<.01
13–14	2,051	10.1	1.3	
≥15	329	10.7	1.2	
No. of pregnancies				
0	236	11.3	1.2	<.01
1	84	11.1	1.4	
2	823	10.0	1.4	
3	1,097	10.2	1.2	
4	408	10.2	1.3	
≥5	165	10.1	1.2	
Years since first pregnancy				
0	236	11.3	1.2	<.01
<7	1,043	10.2	1.3	
≥7	1,513	10.1	1.3	
Pregnancy outcome				
Live births only	1,959	10.1	1.3	<.01
No live births	41	11.4	1.4	
Varied outcome (live births and/or abortions or stillbirths)	577	10.3	1.3	

a. Numbers vary because data for some women are missing.

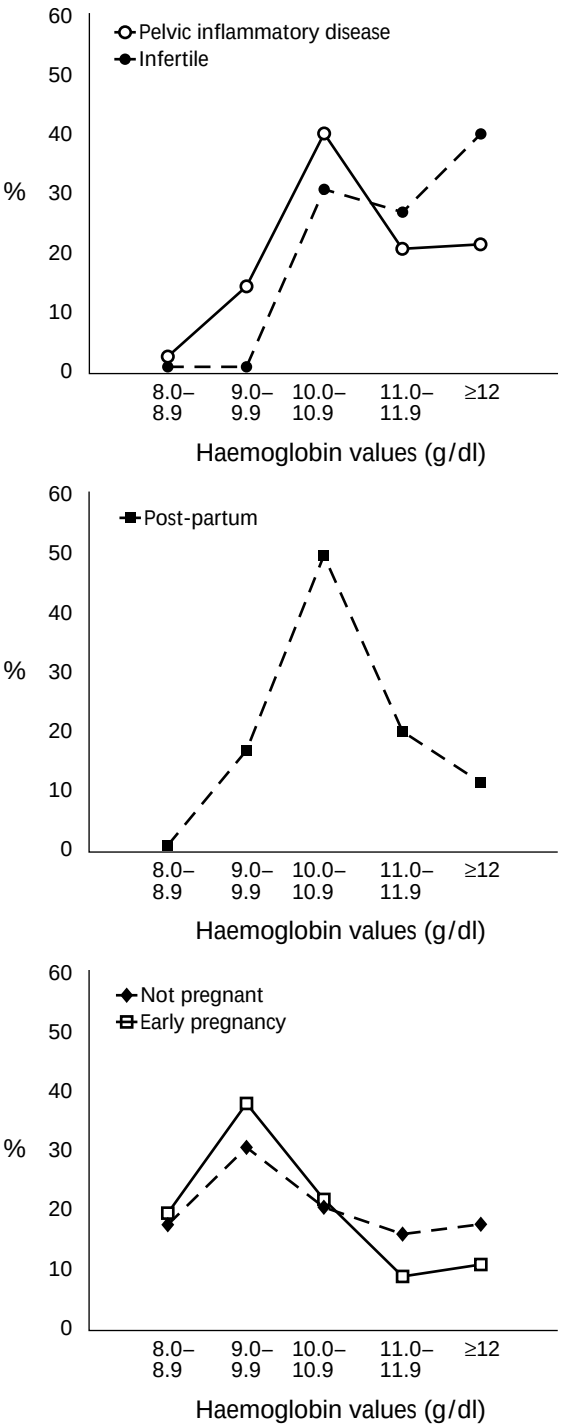

FIG. 1. Distribution of haemoglobin values for women in five groups defined by reproductive status

pelvic inflammatory disease who had impaired fertility, probably as a result of this disease [13]. The proportion of both pregnant and non-pregnant women with moderate anaemia was higher than that recently reported from studies in five other countries [14]. A study in Indonesia reported a 27.9% prevalence of anaemia (<12.0 g/dl haemoglobin) among non-pregnant working women, 21.1% among adolescent girls, and 52.3% (<11.0 g/dl haemoglobin) among pregnant women [15]. In the present study, 82.2% of non-pregnant women and 79.6% of pregnant women fell below recommended values (fig. 1), which represents a staggering level of anaemia.

That women without children had higher haemoglobin values than women with living children (table 2) supports the view that childbirth, lactation, and childbearing tax a woman's nutritional condition. However, the magnitude of the effects of child-bearing on haematological status in this population was limited. The regression analysis showed a difference of -0.1 g/dl from the mean baseline haemoglobin value for each live birth, which is small. The explanation for this is probably the low mean number of children born to currently married women in Maharashtra State: 2.95, with a mean of 2.62 children still living [9]. In our study population, women had a mean of three pregnancies over an average reproductive span of 10 years [8]. The short reproductive span is a result of tubal sterilization at an early age (mean, 28 years). Thus, increased child survival, reduced fertility, and short-term measures such as iron supplementation during pregnancy are likely to have mitigated some of the effects of childbearing on anaemia, and may account for the absence of severe anaemia (<8 g/dl haemoglobin).

The results of this study suggest that in India, interventions that focus on reducing fertility or on iron supplementation during pregnancy will have beneficial nutritional effects but will still leave most women iron deficient. In Mumbai the women studied were largely from poor backgrounds and probably had inadequate diets. However, the problem of undernutrition generally started much earlier in life, with gender discrimination resulting in undernutrition of girls [16–18], which was exacerbated by menstrual iron losses after menarche [19]. The higher haemoglobin values in women who had had either early or late menarche is not surprising, since early menarche is associated with better nutrition and late menarche is associated with fewer years of monthly blood loss. Health promotion to improve the diet of girls and iron supplementation in adolescence are required to redress nutritional deficits and, in the longer term, to reduce anaemia in older women of reproductive age.

Although this policy has been recommended by several authors [4, 15], it has rarely been implemented, probably because adolescents are less easy to reach than

TABLE 2. Least-squares regression analysis of reproductive factors affecting haemoglobin status

Variable	Difference in mean Hb from baseline value	SE	95% CI for mean difference	*p*
Baseline group	10.2	0.2		
Study groups				
Infertility	1.2	0.11	0.98 to 1.43	<.01
Suspected PID	0.5	0.12	0.31 to 0.77	<.01
Early pregnancy	– 0.3	0.06	– 0.44 to 0.19	<.01
Post-partum	0.4	0.07	0.28 to 0.54	<.01
Pregnancy outcomes[a]				
Abortions[b]	0.2	0.04	0.08 to 0.25	<.01
Stillbirths	0.1	0.12	– 0.15 to 0.33	.44
Post-natal deaths	0.1	0.05	– 0.03 to 0.18	.17
Livebirths (children surviving)	– 0.1	0.03	– 0.13 to 0.00	.05
Age at menarche in baseline group (yr)				
≥15	0.5	0.07	0.35 to 0.62	<.01
10–12	0.2	0.07	0.04 to 0.30	.01

Abbreviations: Hb, haemoglobin; CI, confidence interval; PID, pelvic inflammatory disease.

a. Mean haemoglobin concentrations were calculated on the basis of women's histories for any of the listed pregnancy outcomes.

b. Includes women with a history of spontaneous abortion or medical terminations.

pregnant women. This situation is changing, however, because adolescent reproductive health is now an important item on international agendas [20], and governments are starting to draw up national policy guidelines to improve adolescent sexual and reproductive health. Nutritional information and supplementation should be included in these policies, and every effort should be made to link supplementation to other interventions reaching young girls. Although the factors investigated are significant in some cases, it should be emphasized that they leave 84% of the variability unaccounted for.

Anaemia surveillance, focusing on moderate to severe anaemia, has been proposed as a way to help donors and governments focus their efforts to reduce anaemia [14], and it can help dispel the misconception that little can be done because anaemia is widespread in all countries. Monitoring haemoglobin levels can draw attention to anaemia as a major public health problem, facilitate health promotion related to improved dietary practices for girls, and provide a relatively simple approach to assessing the nutritional status of women.

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Operationalizing household food security in rural Nepal

Joel Gittelsohn, Sangeeta Mookherji, and Gretel Pelto

Abstract

This paper operationalizes household food security and links it to household food consumption patterns in rural Nepal. Food security has long been used as a macro-level indicator of agricultural stability by both agricultural and economic researchers. However, little work has been done to operationalize it at the household level. We view household food security as reflecting three different dimensions: past food supply, current food stores, and future supply of food adequate to meet the needs of all household members. A key method is the construction of scales that capture these different aspects of household food security. When operationalized in this way, household food security is associated with increased consumption of non-staple foods in this setting. Past household food security is associated with increased frequency of meat consumption and increased variety of food consumed. Current household food security predicts a higher frequency of meat and dairy intake and greater dietary variety. Future household food security is associated with increased total dietary variety and future consumption of dairy products. We feel that this conceptual approach to assessing household food security, i.e., the use of scales to measure past, current, and future components of food security, can be used as a framework in other settings.

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Introduction

Food security has long been used as an important macro-level indicator of agricultural stability and progress for both agricultural and economic researchers. However, little work has been done to operationalize the concept at the household level. We view household food security as a concept that integrates environmental, economic, and cultural factors in a manner that can provide a useful tool for predicting dietary patterns within the household. These factors affect the manner in which households manage their food resources, either by affecting initial food selection and acquisition or by affecting the use of food once it has been selected. Household food security is an outcome of these decisions.

This paper seeks to further the operationalization of household food security in three ways. First, a theoretical framework for household food security is presented, describing the set of relevant independent, intervening, and dependent variables. Second, a framework for operationalization is presented, using data collected from rural households in Nepal. Third, the relevance of household food security, measured at the micro level, is examined through regression models that predict household food security and that use household food security to predict diversity of diet at the household level.

Food security and household food security: An economic perspective

Economic approaches to food security have traditionally focused on assessing aggregate levels of food supply, agricultural production, and the balance of agricultural trade [1–6]. In the 1970s, food security was defined at the macro level as the ability to avoid short-term deficits in aggregate food supply [7], and it was directly linked to grain stocks at the global and national level [8]. At the micro level, food security was conceptualized primarily as the ability to successfully weather transitory shocks to food supply, such as drought, floods, market failure, or civil strife [9]. The focus was on food staples (i.e., grains), national stores

of grain, and agricultural policy that ensured stable supplies and stores of grain. Most importantly, food security was conceptualized as the outcome measure of agricultural policies.

As world food supplies stabilized at more than adequate levels and hunger and malnutrition continued to be prevalent, it became clear that aggregate food supply was not a useful proxy for food consumption at the household or individual level. From an economic perspective, malnutrition was increasingly recognized as the individual-level manifestation of a complex combination of household, community, regional, national, and international factors [10–12]. Seminal work on the phenomenon of famine by Sen [13] brought attention to the issue of access to food by households and by individuals, which could be constrained by economic, social, and cultural factors and was most often a chronic, not transitory, condition at the household level. Food insecurity could occur at the household level, and was occurring, in the absence of regional and national food insecurity.

The neoclassical economic theory of household production added further to the concept of food security by emphasizing the decision-making processes within the household that determine how scarce resources are allocated. Since households have limited access to resources and strive to fulfil a variety of basic needs, procurement of food competes with acquisition of health services and other goods and services. Therefore, food needs are not necessarily the most dominant basic needs for a given household's subsistence or survival [9].

Interest focused on household food security as a measure that would link national-, regional-, and community-level measures of food security to household food consumption and individual nutritional status. Household food security is seen as a concept that will relate agricultural policy to issues of nutrition [12]. Once household food security was identified as an important variable in the food security–nutritional status continuum, a variety of definitions and conceptual frameworks of household food security were proposed from the agricultural economic perspective. Whereas previous definitions of macro-level food security focused on food availability (supply), most of the recent household food security frameworks are concerned primarily with household access to food, although all recognize that access is just one component of household food security. The issue of food distribution at the community level is also addressed by some of the frameworks, in that all groups in a society are viewed as requiring equal access to sufficient food.

The International Fund for Agricultural Development concisely defines household food security as "the capacity of a household to procure a stable and sustainable basket of adequate food" [14]; however, some of the terminology used is difficult to operationalize. Adequacy may be defined in terms of quality and quantity of food, which contribute to a diet that meets the nutritional needs of all household members. Stability refers to the household's ability to procure food across seasons and transitory shortages, the more traditional definition of food security. Sustainability is the most complex of the terms, encompassing issues of resource use and management, human dignity, and self-reliance, among others [14].

Household food security: An anthropological perspective

Anthropology has a great deal to contribute to the conceptualization of household food security. Anthropologists have traditionally collected information on food provisioning, preparation, and consumption practices as part of their ethnographic descriptions of cultural settings [15–19]. Anthropological perspectives on food have focused on eliciting indigenous belief systems surrounding food, such as food classification, food proscriptions and prescriptions, and so on.

Ecological and medical anthropologists have investigated household responses to food shortages, with a particular emphasis on understanding and identifying adaptive strategies for subsistence [20–22]. Although "household food security" has not been a common component of anthropological studies, in recent years anthropologists have turned their attention to examining food security at the community level [23, 24]. Anthropologists have a number of tools at their disposal for investigating household food security. The primary focus of anthropology is on human belief, perception, and behaviour at the community, household, and individual levels. Through intensive study of small groups, anthropologists are in a good position to uncover the subtle dynamics that mark household-level decision making and activity and to understand this behaviour to a certain degree from the point of view of the people themselves.

Theoretical framework

The theoretical framework presented here draws on both anthropological and economic perspectives. The ecological approach in nutritional anthropology typically considers the physical and social environments, social organization, available technology for food production, and cultural and ideological systems when assessing the determinants of food choices and diet [25]. Economists see household income as the key potential "shock" to household food security, along with market food prices. At a more micro level, it is important to acknowledge other types of coping strategies and social mechanisms that function to buffer the effects of income and price fluctuations. Food gifts, loans, and other mechanisms often alleviate short-term stresses on household food supply [26].

Our framework (fig. 1) begins at the macro level of agricultural policies regarding both production and trade that influence food supply. Regional food supplies are affected by governmental inter-regional trade policies, seasonality, and climate. The state of regional food supplies determines what foods are available in the community-level markets where households go to sell, trade, and purchase foods for consumption. Community food markets are affected by seasonality and climate, but also by a host of cultural factors. The cultural factors are primarily rules that determine food selection by households and patterns of inter-household food sharing. The household is a multilevel construct, with cultural factors influencing not only food selection and preparation but also intra-household allocation of food. Individual dietary intake is the outcome of the intra-household distribution of the food available in the family. Community-level factors, such as the health services available and the status of sanitation and water supply, are included as exogenous variables that influence individual nutritional status through morbidity.

Figure 2 describes the household-level dynamics in more detail. At the household level, food security is determined by a household's current food supplies, past stable food supply, and potential future supply. Potential future food supply is a function of the household's available resources, such as capital (e.g., land), labour, and time. Between household food security and individual nutritional status are patterns of food distribution within the household and individual food consumption, which may include differences in dietary quality and quantity. Gittelsohn [27, 28] has looked at the complexity of factors affecting intra-household food allocation and has found that in rural Nepal culturally specific food-serving behaviours result in nutritional penalties against women. Other exogenous factors include the composition of the household (number of members, structures, female or male headed, number of females versus males, etc.) and factors affecting the social and economic status of the household (land ownership, earned income, caste, education, etc.). Morbidity, a variable that is affected by community-level factors and also by household-level factors such as food preparation and hygiene practices, also affects an individual's nutritional status [12, 29].

Using the theoretical framework proposed above, this paper addresses the following key questions:

» Can an appropriate and reliable measure of food security be operationalized at the household level, and what would such a measure look like?
» How does household food security relate to household food intake and dietary diversity (as a proxy for dietary quality at the household level)?
» How does household food security relate to other determinants at the household level, including socioeconomic status and (in the case of Nepal) caste?

Framework for operationalizing household food security

We view household food security as reflecting three different dimensions: the past (stable) food supply, the current food stores, and the anticipated future supply of food adequate to meet the nutritional needs of all

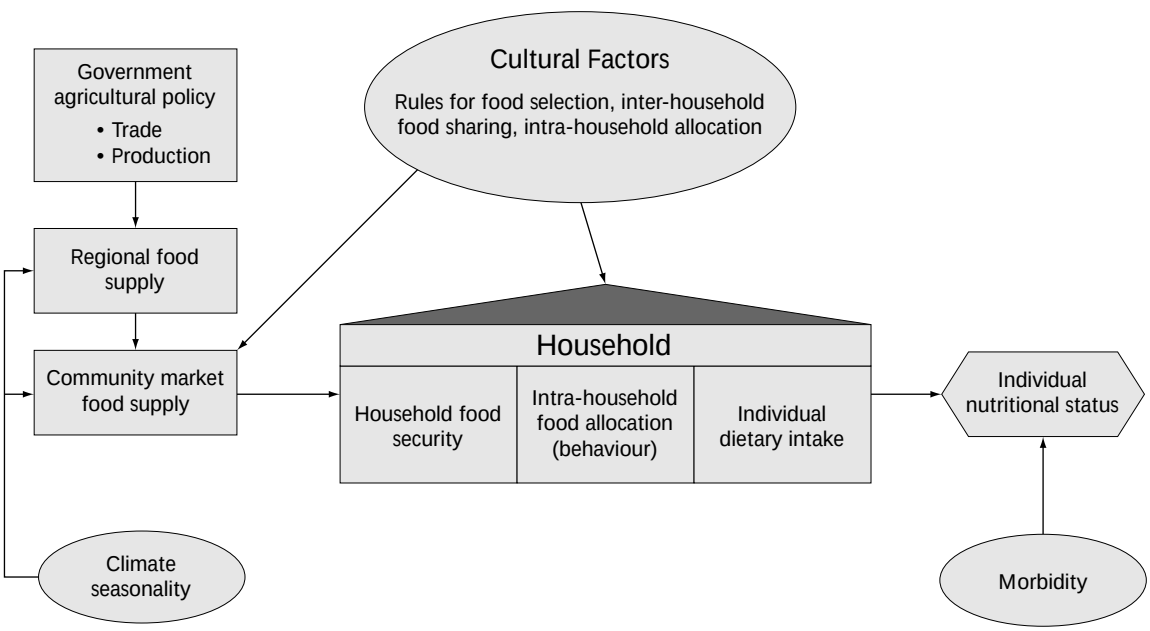

FIG. 1. Broad conceptual framework for examining household food security

household members. We define a secure past food supply as reflected by the stable flow of food into the household, its storage and consumption within the household, and its flow out of the household. The flow of foods into a household via different modes (self-production, purchase, receipt as gifts, etc.) should theoretically meet or exceed the outflow of food sold, paid as rent, given to others, etc. Our definition of current food security is the presence of sufficient household stores (defined broadly) to meet the immediate nutritional needs of the household members. In agricultural communities we define future food security as that portion of existing food stores which is invested in planting and in feed to animals to ensure adequate food supplies in the future.

Figure 3 presents a provisional theoretical model that will be tested with empirical data from Nepal. Essentially, it is a model of food flow through the Nepali household that illustrates the relationships outlined above. The assumptions behind this model of household food security revolve around a concept of general household food stores. The various means by which foods enter and leave the household represent a pattern of interactions. Households differ in their use of one or more pathways for obtaining and reallocating food. The model incorporates time-specific data on current food stores. Information collected about food flow through the household during the course of the preceding year can be used to give a picture of past household food security. By using a food-flow model for household access to food, we can address issues of both adequacy and stability of food supply. This approach is similar to those used in other studies to estimate household-level food security; however, the flow of food *out* of the household is typically not included in their estimations [29]. Finally, the model permits an examination of food resources allocated for the purpose of producing food some time in the future.

Operationalizing household food security according to a household food-flow model has the potential to incorporate food adequacy, stability, and sustainability (to a more limited degree) into measurement of food security. This provides a more comprehensive measure of household food security and can permit associations between household-level measures and individual-level measures to be investigated. The food-flow model is relevant for a variety of economic environments, both rural and urban, and for subsistence farming, cash cropping, or market-dominated food procurement.

Methods

Description of the research site

The data used to operationalize household food security come from the principal author's dissertation research, conducted from November 1986 through August 1987 in Pahargaon (a pseudonym) Village Development Committee (formerly called a *panchayat*) in the western hills of Nepal. A total of 115 households were randomly sampled, representing 767 individuals in six villages. The villages included in the study area lie along the slopes of hills at altitudes ranging from 3,500 to 4,800 feet. Agricultural fields range from approximately 10,00 feet (down in the river valley) up to 5,000 feet. The lower river valley fields (irrigated cropland, or *khet*) are considered more valuable because they are more productive. All study households owned some land, but for many the amount was inadequate for subsistence. A system of land rental (*adhiyaa*) is well established in Pahargaon, in which landowners permit villagers to cultivate plots of land and receive half of the harvested produce as payment.

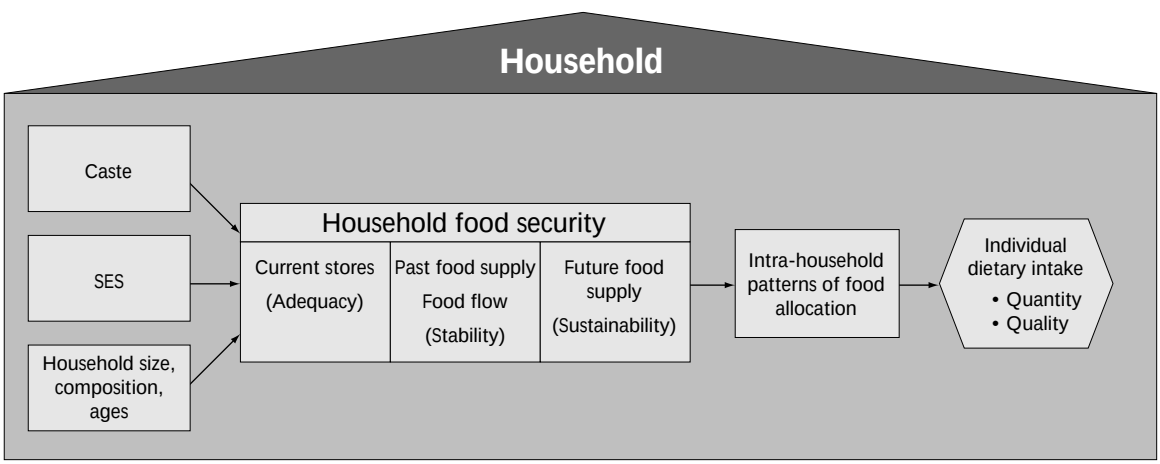

FIG. 2. Detailed framework of food security within the household

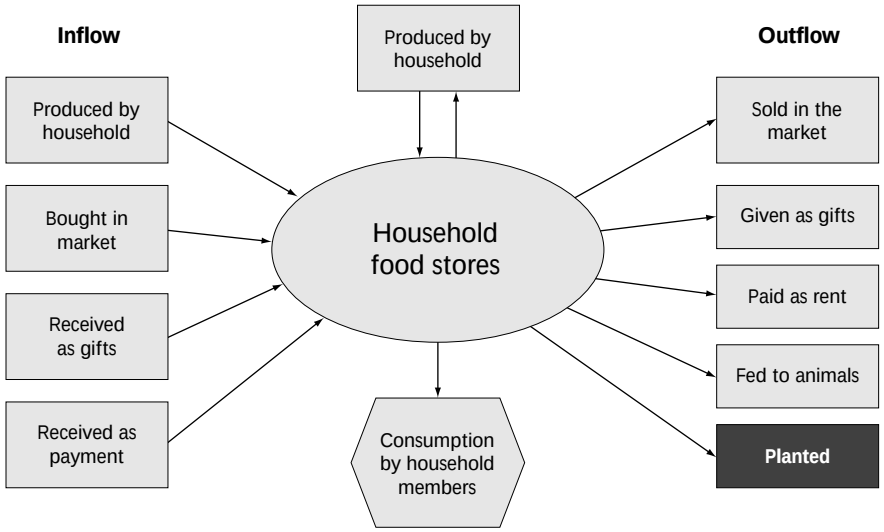

FIG. 3. Food flow through the Nepali household

Villages in Pahargaon are largely isolated from the larger market areas and centres of power for the region. The area around Pahargaon is heavily deforested, and villagers must walk three to five hours to obtain firewood. Water is available mainly from ground springs, which vary in distance from a few minutes to a half-hour round-trip walk from Pahargaon households. Ethnically, Pahargaon is composed of members of all four main caste groups in the Hindu Varna system: Brahmin, Chhetri, Vaisya, and Shudra. There are notable differences between higher and lower castes in terms of education, occupation, wealth, and, consequently, political power. In rural Nepal these differences extend also to food proscriptions related to caste status and thereby to diet.

Data-collection techniques

Before the initiation of data collection using structured instruments, exploratory qualitative research was conducted using key informant interviewing, focus groups, and unstructured observation techniques. This period of preliminary ethnographic data collection assisted in developing culturally appropriate and valid quantitative instruments for later phases of the research and contributed to the final interpretation of the quantitative data results.

Structured data collection was focused on four key areas. All four instruments were administered from January to April 1996. This is generally the period of greatest food availability in the *panchayat*. The household food-frequency instrument was administered a second time in almost all study households approximately three to five months later from June to August 1996. From June to August is the pre-monsoon and early monsoon season, which is generally regarded as the period of greatest food scarcity in the *panchayat*.

Household and individual demographic data, including information on caste status, age, and sex, were collected using a survey administered to the male head of the household.

Economic status indicators were collected at the household level from the male head of the household, including ownership of land, animals, and material possessions and quality of the house.

Household food stores and usage patterns were obtained through a structured interview. The male head of the household was asked to estimate the amounts of 20 key foods (identified in the ethnographic survey) acquired by the household over the preceding 12 months and how the food had been used by household members (an indicator of past food security). He was also asked to describe the amounts of each food currently in storage (an indicator of current food security), limited to "storable" foods, such as grains and tubers. In addition, the respondent was asked to describe the amount of land currently planted and the numbers of each kind of animal currently owned (indicators of future food security).

The accuracy of recall by the informant over an extended period of time was of concern. Accuracy was enhanced by several methods:

» Different means of food inflow and outflow were identified by ethnographic methods and distinguished from one another. For instance, respondents were asked not only the total amount of rice that came into the household, but also how much rice they produced on their land, received as payment, received as gifts, received in trade, or purchased.
» Information was cross-checked during the interview,

both within and between foods, and with other questions. The total food coming into the household should be roughly equal to the amount reportedly flowing out of the household, plus the amounts reported as eaten and stored. A household owning a lot of rice-producing land but reporting very low rice production would be asked to explain the inconsistency.

» Respondents were encouraged to report quantities using a variety of local measures, which were later translated into grams.

» Other household members, especially those involved in agricultural production, were encouraged to participate during the interview and often served to refresh the memory of the principal respondent.

Household food consumption patterns were estimated using a weekly food-frequency instrument. This instrument was administered twice in each study household. The female head of the household was asked to report the number of times any household members had consumed 70 different foods during the previous week and to give an estimate of the amount of food consumed by household members each time (familiar household measures were used to estimate quantity). The 70 foods were identified as the most commonly consumed through preliminary ethnographic interviews with key informants; however, additional spaces were provided for other foods.

Scale and score construction

This section describes how we operationalized food security at the micro level of the household. A key method was the construction of scales and scores that captured the complexity of the factors that make up household food security [30]. Separate exploratory factor analyses were conducted to identify key components of three different scales representing past, current, and future household food security. Factor analysis is an appropriate analytic method when the investigator wants to identify key constructs underlying a set of data [31]. The method has been used in dietary studies to identify patterns of food consumption for specific populations [32–34]. Although we initially experimented with developing our own scoring system, we soon discovered that the complexity of the data (multiple sources of food, multiple ways that food could leave the household, multiple styles of managing food resources) necessitated an analysis strategy that would permit underlying patterns to emerge, effectively summarize data, and provide optimal weights for component variables.

The principal-factor method was used to identify components of each scale [31]. A combination of scree test (a plot of the eigenvalues of the factors) and assessment of the proportion of the variance accounted for by the factors was used to determine the number of factors to be retained for rotation (conducted using the varimax method). In interpreting the rotated factor pattern, a selected item was considered to load on a given factor if the loading was 0.40 or greater for that factor and was less than 0.40 for all other factors. No item was permitted to load on more than one factor. Factor scores for each item in the three scales were computed by multiplying its value by its factor weighting. Reliability for all scales was assessed by calculating coefficient alpha [35].

Past food stability scale

To obtain some indication of past food supply stability (PASTFDSC), respondents were asked to recall the flow of 20 key foods into and out of the household during the 12 months leading up to the interview date. The foods were rice, *shuto* (dried ginger), wheat, corn, mustard, potatoes, barley, lentils, millet, soya beans, peanuts, vegetables, fruit, milk, eggs, goat, chicken, buffalo, and pig. The respondents were asked to estimate the amount of each food coming into household stores through five specific pathways: production, purchase, gift, payment, and trade. The respondents were then asked to estimate how much of these foods left household stores through six pathways: consumed by household members, sold, traded, given to others, paid in rent, and fed to animals. Payment includes food received as rent for land use. Trade indicates food traded for other types of food. Gifts can mean food received either as a gift or, as many low-caste families do, as compensation for services rendered (e.g., leatherwork, blacksmithing, or tailoring). All 20 food categories were combined on the basis of source (how they came into the household) and use (how they left the household). Each of these scores was then adjusted according to household caloric requirements (to account for age and sex composition differences between households). These adjusted variables were then converted into common "units" by recoding each score into quartiles.

Factor analysis was then used to identify the main patterning in the scores. Most loaded on factor 1 (amount of food stored, sold, given in rent, produced, fed to animals, or given as gifts). Traded (either received or given) food consistently loaded on its own factor (factor 2). Food purchased (bought) and food received as pay consistently loaded on their own factor (factor 3). A second round of correlation analysis was conducted to verify the factor analysis findings. The final Cronbach's alpha of the six-item PASTFDSC scale was 0.747, indicating a reliable unidimensional scale. Finally, confirmatory factor analysis was used to generate standardized scoring coefficients for these items to use as weights when combining the items into a single-scale score. All items loaded onto one factor. The final PASTFDSC variable had a mean of 1.61, a standard deviation of 1.06, a median of 1.63, and a range of 0 to 3.42 and was approximately normally distributed. A high score on the PASTFDSC therefore indicates that

in comparison with households with lower scores, the household produced a lot of its food, had a lot of food in stores, gave out a lot of food in rent (and therefore had people working on its land), gave out a lot of food as gifts, and used a lot of food to feed its animals.

Current food supply/stores scale

The current food security scale (CURRFDSC) reflects household food stores at the time of the household interview. The 20 foods recorded in the household food stores and usage instrument were combined into 8 food groups. For example, rice, corn, wheat, and millet stores were combined into the grains group. Factor analysis and correlation analysis were used to select food-store variables to constitute a unidimensional scale. The final scale included grains, vegetables, nuts and beans, and milk (based on current productivity estimates of milk-producing animals) and had a Cronbach's alpha of 0.711. Factor analysis was then used to generate weights that were used to combine the four food groups into one scale. Univariate statistics on the scale CURRFDSC indicated a fairly normal distribution, with a mean of 1.5, a standard deviation of 0.96, and a range of 0 to 3.26.

Future food productivity scale

This scale reflects the amount of land currently planted in a variety of crops and the numbers of work animals and meat- or milk-producing animals currently owned as a means of indicating the potential of the household to produce food in the near future (FUTUFDSC). For each of 11 planted food crops, the amount planted in seed (e.g., the amount of rice seed) in the current year was weighted by the proportion of total land that was owned or rented by the household. Plantings on rented land were weighted by 0.5, since the household would only receive half of what they planted. These foods included those crops that are most commonly planted in large quantities and not in kitchen gardens (except *tirmilo* [an indigenous black oilseed] and mustard).

For fruits and vegetables, households were only asked whether or not they grew a particular variety on their own land. Correlation analysis was done to construct additive fruit variety (13 items, alpha=0.825) and vegetable variety (18 items, alpha=0.881) subscales. In terms of animals, correlational analysis resulted in an additive subscale that included numbers of cows, bulls, goats, and buffaloes (alpha=0.530).

Each of these scores—13 planted foods (amounts planted), fruit variety subscale, vegetable variety subscale, and animal ownership subscale—was then converted into quartiles. Correlation analysis was done on the converted variables to construct a scale for future household food security. Thirteen items remained in the final scale: fruits subscale, vegetables subscale, animals subscale, and the following planted crops: tirmilo/*baari*, peanuts/*baari*, millet/*baari*, lentils/*baari*, potatoes/*baari*, mustard/*baari*, corn/*baari*, wheat/*baari*, wheat/*khet*, and rice/*khet*. (*Baari* is unirrigated cropland and *khet* is irrigated cropland.) The final scale (FUTUFDSC) has an acceptable Cronbach's alpha of 0.784. The scale values have a normal distribution, with a mean of 14.7, a standard deviation of 7.09, and a range of 0 to 30.

Data analysis

The effect of the three measures of household food security on household food consumption patterns was examined using multiple regression. Separate models were run to examine the effects of past, current, and future food security on the frequency of consumption of different food groups and on the variety of foods consumed by the household (both between and within food groups). Scale scores for each of the three measures were converted into quartiles, with the second, third, and fourth quartiles entered into the models as dummy variables. The primary outcome variables for the analyses were based on the food-frequency results. These data were summarized by calculating additive scores by food group (grains, beans, green leafy vegetables, tubers, other vegetables, fruits, meats, and dairy products). Dietary variety, a proxy for dietary quality, was calculated in two ways: as total food group variety (whether or not one or more foods were consumed within each food group; maximum score, 8) and as total food group intensity (summing all foods in all food groups; maximum score, 30).

Other variables included in the models were dummy variables for caste (Brahmin, Chhetri, and Vaisya were included; Sudra, the lowest-caste group, was not included) and socio-economic status (the second and third terciles were included; the lowest tercile was not included), based on the total value of all possessions. In addition, an independency ratio (number of adult male and female household members aged 15 to 60/number of children and elderly in the household) was calculated and incorporated into the models. Standardized beta coefficients were generated for each of the models. Statistical analysis was performed using the SAS statistical package (SAS/STST version 6.11, SAS Institute, Cary, NC, USA).

Results

Tables 1 to 3 present models examining the relationships between the three measures of household food security and weekly frequency of consumption of foods in eight groups. In general, caste status and socio-economic status were more associated with frequency of consumption of the different food groups than the food security scales. Being Brahmin or, to a lesser degree, Chhetri, was associated with significantly more frequent consumption of green leafy vegetables, tubers, and dairy

TABLE 1. Relationship between past food security variables and frequency of household consumption of different food groups (standardized beta coefficients) (N=114 households)

Independent variable	Food group							
	Grains	Beans	Green leafy vegetables	Tubers	Other vegetables	Fruits	Meat	Dairy products
F	ns[a]	ns	2.419	2.406	ns	ns	3.725	3.182
R^2			0.172	0.171			0.242	0.214
PASTQ4			–0.16	–0.04			0.26**	0.20
PASTQ3			0.13	–0.17			0.10	0.05
PASTQ2			–0.04	–0.09			0.03	0.04
Brahmin			0.21*	0.21*			–0.39**	0.41***
Chhetri			0.06	–0.07			–0.26**	0.03
Vaisya			–0.11	–0.17			0.13	0.08
SESL3			0.12	0.26**			0.008	0.09
SESL2			0.18*	0.13			0.01	0.08
Independency ratio			–0.08	–0.02			0.10	–0.02

a. ns = not significant.
* $p \leq .10$.
** $p \leq .05$.
*** $p \leq .01$.

TABLE 2. Relationship between current food security variables and frequency of household consumption of different food groups (standardized beta coefficients) (N=114 households)

Independent variable	Food group							
	Grains	Beans	Green leafy vegetables	Tubers	Other vegetables	Fruits	Meat	Dairy products
F	1.902	ns[a]	1.774	2.314	ns	ns	3.564	3.6
R^2	0.140		0.132	0.165			0.234	0.236
CURRQ4	0.004		–0.08	0.12			0.23*	0.28**
CURRQ3	0.16		0.06	0.01			0.19*	0.19
CURRQ2	0.18		–0.03	–0.03			0.06	0.10
Brahmin	–0.06		0.22*	0.15			–0.43***	0.34***
Chhetri	–0.01		0.04	–0.12			–0.3**	–0.04
Vaisya	0.25*		–0.12	–0.18			0.08	0.02
SESL3	0.18		0.07	0.22*			0.06	0.10
SESL2	0.14		0.16	0.14			0.05	0.10
Independency ratio	0.04		–0.04	–0.05			0.10	–0.04

a. ns = not significant.
* $p \leq .10$.
** $p \leq .05$.
*** $p \leq .01$.

products and significantly less frequent consumption of meat. Households in the upper terciles of socio-economic status tended to be more likely to consume green leafy vegetables and tubers. It is important to note that caste and socio-economic status are highly correlated in this setting (Spearman's $r = .3666$), with higher-caste households tending to be of higher socio-economic status. Independency ratio did not have a significant effect. High scores for past and current household food security were associated with more frequent consumption of meat and, to a lesser degree, of dairy products.

Tables 4 to 6 model the relationships between the three household food security scales and the dietary variety scores. In these models, past, present, and future household food security and socio-economic status are all associated with the dependent variables. Caste status and independency ratio are not significant in any of the models. Higher socio-economic status appears to be particularly related to total food group variety score. On the other hand, the highest quartiles for the past and current household food security scores are associated with total food group intensity. Current

and future food security scores are associated with total food group variety.

Tables 7 to 9 present models depicting the relationships between the three household food security scales and frequency of consumption from the eight food groups in the second round of household food frequencies. In general, the effects of caste and socio-economic status are much the same as those shown in tables 1 to 3. High-caste status is associated with increased frequency of intake of beans, green leafy vegetables, dairy products, and tubers in some instances. Higher socio-economic status is associated with increased frequency of intake of beans, tubers, meat, and dairy products. Past and current food security are negatively associated with green leafy vegetable intake. Future food security is only associated

TABLE 3. Relationship between future food security variables and frequency of household consumption of different food groups (standardized beta coefficients) (n=114 households)

Independent variable	Food group							
	Grains	Beans	Green leafy vegetables	Tubers	Other vegetables	Fruits	Meat	Dairy products
F	ns[a]	ns	1.856	2.321	ns	ns	3.224	2.965
R^2			0.137	0.166			0.216	0.203
FUTUQ4			–0.03	0.02			0.03	0.09
FUTUQ3			0.12	–0.04			–0.001	0.03
FUTUQ2			0.08	0.16			–0.13	–0.04
Brahmin			0.22*	0.16			–0.36***	0.42***
Chhetri			0.02	–0.11			–0.21*	0.05
Vaisya			–0.14	–0.2			0.11	0.06
SESL3			0.06	0.19			0.10	0.12
SESL2			0.14	0.13			0.06	0.10
Independency ratio			–0.04	–0.04			0.10	–0.03

a. ns = not significant.
* $p \leq .10$.
** $p \leq .05$.
*** $p \leq .01$.

TABLE 4. Relationship between past food security variables and variety of household consumption of different food groups (standardized beta coefficients) (*N*=114 households)

Independent variable	Dependent variable	
	Total food group variety (across food groups)	Total food group variety and intensity of consumption (across and within food groups)
F	1.777*	1.921*
R^2	0.132	0.141
PASTQ4	0.18	0.28**
PASTQ3	0.09	0.21*
PASTQ2	0.01	0.12
Brahmin	0.04	0.04
Chhetri	–0.06	0.03
Vaisya	0.02	0.18
SESL3	0.28**	0.18
SESL2	0.22**	0.13
Independency ratio	–0.07	-0.14

* $p \leq .10$.
** $p \leq .05$.
*** $p \leq .01$.

TABLE 5. Relationship between current food security variables and variety of household consumption of different food groups (standardized beta coefficients) (*N*=114 households)

Independent variable	Dependent variable	
	Total food group variety (across food groups)	Total food group variety and intensity of consumption (across and within food groups)
F	2.541**	2.100**
R^2	0.179	0.153
CURRQ4	0.28**	0.32**
CURRQ3	0.13	0.16
CURRQ2	–0.04	0.18
Brahmin	0.01	0.02
Chhetri	–0.11	–0.03
Vaisya	0.001	0.13
SESL3	0.27**	0.22*
SESL2	0.25**	0.15
Independency ratio	–0.08	–0.15*

* $p \leq .10$.
** $p \leq .05$.
*** $p \leq .01$.

with increased frequency of consumption of dairy products.

Similar patterns were observed when the effects of the three household food security scales on the two dietary variety scores were examined, calculated from the second round of food frequencies. Higher caste is particularly associated with increased variety of foods consumed at the household level.

TABLE 6. Relationship between future food security variables and variety of household consumption of different food groups (standardized beta coefficients) (N=114 households)

Independent variable	Dependent variable	
	Total food group variety (across food groups)	Total food group variety and intensity of consumption (across and within food groups)
F	2.166**	1.783*
R^2	0.157	0.133
FUTUQ4	0.24*	0.19
FUTUQ3	0.12	0.19
FUTUQ2	–0.03	0.02
Brahmin	0.04	0.06
Chhetri	–0.07	0.04
Vaisya	–0.03	0.13
SESL3	0.23*	0.18
SESL2	0.22**	0.14
Independency ratio	–0.06	–0.13

* $p \leq .10$.
** $p \leq .05$.
*** $p \leq .01$.

Discussion and conclusions

We were able to operationalize three scales that each reflects a different aspect of household food security. Past household food security, as represented by patterns of food flow through the household during the previous year, is associated with increased frequency of meat consumption and increased variety of food consumed at the time of the interview. Its negative association with consumption of green leafy vegetables in the second household food-frequency survey performed three to four months later is perplexing and requires further investigation. Possibly more food-secure households are replacing their intake of green leafy vegetables with other foods. Current household food security, represented by household food stores, appears to be a useful predictor of increased frequency of meat and dairy intake and of overall dietary variety. Future household food security, represented by the amount of land planted in different crops and by animal holdings, is associated with increased total dietary variety and future consumption of dairy products. The lack of associations between future household food security and the second food-frequency measure is unexpected, as one would hope that measures of household food security would be useful in predicting inadequacies in household food supplies later in time. One possibility is that our second measure of household food consumption may have been taken too early. It was conducted during the premonsoon and monsoon season when most crops had not been harvested, and therefore we were apparently unable to see the effects of planting on household supply and consumption patterns. A limitation of this study was that the household food security measurements

TABLE 7. Relationship between past food security variables and future frequency of household consumption of different food groups (standardized beta coefficients) (N=103 households)

Independent variable	Food group							
	Grains	Beans	Green leafy vegetables	Tubers	Other vegetables	Fruits	Meat	Dairy products
F	ns[a]	2.059	5.071	2.639	2.092	ns	1.751	3.476
R^2		0.166	0.329	0.203	0.168		0.145	0.252
PASTQ4		–0.147	–0.274**	–0.109	0.431***		–0.046	0.111
PASTQ3		–0.200	–0.229**	–0.139	0.064		–0.170	0.124
PASTQ2		–0.058	–0.253**	0.147	0.216*		–0.122	–0.068
Brahmin		0.072	0.571***	0.265**	0.174		–0.058	0.430***
Chhetri		0.290**	0.116	0.022	0.152		–0.042	0.340**
Vaisya		0.284**	0.004	–0.144	0.169		0.050	0.242*
SESL3		0.299**	0.058	0.245**	–0.098		–0.185	0.174
SESL2		0.345***	0.045	–0.044	–0.061		–0.331***	0.016
Independency ratio		–0.040	–0.148*	–0.010	0.117		–0.111	0.004

a. ns = not significant.
* $p \leq .10$.
** $p \leq .05$.
*** $p \leq .01$.

TABLE 8. Relationship between current food security variables and future frequency of household consumption of different food groups (standardized beta coefficients) (N=103 households)

Independent variable	Food group							
	Grains	Beans	Green leafy vegetables	Tubers	Other vegetables	Fruits	Meat	Dairy products
F	ns[a]	1.991	4.557	1.750	ns	ns	2.000	3.586
R^2		0.162	0.306	0.145			0.162	0.258
CURRQ4		−0.056	−0.118	−0.042			0.165	0.201
CURRQ3		−0.088	−0.221*	−0.011			−0.066	0.031
CURRQ2		0.086	−0.111	−0.012			−0.046	−0.031
Brahmin		0.034	0.575***	0.237*			−0.096	0.440***
Chhetri		0.270*	0.126	0.001			−0.093	0.317**
Vaisya		0.271*	0.041	−0.128			0.061	0.241*
SESL3		0.278**	−0.014	0.201*			−0.248**	0.155
SESL2		0.335***	0.021	−0.055			−0.337***	0.016
Independency ratio		−0.059	−0.145	−0.033			−0.136	0.011

a. ns = not significant.
* $p \leq .10$.
** $p \leq .05$.
*** $p \leq .01$.

TABLE 9. Relationship between future food security variables and future frequency of household consumption of different food groups (standardized beta coefficients) (N=103 households)

Independent variable	Food group							
	Grains	Beans	Green leafy vegetables	Tubers	Other vegetables	Fruits	Meat	Dairy products
F	ns[a]	1.769	4.161	1.917	ns	ns	ns	3.533
R^2		0.146	0.287	0.157				0.255
FUTUQ4		−0.094	−0.081	−0.051				0.219*
FUTUQ3		−0.026	−0.010	0.088				0.173
FUTUQ2		−0.049	−0.034	0.045				0.010
Brahmin		0.018	0.513***	0.213				0.431***
Chhetri		0.251*	0.053	−0.010				0.310**
Vaisya		0.272*	−0.006	−0.147				0.167
SESL3		0.289**	0.015	0.209				0.104
SESL2		0.352***	0.037	−0.056				−0.002
Independency ratio		−0.049	−0.138	−0.030				0.033

a. ns = not significant.
* $p \leq .10$.
** $p \leq .05$.
*** $p \leq .01$.

were performed cross-sectionally. Future studies would be wise to measure household food consumption 6, 9, and even 12 months after the initial assessment of food security status. In addition, the concept of household food security also implies stability over time. Ideally, estimates of household food stores should be obtained several times throughout the year to capture the effects of seasonality and other secular trends.

No significant relationships were observed between the household food security scales and the current consumption of grains and beans. This was an expected result, as grains and beans constitute staple foods in this region and are consumed daily in all households. Nor were associations observed between the household food security scales and consumption of other vegetables and fruits. The availability of these foods is highly seasonal, which undoubtedly reduced the chance of finding significant associations.

It is clear also from the analyses that household food consumption patterns are the product of several factors in this setting. Socio-economic status plays a role in predicting the total dietary variety of foods consumed and the frequency of consumption of food groups such as beans, tubers, and green leafy vegetables. This find-

ing agrees with other research in the region [36, 37].

Perhaps surprisingly, socio-economic status is not correlated or, in some cases, is negatively correlated with the consumption of meat and dairy products. The effect of caste status of the household is very strong and appears to predict consumption in every food group. In general, due to dietary prohibitions, members of higher castes (especially Brahmins) are much less likely to consume meat than members of lower castes. This finding helps to explain why socio-economic status is negatively correlated with meat consumption in this setting. On the other hand, members of higher castes are much more likely to consume dairy products and to eat green leafy vegetables.

Overall, the operationalization of household food security in research studies has traditionally focused on specific, easily measured aspects, such as current food supply, individual caloric intake, and so on, without capturing the complexity of household food security. It appears that the traditional economic focus on staple grain supply as the indicator of national food security has translated into a focus on total caloric intake and anthropometric status as primary indicators of household food security [38]. This definition overlooks the issue of stability in household food security as well as the role of dietary quality. Recent studies indicate that although total caloric consumption is correlated with consumption of other macronutrients, it is not necessarily correlated with micronutrient intake, particularly for vulnerable subgroups within the household [28]. Economic studies have found that the income elasticity of staple foods is much less than that of non-staple foods; this reinforces the need to look at dietary quality rather than quantity, since this is where the most variability among households occurs.

Operational frameworks used for empirical measurement of household food security therefore need to evolve to encompass a broader range of components, such as those identified in this paper. Our findings indicate that our three components of household food security—past stable supply, current stores, and future production—were differently associated with intakes of different foods. Both stability and adequacy of household food supply need to be included in the operationalization. Within adequacy of food supply, both the quantity and the quality of food should be measured.

The conceptual approach used here to operationalize household food security is based on the creation of three scales, representing past, current, and future food security. Factor analysis enabled us to construct these scales in the rural Nepalese setting as stability of food flow, current food stores, and investment in future food production, respectively. It will be important to further test and refine these scales in other settings. Further analytic work needs to be done to examine the relationship between these scales and individual dietary intake and nutritional status. Household food-frequency data, while relatively easy to collect, are a crude indicator of consumption patterns within the household and cannot reflect within-household differences.

We feel that we have developed a useful conceptual framework for food security at the household level that comes closer to capturing the complex dynamic that results in the household production of nutritional status and health. Using this conceptual framework, we were able to identify components of household food security that can serve as proximate determinants of household food consumption patterns, and perhaps eventually as indicators of individual dietary intake and nutritional status.

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Trends in body mass index in developing countries

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Abstract

The purpose of this study was to examine the extent to which adult body mass index (BMI) has changed in developing countries over the past several decades. The analysis is based on a compilation and analysis of mean BMI in 1,432 published samples from developing countries measured between 1957 and 1994. A hierarchical multiple-regression model is applied to these data, controlling for country and study as random covariates and modelling age, sex, socio-economic status, and year as fixed effects. The results reveal a statistically significant increase in mean BMI between 1957 and 1994 in all major regions of the developing world. The size of the increase was 1.4 kg/m^2 over the 37-year period, with a 95% confidence interval of 0.4 to 2.4 kg/m^2. Mean BMI appears to have increased in all major regions of the developing world, although the size of the increase varies across regions. Using assumptions about the statistical distribution of BMI within populations and cut-off points recommended by the World Health Organization, the analysis suggests that the increase in mean BMI may have resulted in a slight decrease in the prevalence of underweight (BMI<18.5 kg/m^2) but is unlikely to have produced an increase in obesity (BMI>30 kg/m^2) in most regions. By contrast, the use of lower cut-off points to define obesity, as is done in many individual studies, would suggest that obesity has increased in developing countries. These results highlight the importance of using standardized definitions for underweight and obesity among adults, the need to assess and consider the prevalence of both conditions simultaneously during planning and policy development, and the need to identify policy instruments appropriate to the nutritional profile within a country.

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Introduction

For the world as a whole, the overall rates and causes of death have undergone dramatic changes in the past several decades. Taking the estimates from Bulatao [1] for the years 1970 to 1985 as an example, the total mortality rate for the world has declined from 1,287 to 1,034 per 100,000. This decline is even more marked among developing countries, from a rate of 1,378 in 1970 to 1,035 in 1985. These declines in overall mortality are associated with concomitant declines in virtually all identifiable categories of death for the world and for developing countries as a whole, with the most rapid declines being found for infectious diseases. Another important observation is that, in the developing world, there is an increase in the number and percentage of all deaths attributable to circulatory diseases and neoplasms, trends that are expected to accelerate sharply in the coming years [2].

There are three potential reasons for these changes, which have quite different policy implications and, therefore, are important to distinguish from one another. The first is that the spread of public health measures and knowledge has contributed to a rapid decrease in mortality from communicable diseases, which is most marked among young children and has accelerated since 1960, continuing a trend that began near the turn of the century in developed countries. This has been noted by several authoritative sources and appears well established [3–5]. The second is that, fuelled by simultaneous changes in fertility and age-specific mortality rates, a greater proportion of people are living into adulthood, when chronic diseases become manifest. This demographic transition is reflected in significant decreases in total and age-specific fertility rates and increases in life expectancy at birth and at age 15, and is also well established.

A third potential explanation is that the causes of death *within* various age and sex groups (notably among adults) have undergone changes. According to this explanation, changes in diet, exposure to infectious agents and environmental hazards, and various life-style fac-

tors (e.g., tobacco and alcohol use, occupational exposures, sedentary life-style, and psychosocial stress) have led to an increased biological risk for chronic disease. There is a large body of evidence establishing the relevance of these factors to chronic disease in developed countries, but a central question is whether, or to what extent, these changes are having potent and broad-scale effects on mortality in the developing world today. The use of proportional mortality rates (i.e., percentage of total deaths due to different causes) or all-ages mortality rates is inappropriate for testing this explanation, because such comparisons are potentially confounded by the above-mentioned changes in population age structure and the precipitous decrease in infectious diseases that are well established. Unfortunately, many authors have failed to distinguish among these three explanations, and have mistakenly assumed that the sharp increase in the share of total deaths due to chronic disease, or in the rate of death from chronic disease for the population as a whole, implies comparable changes in biological risk for chronic disease among adults in the developing world [6].

To illustrate the importance of methodology for conclusions concerning chronic disease trends in the developing world, table 1 compares the results based on four measures of mortality, adapted from Bulatao and Stephens [7]. The first three measures lead to the clear conclusion that chronic diseases are an emerging problem in developing countries, and, indeed, in a certain sense they are emerging problems. However, the trends in these indicators are being driven by changes in total population size and structure (measure 1), changing age structure (measure 3), and a combination of changing age structure and decline in infectious diseases (measure 2). When these forces are removed by examining age-specific death rates among adults (measure 4), it can be seen that the trend is one of stability or decline, consistent with the overall decline in mortality in these countries. Similar findings were reported for males and females in five developing countries with adequate vital registration systems [6] from 1955 to 1985, and similar findings emerged from the Global Burden of Disease Study [2].

The upward trends in the first three mortality indicators of table 1 have important policy implications for developing countries, even if they cannot be taken as evidence that the biological risk for chronic disease is increasing. These trends do imply that the health systems in these countries will increasingly need to adapt to the prevention and treatment of chronic diseases, because their populations are growing older and are growing in absolute size, and the ratio of deaths due to chronic diseases versus infectious diseases is increasing rapidly. This will create added competition for resources within the health sector, especially if expensive medical intervention strategies are chosen in lieu of primary prevention. However, from a broader policy perspective, it is important to determine the extent to which adults in the developing world are experiencing increases in biological risk for chronic disease as a result of changes in diet, environmental exposures, life-style, and other factors. The answers to this question would help decide the extent to which chronic disease risk should be another consideration in the formulation of food, agriculture, environmental, and nutrition policy. The age-specific mortality trends shown in table 1 (measure 4) suggest that this is *not* the case, contrary to the forceful impression created by the first three indicators that are more commonly seen and quoted in the journal literature, policy documents, and the media.

This paper extends an earlier report [8] that addresses the "diet, environment, and life-style" question using two quite different approaches. The first approach was to apply a demographic model to predict causes of mortality on an age-specific basis, using a number of other refinements not used in the projections published by the World Bank [7] and the National Research Council [5]. This analysis yielded results broadly similar to

TABLE 1. Trends and projections in deaths due to circulatory disease and neoplasms in the developing world according to four mortality measures

Measure	Cause of death	Males				Females			
		1970	1985	2000	2015	1970	1985	2000	2015
No. of deaths × 1,000, 45–65 yr	Circul.	989	1,151	1,818	2,812	727	870	1,223	1,744
	Neopl.	380	617	890	1,466	368	521	802	1,299
% of deaths, all ages	Circul.	16.9	18.5	29.4	35.4	16.4	19.2	47.1	35.3
	Neopl.	4.9	7.3	10.8	13.5	4.9	7.0	10.4	13.7
Deaths per 100,000, all ages	Circul.	234	198	244	291	225	192	216	252
	Neopl.	68	78	90	111	68	70	79	98
Deaths per 100,000, 45–65 yr	Circul.	606	479	516	494	459	377	357	314
	Neopl.	233	257	252	257	232	226	234	234

Source: ref. 7.

those of the Global Burden of Disease Study [2] and are not included in this paper.

The second approach is to study trends in biological risk factors for chronic diseases, rather than cause-specific death rates. Biological risk factors have the advantage that they are more responsive to current or recent behavioural and environmental conditions, as compared with mortality rates, which typically have a lag period of several decades. Obesity is one such risk factor, and, consistently with the focus on the epidemiologic transition, many authors have suggested that obesity is increasing in developing countries. However, the empirical evidence for this conclusion has been quite fragmentary and seems based on observed differences between contemporary rural and urban populations or socio-economic strata, rather than temporal differences *per se*. The analysis provided here is intended to extend earlier analyses by the World Health Organization (WHO)[9] and the US Centers for Disease Control (T. Byers, personal communication, 1996), both of which concluded that the database for estimating trends in relative weight in developing countries is inadequate. The present paper employs a different approach to the problem from these previous attempts.

Methods

An initial overview of available data in 1990 by WHO [9] located only seven developing countries with national surveys from which the prevalence of obesity could be estimated, none of which had data from two points in time for estimating trends. A more recent review (T. Byers, personal communication, 1996) located another 10 large-scale surveys, but none of these were able to estimate trends over time. That report did note large differences in mean body mass index (BMI: weight/height^2) between population groups differing in rural/urban residence or socio-economic conditions, with the urban, upper socio-economic groups having consistently higher mean BMIs and obesity prevalences.

In light of the current dearth of large-scale survey data from two or more points in time in developing countries, the present study uses an alternative approach to estimate time trends in BMI. Specifically, it is based on the compilation and analysis of the many small-scale, community-based surveys in developing countries, as reported in the scientific literature since 1960. Whereas none of these studies is individually able to indicate time trends in BMI, this study was undertaken to determine whether they might, in the aggregate, reveal the presence of such trends when analysed on a country-specific or region-specific basis. In addition, information on age, sex, and socio-economic characteristics was retrieved from these reports in order to analytically remove variation due to these sources and test the extent to which socio-economic variation (a proxy for future trends in developing countries) is associated with variation in adult BMI.

The data for this study were obtained by conducting a literature search for studies published between 1960 and 1995. The criteria for inclusion in the study were the following: data were provided on mean BMI, the prevalence of either high or low BMI, or mean weight and height from which BMI could be calculated; samples were taken from developing countries and represented non-European populations; samples did not represent clinical cases from hospitals or clinics; samples were entirely or largely composed of persons 18 years of age or above.

Three methods were employed for the literature search: computer-assisted search based on keywords, a systematic search of key journals based on geographic or topical focus, and the usual bibliographic branching or "snowballing" technique. These methods yielded 176 papers with data from 66 developing countries (see Appendix). It is suspected that many more papers of this type could have been found if the search had been extended, but this was not possible for the purposes of this paper.

Most of the 176 papers presented data on BMI, weight, and height for several strata from the overall sample, with strata defined according to age, sex, occupation, rural/urban location, education, and other socio-economic variables. Thus, the 176 papers yielded a data set of 1,432 observations, with each observation eventually representing the BMI for one particular stratum, from one study, in one country. The associated age, sex, and socio-economic descriptors for each stratum were recorded and used in the analysis. In recognition of the non-independence of such observations, a hierarchical modelling procedure was used for the analysis, as described below. The median sample size for the 1,432 observations, upon which a mean BMI was calculated, was 77 persons. The lowest quintile had a sample size of 25 or less and the highest quintile had 448 or more.

Although the central interest in this paper is on trends in obesity in developing countries, the available data from these countries usually take the form of mean weight, height, and BMI, as opposed to estimates of the percentage of adults with elevated BMIs, which would be more indicative of obesity. When prevalences are reported, they tend to refer to the percentage of adults with low rather than high BMI values, reflecting the predominant concern for undernutrition in these countries. For these reasons, the primary analysis is based on mean BMI values as the dependent variables. Mean BMIs were directly available for 40% of the observations and could be calculated from mean weight and height in another 40%. The remaining papers provided only prevalence data. Mean BMIs were estimated in these remaining cases by using prediction equations derived from 154 observations in the data set that contained mean BMI data as well as prevalence

data.* Although the use of prediction equations for 20% of the sample introduces an additional random error component, there was no difference between the mean BMIs that were directly reported and those estimated through these equations.

The independent variables used in the analysis include sex, age, year of measurement, region, and socio-economic level. Data for men and women were reported separately in most papers and are treated separately in the analysis. For the minority of observations that combined men and women, those observations are given the same code as the male samples. Data on the age range of the sample were extracted or inferred from the published papers and were used to estimate a midpoint age for use in the analysis. The mean midpoint age for the entire sample was 42 years, with a standard deviation of 12.6 years and with the means for all regions ranging from 39.5 to 46.8 years. The year of measurement was directly reported in most cases and was inferred from the year of publication in the remainder. Although the intention was to include measurements since 1960, the final sample included samples since 1957. Eight regions were defined: sub-Saharan Africa, North Africa and the middle Asian countries, China, India, the remainder of South and South-East Asia, Australasia (Papua New Guinea and related Melanesian groups), Polynesia and Micronesia considered as a single group, and Latin America and the Caribbean considered as a single group. China and India were considered separately because of the size of their populations and their important influences on the world supply and demand for food. All of these regions were found to have sufficient data, except for the North African and middle Asian region, which was deleted from the analysis. In addition, data from China prior to 1982 were very sparse and exerted a large influence on the results in multivariable models. Thus, the China results were analysed with the full data set and separately after excluding the data points prior to 1982.

A socio-economic index was estimated for each observation by using whatever information was provided in the published papers. Information on occupation, rural/urban residence, or other socio-economic indicators was available for 86.3% of the observations, and this information was used to create a combined socio-economic index. Although the nature and extent of this type of information vary widely across studies, an index was created with three "socio-economic levels." Depending upon the information available, the lower level may represent rural populations, poor urban or peri-urban populations, traditional or agricultural occupations, or a variety of other descriptors of poverty as used by the authors. The higher socio-economic stratum represents sedentary, skilled, or high-wage occupations, students, "urban" samples not further distinguished by the authors, or groups designated as well-off or of high socio-economic status (SES) by the authors. The middle level includes mixed samples, those employed in the formal sector but not in high-wage jobs, "housewives," the unemployed, and those designated as mid-level status by the authors. The middle level also includes the 13.7% of observations that could not be clearly classified in the other two levels because no information was available. The resulting socio-economic index is assumed to represent an ordinal variable whose primary validity relates to intra-paper comparisons as presented in the original papers and may have additional validity across papers from the same country or region. However, the index is assumed to have much weaker validity across regions and cannot be used to make strict comparisons across regions.

Table 2 provides a breakdown of the sample according to socio-economic level and region. The distribution of observations by socio-economic index favours the lowest category in the case of sub-Saharan Africa, India, South and South-East Asia, and Australasia, where roughly 50% to 65% of observations fall into this cat-

TABLE 2. Distribution of samples according to socio-economic index and region

Region	Socio-economic index[a]		
	Lower	Middle/ mixed/ unstated	Higher
Sub-Saharan Africa	65.4	21.2	13.5
South and South-East Asia	48.7	28.2	23.1
India	54.6	18.2	26.8
China	18.6	7.8	73.6
Australasia	56.7	32.3	10.9
Polynesia and Micronesia	34.6	36.2	29.1
Latin America and Caribbean	31.8	52.5	15.7
North Africa and middle Asia	30.4	42.9	26.8
All regions	46.8	29.4	23.8

a. The index is a composite variable based on residence (rural/urban), occupation (10 categories), and/or information provided in the text of each paper; 13.7% of observations could not be classified and were assigned to the middle category. In the final regression analyses, the middle and higher SES categories were combined into a single group to simplify interpretation.

* A variety of prediction models were tested, but the final one adopted for this purpose expresses mean BMI as a function of the prevalence above or below a given cut-off point, the cut-off point itself, the square and cube of the prevalence, and an interaction term between prevalence and the cut-off point. This equation has an R^2 value of 85% and a standard error of the estimate of 1.9 for estimating mean BMI.

egory and the remainder are divided between the middle and highest categories. The opposite pattern is seen with the China samples, in which 74% of observations were classified into the highest level. The remaining regions have more balanced distributions. For reasons given above, these distributions are assumed to reflect the characteristics of the particular sample of studies used in this study, rather than the regions as a whole, and the socio-economic distinctions are primarily assumed to have internal validity (i.e., within-paper and within-country validity).

The statistical analysis employed here is hierarchical multiple regression using the MIXED procedure in SAS [10]. In this analysis, the 66 countries and 176 papers are treated as random covariates whose influences on mean BMI are removed before testing for the fixed effects of year, region, age, sex, and socio-economic index. This procedure adjusts for the non-independence of observations derived from a given paper and from multiple papers within the same country. This is a powerful advantage, because it takes account of unmeasured sources of variation in mean BMI among papers and among countries (which are expected to be powerful sources of variation) before estimating temporal trends (year) and other sources of variation (region, age, sex, and socio-economic index). In addition to estimating the main effects from these sources, models were created with interaction terms to test for differential time trends in BMI across various regions, age and sex groups, and socio-economic groups. In all analyses, the continuous variables (year and midpoint age) are centred near their means to facilitate interpretation. Thus, the variable year represents the number of years intervening between 1975 and the year of measurement, and the variable age represents the number of years by which the midpoint age deviates from 45.

Results

The mean BMI, weight, and height for this sample of studies are shown in table 3 according to region. BMI is lowest in India (20.1) and the rest of South and South-East Asia (20.2), followed by sub-Saharan Africa (21.2), China and Australasia (22.1), North Africa and middle Asia (23.2), and Latin America and the Caribbean (23.3). Polynesia and Micronesia has the highest mean BMI (28.5), which stands out from the rest of the sample.

Table 4 presents the results of three hierarchical regression models to estimate the influence of the two random effects variables (country and paper) and the two fixed effects of greatest interest here (year and region). As revealed by the variance estimates in model 1, country and paper do contribute significantly to the observed variance in BMI. In model 2 it can be seen that the addition of region reduces the apparent influence of country, but country and paper both remain significant variables. Region itself is highly significant in model 2 ($F = 16.89$, $p < .0001$), and the coefficients for each region conform to the same ranking of regions as that shown in table 3. Model 3 reveals that there is a significant positive coefficient for the variable year ($p = .0043$), suggesting that for the developing world as a whole, mean BMI has increased by 0.038 kg/m^2 per year during the period from 1957 to 1994. This implies an increase of 1.41 kg/m^2 over the entire period, with a 95% confidence interval of 0.44 to 2.37 kg/m^2.

Table 5 presents the F ratios and significance levels for regression models that incorporate an increasing number of main effects and interaction terms. In reviewing the results of these models, particular attention is given to the main effect of year and its interaction with other main effects, in order to understand the ways in which the temporal trends in mean BMI

TABLE 3. BMI, weight, and height according to region

Region	N^a	BMI (kg/m^2)	Weight (kg)	Height (cm)	N^b
Sub-Saharan Africa	312	21.2±2.5	55.7±6.3	164.8±6.9	196
South and South-East Asia	156	20.2±1.8	49.3±5.1	156.8±7.0	50
India	203	20.1±2.4	47.3±8.0	156.2±9.2	102
China	128	22.1±1.4	52.7±3.1	161.8±6.2	6
Australasia	201	22.1±2.3	51.2±7.0	154.2±6.6	116
Polynesia and Micronesia	127	28.5±3.2	73.0±8.4	164.5±6.4	42
Latin America and Caribbean	231	23.3±1.9	56.4±6.8	156.1±7.4	70
North Africa and middle Asia[c]	54	23.2±2.0	56.6±6.4	158.6±7.9	23
All regions	1,412	22.2±3.2	54.1±9.2	159.4±8.6	605

Plus-minus values are means ± SD.

a. Sample sizes refer to the total number of observations in the data set, with the number of observations from each published paper being determined by the number of persons of each age, sex, and SES for which BMI, weight, or height was reported.

b. Sample sizes refer to observations reporting mean weight and height instead of, or in addition to, mean BMI or BMI prevalences.

c. This region is excluded from subsequent analyses because most observations arise from only three countries, each measured at only one point in time.

TABLE 4. Results of hierarchical regression analysis on BMI

Model	Independent variable	Coefficient	*P*
1	Country	5.03	.0001
	Paper	1.94	.0001
	Residual	2.22	.0001
	Intercept	22.59	.0001
2	Country	1.58	.0015
	Paper	2.02	.0001
	Residual	2.18	.0001
	Intercept	20.81	.0001
	Sub–Saharan Africa	0.74	.2709
	South and South–East Asia	–0.11	.8414
	China (full)[a]	–0.13	.8479
	Australasia	2.32	.0001
	Polynesia and Micronesia	6.59	.0001
	Latin America and Caribbean	2.66	.0001
	India (reference)	—	—
3	Country	1.64	.0012
	Paper	2.00	.0001
	Residual	2.17	.0001
	Intercept	20.61	.0001
	Sub–Saharan Africa	0.74	.2748
	South and South–East Asia	–0.12	.8306
	China (full)[a]	–0.16	.8117
	Australasia	2.28	.0001
	Polynesia and Micronesia	6.66	.0001
	Latin America and Caribbean	2.73	.0001
	India (reference)	—	—
	Year	.038	.0043

a. Includes all data points from China.

may vary across regions, age and sex groups, and socioeconomic groups. Note that the middle and upper socioeconomic groups have been merged into a single category in the results presented here, to simplify the interpretation.

Model 3 in this table corresponds to model 3 in table 4 and is repeated here for the sake of continuity. As shown, the effects of year and region are both highly significant. The addition of the other main effects (model 4) reveals that sex, SES, and age are all strongly associated with variation in mean BMI, and region remains a highly significant variable in this model. The *F* ratio for year is reduced to 2.97, with a positive regression coefficient of .021 and a probability value of .0851.

Model 5 includes an interaction term between region and year, to test whether the apparent increase in mean BMI over time varies across regions. The *F* ratio for the interaction term is statistically significant and restores the *F* ratio for year to statistically significant levels ($F = 7.14$, $p = .0077$). Model 6 further includes the interactions between region and each of the other explanatory variables (age, sex, and SES). The *F* ratio for each of these is highly significant, indicating that these variables are differentially associated with mean BMI across the regions. The *F* ratio for the year main effect remains significant ($F = 4.36$, $p = .0370$).

Model 7 includes the three-way interactions involving year and region with each of the other variables in turn (age, sex, and SES). The three-way interactions involving sex and age-squared are not statistically significant. Those involving SES and age are significant, indicating that the region-specific time trends in mean BMI vary with age and SES group. The main effect of year remains statistically significant in this model ($F = 5.59$, $p = .0182$). Model 8 includes the two-way interactions between year and each of the other explanatory variables, along with two-way interactions involving age, sex, and SES. The statistically significant interactions among this group are year by age, age by SES, and SES by sex. As before, the year main effect remains statistically significant ($F = 4.63$, $p = .0316$).

In order to examine the implications of these results for time trends in mean BMI, a series of predicted means was generated for men and women from each region, stratifying by the SES variables. The results from model 6 were used for this purpose in order to incorporate the strong effects of the interactions in that model. Although some of the interaction terms in models 7 and

TABLE 5. Results of hierarchical regression analysis on BMI incorporating age, sex, SES, and interactions (*F* values)[a]

Independent variable	df	Model					
		3	4	5	6	7	8
Year	1	8.19***	2.97*	7.14***	4.36**	5.59**	4.63**
Region	6	16.87****	18.82****	15.67****	16.03****	14.88****	14.56****
Sex	1		37.87****	38.19****	50.80****	16.25****	14.22****
SES	1		179.45****	174.14****	186.14****	43.21****	49.11****
Age	1		2.71*	2.58	2.84	0.00	0.00
Age^2	1		83.49****	83.76****	100.81****	57.55****	54.66****
Year × region	6			2.60**	1.9*	2.00*	2.06*
Sex × region	6				16.27****	15.61****	15.05****
SES × region	6				6.67****	2.21**	2.10**
Age × region	6				12.90****	9.24****	6.21****
Age^2 × region	6				6.84****	6.13****	6.37****
Year × region × sex	7					1.75*	2.13**
Year × region × SES	7					2.12**	2.59**
Year × region × age	7					2.23***	1.92*
Year × region × age^2	7					0.09	0.23
Year × age	1						2.77*
Year × age^2	1						.28
Year × sex	1						1.49
Year × SES	1						.01
Age × sex	1						.60
Age^2 × sex	1						.44
Age × SES	1						28.05****
Age^2 × SES	1						1.86
Sex × SES	1						15.83****

a. *F* values refer to type III sums of squares in which all other model variables are controlled simultaneously. All models include country and paper as random effects, as in table 6, which were significant in all cases. Includes all data points from China.

$p \geq .100$ for figures with no asterisk.

* $.05 < p < .10$.

** $.01 < p < .05$.

*** $.001 < p < .01$.

**** $p < .001$.

8 are also significant, the precision of the time-trend estimates from these models is likely to be much lower, and therefore they were not used for this exercise. The results from model 6 were used to estimate the mean BMI levels in various groups in the years 1960 and 1990. The SES stratification contrasts the low socio-economic group with all others (middle and high combined). The results are shown in table 6 and figure 1.

The overall conclusion is that predicted mean BMI increases over time in men and women from both SES strata and from all regions except Australasia (representing Papua New Guinea and island Melanesians). High-SES groups have higher mean BMIs than low-SES groups in all regions, all time periods, and both sexes. The magnitude of this SES difference varies across regions and between the sexes. The steepest slope estimates for mean BMI on year are found in Polynesia and Micronesia, and intermediate slopes are estimated in sub-Saharan Africa, South and South-East Asia, Latin America and the Caribbean, and China. India's estimated slope is virtually zero, and Australasia's slope is negative.

It should be noted that the results for China described above are based on all data points available for this analysis, i.e., the row labelled "China (full)." Model 6 was also tested after excluding eight data points from the early 1970s in China, which are the only other data points available for that country before the 1980s. The deletion of these data points has a dramatic effect on the slope estimate (B=1.477) and on the estimates of mean BMI for China in 1960 and 1990. This suggests the possibility that a modest increase in BMI may have taken place during the 1970s in China, but a much more rapid increase took place during the 1980s.

Finally, the data in table 6 were converted into order-of-magnitude estimates of the prevalence of underweight, overweight, and obesity to gain some perspective on the extent to which changes in mean BMI are associated with changes in prevalences. This conversion was accomplished through the use of normal curve properties after making some assumptions about the

TABLE 6. Predicted mean BMI according to region, year, sex, and SES (from model 6)

Region	Slope[a]	High SES		Low SES	
		1960	1990	1960	1990
Women					
Sub-Saharan Africa	.207	23.2	23.8	21.4	22.0
South and South-East Asia	.169	20.9	21.4	20.3	20.8
China (full)[b]	.106	20.1	23.3	18.0	21.1
India	.048	21.6	21.8	19.5	19.7
Australasia	–.295	24.1	23.2	22.7	21.9
Polynesia and Micronesia	.957	27.9	30.8	25.7	28.6
Latin America and Caribbean	.112	24.8	25.1	23.8	24.1
China (1980s)	1.477	18.5	22.9	17.7	22.1
Men					
Sub-Saharan Africa	.207	22.1	22.7	20.3	20.9
South and South-East Asia	.169	20.9	21.4	20.4	20.9
China (full)[b]	.106	19.8	22.9	17.4	22.2
India	.048	21.5	21.6	19.4	19.5
Australasia	–.295	24.6	23.7	23.2	22.4
Polynesia and Micronesia	.957	26.0	28.9	23.8	26.6
Latin America and Caribbean	.112	24.2	24.6	23.2	21.8
China (1980s)	1.477	18.1	22.6	17.4	21.8

a. Represents the estimated change in mean BMI per decade.
b. Includes all data points from China.

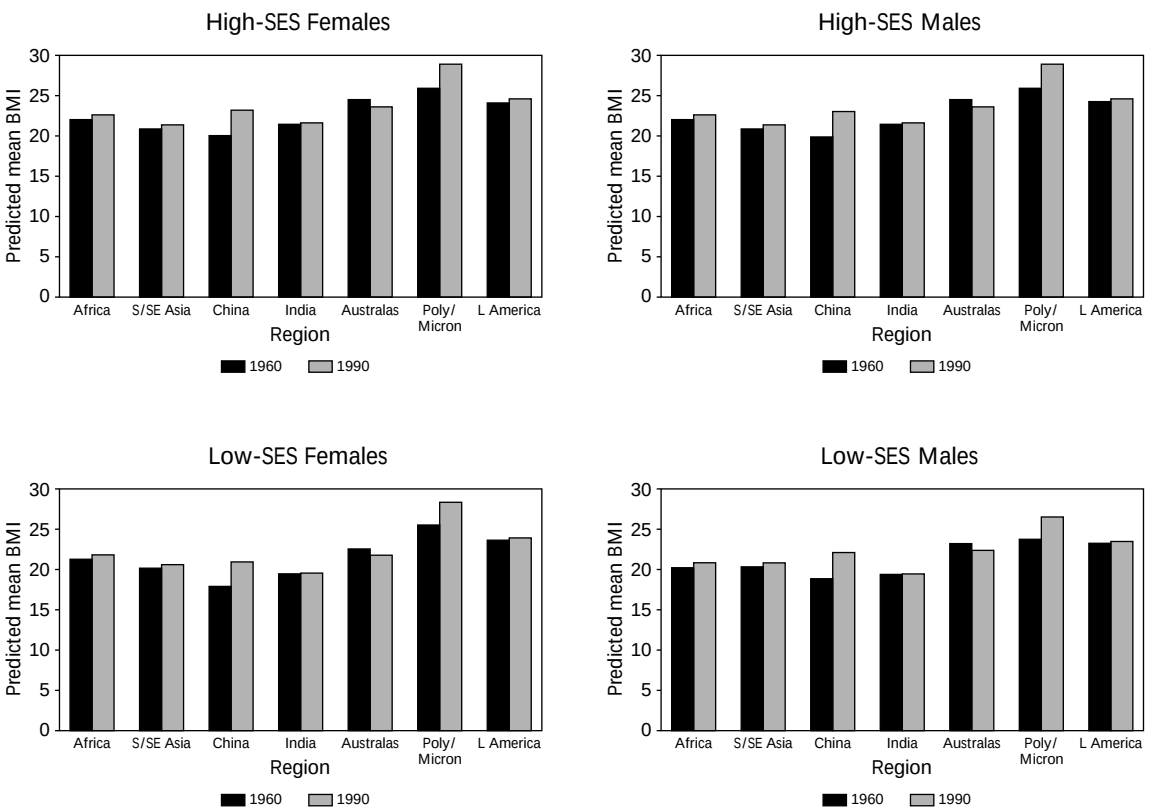

FIG. 1. Predicted mean BMI according to region, year, SES, and sex (from model 6)

TABLE 7. Calculated prevalence of underweight, overweight, and obesity according to region, for high-SES women and low-SES men

Region	Underweight (BMI < 18.5 kg/m^2)		Overweight (BMI > 27 kg/m^2)		Obesity (BMI > 30 kg/m^2)	
	1960	1990	1960	1990	1960	1990
High-SES women						
Sub-Saharan Africa	7.1	6.1	11.7	17.4	1.7	3.5
South and South-East Asia	15.1	12.5	0.5	1.3	0.0	0.0
China (full)	21.8	7.0	0.0	12.7	0.0	1.9
India	11.7	10.4	1.9	2.6	0.1	0.1
Australasia	5.7	7.1	20.6	11.7	4.8	1.7
Polynesia and Micronesia	2.9	2.1	57.1	73.6	33.7	55.2
Latin America and Caribbean	4.9	4.6	28.1	31.2	8.5	10.5
China (1980s)	50.0	7.8	0.0	9.2	0.0	1.1
Low-SES men						
Sub-Saharan Africa	19.8	15.1	0.1	0.5	0.0	0.0
South and South-East Asia	19.0	15.1	0.1	0.5	0.0	0.0
China (full)	35.8	10.5	0.0	4.5	0.0	0.3
India	30.5	29.1	0.0	0.0	0.0	0.0
Australasia	7.1	8.9	11.7	5.6	1.7	0.4
Polynesia and Micronesia	6.1	3.5	17.4	47.4	3.5	22.4
Latin America and Caribbean	7.1	6.4	11.7	15.6	1.7	2.8
China (1980s)	35.8	11.0	0.0	2.6	0.0	0.1

standard deviation of BMI.* Cut-off values of 18.5 and 30.0 were used for estimating underweight and obesity, respectively [12], and an arbitrary cut-off value of 27.0 was used for estimating overweight. This analysis was performed for high-SES women and low-SES men, which represent the groups with the highest and lowest mean BMIs, respectively, in table 6. As shown in table 7, the estimated prevalence of underweight is far greater than the prevalence of obesity in most of the world, even in 1990. This is seen in sub-Saharan Africa, South and South-East Asia, China, India, and (among low-SES men) Latin America. High-SES women in Latin America and the Caribbean are an exception, in that the estimated prevalence of obesity is somewhat greater than the prevalence of underweight. Polynesia and Micronesia also differ (markedly so) from the rest of the world, in displaying much higher prevalences of obesity than underweight. Even when the much lower cut-off point of 27.0 is used, these estimates suggest that underweight remains the more common condition among low-SES men in most regions, even in 1990. Among high-SES women, however, the use of this lower cut-off point creates the appearance that overweight is surpassing underweight as the more common condition in sub-Saharan Africa, China, Australasia, and (for both sexes) Latin America. This lower cut-off point has little effect on the prevalence estimates in India and South and South-East Asia.

Discussion

The present analysis represents a second-best strategy for estimating time trends in BMI in developing countries, the choice of which is necessitated by the virtual absence of large-scale, representative surveys at two points in time in such countries. That said, the approach has several strengths, including the existence of a large number of small-scale surveys from a wide variety of countries in all major regions; the availability of ancillary information on age, sex, and socio-economic characteristics to refine the estimate of time trends and explore a variety of interactions; and the use of a hierarchical modelling procedure that permits the statistical removal of any "extraneous" variation in BMI that may be associated with a particular country or survey (e.g., differences in level of economic development,

* The standard deviation of BMI was assumed to vary in a linear fashion from 2.0 in low-BMI populations (i.e, BMI=20, as in Norgan [11]) to 3.5 in medium-BMI populations (i.e., BMI=24, as in WHO [12], p. 337) to 5.0 in high-BMI populations (i.e., BMI=28, as in Pawson [13]). By further assuming that BMI is normally distributed, the normal variate (Z) was calculated for each mean BM

The percentages of individuals with BMIs above or below the cut-offs specified in table 7 were then estimated using tabled values for the cumulative normal frequency distribution.

genetic or climate-related influences on adult physique, and survey methods that may vary across studies).

If the results concerning time trends had supported the null hypothesis (i.e., no evidence of trends in BMI), they would have had numerous possible explanations, notably the existence of excessive random error in the mean BMI data. As it stands, the results suggest an *increase* in mean BMI for most regions of the world, which is unlikely to have arisen due to random error in the mean BMI data. Thus, the only serious threat to the validity of the time-trend findings would be if more recent surveys in each country or region were purposely conducted (or published) in populations at risk for higher mean BMI or obesity, whereas the older studies were conducted in populations less prone to obesity. In all likelihood, this would have taken the form of more frequent surveys in the urban or high-SES in recent years, but the use of an SES index in the analysis serves as a control against this possibility. It is notable (from table 5) that the main effect for year remains statistically significant, regardless of whether the SES main effect or its interaction with year is included in the model.

Of perhaps greater importance for interpreting the present results are the biological considerations related to BMI and, in particular, the extent to which increases in obesity can be inferred from these findings. BMI is a convenient indicator of obesity at high cut-off points (e.g., a value of 30 as recommended by WHO [12]), but it is much less useful at lower values when applied at an individual level. For instance, among 138 male Italian shipyard workers with an average BMI of 25.3 kg/m^2 and 22.3% body fat (estimated through densitometry), the standard deviation in percentage of body fatness at a given BMI was 4.0% [14]. Although BMI in that sample was highly correlated with percentage of body fat (r =.75), it was equally correlated with fat-free mass (r =.68). Similar results are observed among men and women from Papua New Guinea and Ethiopia, whose mean BMIs are at the lower end of the range for developing countries seen in the present study (19–22 kg/m^2) [11]. Thus, among adults in developing countries, variation in BMI may be as much a reflection of variation in fat-free mass as fat mass and cannot be reliably used to infer percentage of body fat at the individual level across the low-to-moderate range of BMI values.

In contrast to these interpretational difficulties associated with cross-sectional, inter-individual variation within the moderate range of BMI values, a different set of considerations applies to this paper, which focuses on the group level and on trends in mean BMI over time. First, through an analysis of 285 *samples* of adult men and women from developing countries, Norgan [15] concluded that, at least over the range of BMIs from 20 to 25 kg/m^2, the slight inter-population differences in the relationship between BMI and body composition are unlikely to be meaningful in epidemiologic studies. This conclusion is even more valid in the present case, because the focus is on trends over time *within* countries and regions, rather than cross-sectional differences among countries. Second, at the population level, the mean BMI is an indicator of the central tendency of a distribution of individual BMIs, with some individuals exceeding conventional cut-off points for obesity (e.g., 30 kg/m^2). Groups with relatively high mean BMI are likely to have a higher prevalence of obesity thus defined. The only caveat would be if the variance in BMI becomes compressed as mean BMI increases, but the common observation is just the opposite: groups with high mean BMI tend to have an expanded variance above the median due to greater variance in the upper tail, suggesting that the prevalence of obesity in a population increases in an accelerating fashion as the mean BMI increases (see footnote on page 231).

Applying a population-level interpretation to time trends in mean BMI provides some basis for investigating possible increases in obesity. As shown in table 6, mean BMI appears to have increased in most regions of the world from 1960 to 1990 (with the exception of Australasia), although the size of this increase varies widely across regions. Although this might seem to support the notion that obesity is increasing in the developing world, the results in table 7 suggest otherwise. Specifically, those results suggest that the prevalence of obesity, as defined by a cut-off BMI value of 30 kg/m^2, is not estimated to have increased substantially in most major regions of the world during this period. The reason for this apparent contradiction is that the mean BMI of adults in most regions remains well below the cut-off point of 30 kg/m^2, even in 1990. These results further suggest that the prevalence of underweight (defined as BMI < 18.5 kg/m^2) has shown a slight decline in most regions but remains far higher than the prevalence of obesity.

For reasons given above, the results of the hierarchical regression analysis that is the foundation for this study are likely to be valid for estimating the overall trends in mean BMI in the past three decades, but there is likely to be much lower precision in the estimates of region-specific trends (because of a smaller number of observations in each region). Thus, the most conservative and defensible conclusion from these data is simply that mean BMI has increased in developing countries since 1957 and that this probably reflects a slight increase in overweight (as defined by a moderate cut-off point of BMI > 27 kg/m^2) in certain regions of the developing world, but the increases in mean BMI seen to date do not appear to be associated with an increase in obesity (as defined by the recommended cut-off point of BMI > 30 kg/m^2). To the contrary, the increase in mean BMI is likely to be associated with a slight decline in underweight (defined as BMI<18.5 kg/m^2), but underweight remains the more common condition in most developing regions.

Notwithstanding the above conclusions, four caveats are in order. First, the overall trends suggested in this study refer to large geographic regions, and in no way do they preclude the possibility that obesity exists and is on the increase in smaller geographic areas and/or socio-economic groups. Second, this study does provide evidence that the general upward trend in mean BMI is likely to continue in the future if the underlying behavioural and socio-economic trends persist. This is suggested by the strong cross-sectional association between mean BMI and the socio-economic index in the present study, which is especially marked in certain regions. Third, the cut-off values used here to define underweight and obesity conform to WHO recommendations [12], but these precise cut-off values are not equivalent in statistical and functional terms (e.g., as risk factors for infectious and/or chronic disease in different environments), and the social implications of these two conditions differ markedly (e.g., in terms of social equity in access to food). Finally, this study (specifically, table 7) underscores the common knowledge that estimates of the prevalence of "obesity" (and changes over time) can vary widely, depending upon the cut-off point used to define that condition. The use of low cut-off points to define obesity (e.g., as low as 25 kg/m^2 in some papers) may create the appearance of a current or emerging obesity problem in developing countries and contribute to a shift in policy attention from undernutrition to overnutrition when the social and health conditions may not warrant it.

Given the long time lags required for the development and implementation of preventive policies and programmes, the strong association between socio-economic factors and mean BMI in this study does reinforce the belief that developing countries eventually will face greater heterogeneity in nutrition-related problems. One of the challenges this creates at the policy level is to continue to find ways to meet the energy and nutrient needs of the undernourished segments of rural and urban populations in developing countries, while simultaneously ensuring healthful diets and physical activity patterns to prevent chronic disease in some of these same populations [16]. Although several categories of policy instruments have been identified for intervening in the quality of the diet of populations [17], in the current policy climate the more powerful of these may be construed as trade barriers and/or questionable interference in domestic markets (e.g., legislation, regulation, taxes, and subsidies). In addition, given the administrative weaknesses in many developing countries, it may be difficult to design these instruments in such a way that control of one form of malnutrition (e.g., protein–energy malnutrition) is not compromised by attempts to reduce or prevent another form (e.g., chronic disease–related malnutrition). The reconciling of these trade-offs at the analytical and operational levels is likely to be one of the key challenges for nutrition policy in the coming decades.

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Appendix. Data Sources

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Stability of iodine in iodized salt used for correction of iodine-deficiency disorders. II

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Abstract

The purpose of this study was to assess the effect of humidity and packaging materials on the stability of iodine in typical salt samples from countries with tropical and subtropical climates, under controlled climatic conditions. Initially we examined eight samples. In the second phase we expanded the study to salts from 18 sources and attempted to correlate the observed stability with salt impurities naturally present in these samples. High humidity resulted in rapid loss of iodine from salt iodized with potassium iodate, ranging from 30% to 98% of the original iodine content. Solid low-density polyethylene packaging protected the iodine to a great extent. High losses were observed from woven high-density polyethylene bags, which are often the packaging material of choice in tropical countries. Impurities that provided moisture at the salt surface had the most deleterious effect. Although clear correlations were not obtained, the presence of reducing agents, hygroscopic compounds of magnesium, and so forth seemed to have the most adverse effects on the stability of iodine. Surprisingly, carbonates had little effect on stability over the range present in the samples. Packaging salt in low-density polyethylene bags, which provided a good moisture barrier, significantly reduced iodine losses, and in most cases the iodine content remained relatively stable for six months to a year. The findings from this study indicate that iodine can be highly unstable, and in order to ensure the effectiveness of local salt-iodization programmes, countries should determine iodine losses from local iodized salt under local conditions of production, climate, packaging, and storage.

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Introduction

Perhaps the greatest recent success of public health programmes has been the rapid expansion of salt-iodization programmes throughout the world during the past decade. The food supply of more than 1.6 billion people is lacking in adequate levels of iodine, resulting in the widespread prevalence of a spectrum of iodine-deficiency disorders, and the regular delivery of small doses of iodine to large populations through salt is beginning to have a dramatic effect. More than 50% of the world's population now has access to iodized salt, and the virtual elimination of iodine-deficiency disorders in the world by the year 2000 has been set as a goal at several international forums, including the World Health Assembly [1], the World Summit for Children [2], and the International Conference on Nutrition [3].

Salt is an excellent carrier for iodine, as it is consumed at relatively constant, well-definable levels by all people within a society, independently of socio-economic status. Salt is iodized by the addition of fixed amounts of potassium iodide or iodate, as either a dry solid or an aqueous solution, at the point of production or import.

The actual availability of iodine from iodized salt at the consumer level can vary over a wide range as a result of:

» variability in the amount of iodine added during the iodization process;
» uneven distribution of iodine in the iodized salt, within batches and individual bags;
» losses of iodine due to salt impurities, packaging, and environmental conditions during storage and distribution;
» losses of iodine due to food processing, washing, and cooking processes in the household.

In order to determine the appropriate levels of iodization, an accurate estimate of the losses of iodine occurring between the time of iodization and consumption is required. The purpose of this study was to determine trends in iodine losses from typical salt samples

from 12 countries. Salt samples were iodized with potassium iodate (KIO_3) and stored in typical packaging materials under controlled temperatures and humidities typical of those experienced by packaged salt in many developing countries.

Iodization level

The stability of iodine in salt and levels of iodization are questions of importance to national planners and salt producers, as they have implications for programme effectiveness, safety, and cost. Higher levels of iodine may need to be added to compensate for losses due to known high levels of impurities in salt or the use of lower-grade packaging. This added cost must be compared with the cost of producing more stable, purified salt and the cost of enhanced packaging, while keeping in mind the consumer's need for continuity in sensory qualities of the salt. Significant changes from the traditional products may result in higher costs to the producer and consumer, or reduced consumer acceptability, thus reducing the sustainability of the iodization programme.

Typical iodization levels vary from approximately 30 to 100 μg of iodine per gram of salt. In this work the salt was iodized with potassium iodate at a level of 50 μg of iodine per gram of salt—a value typical of many iodization programmes in tropical and subtropical countries.

Stability of iodine in salt

Elemental iodine readily sublimes and is then rapidly lost to the atmosphere through diffusion. Potassium iodide can be oxidized to elemental iodine by oxygen or other oxidizing agents, especially in the presence of catalysts, such as metal ions, and moisture. Thus, in affluent markets, iodide is always added to salt together with a reducing agent, such as dextrose, and a desiccant or anti-caking agent is usually included.

Potassium iodide can be reduced to elemental iodine by a variety of reducing agents in salt. Moisture naturally present in salt or abstracted from the air by hygroscopic impurities such as magnesium chloride acts as the reaction medium for the decomposition of added iodate. The pH of the condensed moisture on the salt is influenced by the type and quantity of impurities present, and this may in turn affect the stability of the iodine compounds. As in most chemical reactions, elevated temperature increases the rates of the reactions that form elemental iodine and increases the rate of evaporation of iodine.

Salt is extracted from a variety of sources, and the degree of purity depends on the source, extraction, and purification methods used. As a result, salt that is available for iodization may contain not only sodium chloride but also carbonate and sulphates, insoluble matter, and moisture. Physically, salt may be sold as large, crude crystals or as a refined, pure, dry powder.

On the basis of the chemistry, losses of iodine were not unexpected, and there have been a number of published and unpublished studies on the stability of iodine in salt. The relevant published literature was reviewed in the first phase of this programme [4]. The experiments conducted in the first phase clearly indicated that high humidity reduces stability, while the use of a good vapour barrier, which prevents the penetration of moisture and the evaporation of iodine, clearly improved the stability of iodine in iodized salt samples.

In this second phase of the study, the number of samples tested was expanded from the initial 8 to 18, including a Canadian salt as a reference sample. A sample from China was tested at two different levels of added iodine, as its iodine stability in the initial tests was unexpectedly low. The trace components of 23 samples were analysed, and attempts were made to correlate them with the observed iodine stability.

Packaging materials

Salt is sold in developing countries both in consumer packages of up to 2 kg and in bulk. Packaging materials in wide use in developing countries include paper, high- and low-density polyethylene, and woven bags made of jute, straw, or high-density polyethylene. The first phase of the study indicated that solid, non-woven polymer bags were the best moisture barriers and, if properly sealed and intact, would maintain the moisture level of the salt throughout the distribution system, thus minimizing the loss of iodine following the absorption of moisture and subsequent chemical reactions. Accordingly, a solid film of low-density polyethylene and a woven bag of high-density polyethylene were used in the second phase of the study.

Objectives

The purpose of the second phase of the study was to assess the stability of iodine in typical salts, in an effort to identify the causes and extent of iodine loss. The effects of humidity, purity of the salt, and packaging materials on the stability of iodine in typical salt samples from countries with tropical and subtropical climates were determined under controlled climatic conditions. In the short term, the results may be useful for assessing potential losses of iodine from salt between the points of production and consumption. The overall goal of the study was to determine the range and timing of iodine losses that may be expected under typical conditions when iodine is added to salt in the form of iodate, and thus to define the most cost-effective means of controlling or compensating for these losses, to ensure that populations at risk for iodine-deficiency disorders receive effective amounts of iodine from iodized salt.

Materials and methods

Materials

Potassium iodate, analytical reagent grade, was obtained from BDH, Toronto.

Samples of un-iodized salt, such as that consumed by low-income populations, were obtained from 12 countries: Bangladesh, Bolivia, China (two levels of addition), Ghana, Guatemala, India (five sources), Indonesia (four sources), Pakistan, Philippines (three sources), Senegal, Thailand, and Tanzania. The samples were obtained through UNICEF country offices from routine production runs from local salt producers and air shipped to Toronto.

A sample of un-iodized refined salt obtained from Toronto Salt Chemical Co. was also tested. This Canadian sample was used as a reference.

Sample treatment

Salt samples with particle sizes less than 2 mm were used without pre-grinding. Because wet salt could not be sieved, salt samples containing large particles and having a moisture content over 3% were dried in a forced-convection oven at 70°C overnight, ground by mortar and pestle, and sieved to pass through a 10-mesh sieve. The water content was then reconstituted to the original moisture level.

Two-kilogram samples of salt from each source were fortified to contain about 50 mg/kg iodine using potassium iodate added as a 30 g/L solution. The mixtures were blended to ensure uniformity using a 5-L ribbon blender (LeRoy Somer, LSTronics, Montreal).

Packaging materials

In the second phase of the programme, two packaging methods were tested, as the use of open containers was shown to be impractical in the first phase of the programme. For each treatment condition, two 500-g samples were prepared in solid (continuous-film), low-density polyethylene bags, 0.07 mm in thickness, and in woven, high-density polyethylene bags, 0.15 mm in thickness. The bags were folded closed but were not sealed. Both low-density polyethylene and high-density polyethylene are clear, transparent or translucent, plastic materials that are extruded as a thin sheet. High-density polyethylene has a much higher tensile strength, as it is made of longer molecular chains. Low-density polyethylene was made into bags by folding the sheets into appropriate shapes and welding the seams by heating, whereas high-density polyethylene bags were made by cutting the sheets into thin strips 1.5 to 2 mm wide and weaving them into a "cloth," which was then sewn to form bags. Even though high-density polyethylene does not absorb water, the woven bags readily allow the passage of water through the weave.

Storage conditions

The packages were stored under two conditions: elevated temperature and high humidity (40°C, 100% relative humidity) and elevated temperature and medium humidity (40°C, 60% relative humidity).

High-temperature, high-humidity conditions were maintained by using a controlled-temperature oven in which the air was saturated with water vapour by exposure to a tray of water. High-temperature, medium-humidity conditions were maintained in an environmental chamber manufactured by Associated Environmental Systems Division of Craig Systems Corporation (Toronto). Temperature and humidity were automatically monitored.

Analytical methods

Sampling

Packages of salt were sampled at the start of the experimental series (denoted as 0 months in the results) and after 1, 2, 3, 6, and 12 months of storage. To obtain a representative and reasonably homogeneous sample for analysis, the complete solid salt content of a bag was split into two equal subsamples by pouring it through a two-stemmed powder funnel. The splitting of the sample was repeated until only about 15 g of salt was collected. This subsample was used for the analyses.

Moisture

The moisture content was determined gravimetrically. Samples of salt were weighed and then dried at 110°C for 16 hours and reweighed.

Iodine

Iodine content was measured by neutron activation analysis under titration.

Neutron activation analysis

Neutron activation analysis is a non-destructive testing method in which a sample is irradiated at high ray flux in a nuclear reactor, and the specific radiation from selected radioisotopes formed by the irradiation is measured. This technique has a high relative standard deviation (~5%), but it is not subject to interference from reducing or oxidizing agents [5]. Therefore it was used to confirm the results of colourimetric measurements in each sample series.

1. Approximately 1.25 g of salt was accurately weighed into a polyethylene vial. To decrease interference due to the presence of a high concentration of chlorine in the sample, the sample was shielded with cadmium.
2. The vials were irradiated at 1 kW power with a neutron flux of 5.0×10^{11} cm^{-2} s^{-1} for three minutes us-

ing the University of Toronto's SLOWPOKE nuclear reactor.
3. The samples were removed from the reactor and rested for six minutes.
4. After six minutes of delay, gamma emission at 443 keV was measured using a hyperpure germanium–based gamma ray spectrometer.
5. The iodine content was calculated using a calibration curve established by a series of spiked samples that covered the range from 5 to 250 mg of iodine per kilogram of salt.

Titration

The titrimetric analytical method for iodate is more rapid and convenient and significantly less expensive than the neutron activation analysis method. However, there is a potential for large positive or negative errors if the salt contains significant amounts of oxidizing or reducing impurities. All salts were first analysed by neutron activation, but subsequent analyses were done by titration if there was no significant difference between the iodine values obtained by the two techniques.

1. Ten grams of salt was dissolved in approximately 100 ml of water. The pH was adjusted to 2.8 using 0.6% HCl.
2. Thirty milligrams of potassium iodide powder was added (12-fold excess) to convert all of the iodate present to elemental iodine by the reaction:
$$KIO_3 + 5KI + 3H_2O \rightarrow 3I_2 + 6KOH$$
3. The liberated iodine was titrated with 0.004 N freshly prepared sodium thiosulphate solution. Starch was used as the end-point indicator. The relative standard deviation of the analysis was determined to be <1%.

The iodine value obtained by analysis immediately after the time of preparation was used as the starting concentration, at time=0, for all subsequent analyses of the same batch.

Salt impurities

The typical impurities present in salt were determined in each of the salt samples when they were received. The sampling and sample-preparation methods described above were used. The range of analyses is described below.

Elemental analyses

Calcium, magnesium, and iron were measured by atomic absorption spectrophotometry in the absorption mode, using a Perkin-Elmer Model 704 instrument (Perkin-Elmer Canada, Toronto, Ontario). All of the other reported elements were analysed by an inductively coupled argon plasma spectrometer at the facilities of Zenon Environmental (Burlington, Ontario).

Carbonates

Carbonates and bicarbonates were determined by the AOAC standard titrimetric method 33.071 [6].

Results and discussion

All salt samples lost iodine over the 12-month sampling period. Losses ranged from less than 10% to 100% of the original iodine in the sample (from a starting value of 50 μg of iodine per gram of salt ± 5%). The rate of iodate loss was influenced by the salt's origin and composition, the packaging material, and the relative humidity during storage.

Relative humidity

The study was not designed to reproduce the storage conditions of any specific locality. The study's objective was to test extreme conditions that may be encountered in typical distribution systems. As expected, storage of salt samples at 100% relative humidity resulted in the greatest iodine loss. Even under moist, tropical conditions, it is unlikely that the relative humidity would remain at this extreme level for a long period. However, within bags exposed to sunlight, or in storage facilities heated by the sun, the high humidity will be retained, once moisture is absorbed into the bag's contents, and temperatures may readily rise to over 60°C. Only one month of exposure to 40°C and 100% relative humidity resulted in most of the samples in high-density polyethylene bags losing more than 25% of the added iodine.

In all cases, the samples stored at 60% relative humidity lost iodine at a lower rate than those stored in saturated air (100% relative humidity). After six months, storage losses at 60% relative humidity ranged from ~0% to 20%, which is lower than might be expected [7], and losses after 12 months averaged approximately 40%.

At high humidity the losses were more dramatic. Iodine losses over six months of storage ranged up to 100%, indicating that within the 12-month trial period, essentially all of the iodine added to the sample disappeared from high-density polyethylene bags, which are effectively open to the atmosphere.

Packaging material

In the first stage of the study, we demonstrated that packaging type had a significant effect on storage stability. In the second phase of the work, only low-density polyethylene film and high-density polyethylene woven bags were used. Solid low-density polyethylene provided an excellent moisture barrier and thus maintained the total water content of the bags approximately constant, near the level at the time of packaging. Some absorption of moisture was possible, as the bags were not sealed sufficiently to prevent some diffusion of air containing water and/or iodine into and out of the bags.

Woven high-density polyethylene bags readily allowed the moist air to contact the salt and thus release iodine as a vapour, and they also allowed any condensed

moisture to drip out of the bag in the form of a saturated salt solution containing iodate.

The effect of relative humidity and type of container on the average values of iodine retention in all 18 samples tested is presented graphically in figure 1.

Salt purity

The physical characteristics of salt samples, which were affected by the profile of impurities and the extent of processing at the source, had a major effect on the stability of the salt. The salt samples received varied in colour from very bright white to dark gray or rusty brown. The samples had particle sizes ranging from ~100 µm to 30 mm, with great variability in the homogeneity of particle size. A description of all samples is presented in table 1.

A wide range of trace components was found in these samples (table 2). The sample from Guatemala must have been iodized, as it contained 22 µg of iodine per gram of salt. The titrimetric method revealed that it was in the form of iodate.

Two other samples from Indonesia and Pakistan contained oxidizing agents equivalent to 7 and 8 ppm iodate iodine, although the samples contained <1 µg of iodine per gram of salt by neutron activation analysis. Most of the salt samples contained trace amounts of iodine (1–2 ppm by neutron activation analysis). However, this was not a surprise, as earlier studies found similar trace levels in purified sea salt from the United States. This low concentration of iodine cannot be detected by the titrimetric method.

The salt sample from China lost all of its iodine very rapidly, even though it was of high sensory quality, and contained few impurities in significant quantities. Indeed, even at time = 0 a significant loss from the added iodate was observed by the titration method. In an effort to check and quantify this unexpected result, we repeated the test with the addition of 100 µg of iodine per gram of salt as potassium iodate. This sample also showed a rapid initial loss of iodine, but then the iodine level stabilized.

Titration of the un-iodized Chinese salt showed that it contained a reducing agent capable of immediately freeing 14 µg of iodine per gram of salt. On standing, this value would increase slowly, thus accounting for the complete loss of iodine from the addition level of 50 µg of iodine per gram of salt. Subsequently we found that the processor counteracted this effect by adding iodine as potassium iodide. Potassium iodide is actually stabilized by the impurity, which is probably a sulphur compound.

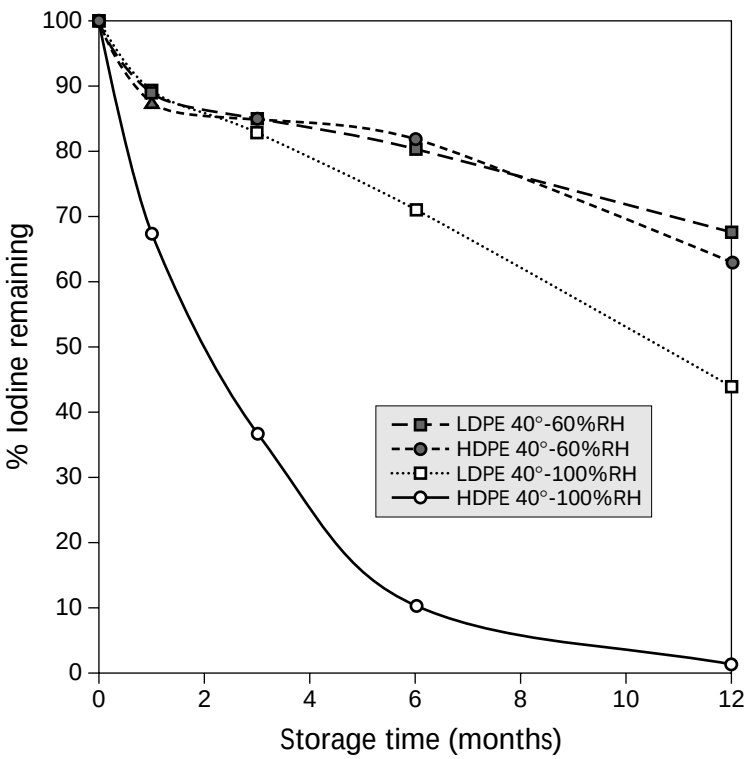

FIG. 1. Effect of relative humidity and container type on iodine retention. Abbreviations: LDPE, low-density polyethylene film bag; HDPE, woven high-density polyethylene bag; RH, relative humidity

Canadian salt, which was of high purity and contained very little moisture or hygroscopic impurities, was relatively stable. At low humidity the iodine losses were less than 10% during the first six months of storage and less than 25% after a year. At 100% humidity the protection of the polyethylene bag maintained iodine losses at less than 8%, whereas in woven high-density polyethylene bags, 63% of the iodine was lost.

Some salt samples with lower levels of purity and higher levels of moisture were as stable as the Canadian sample. Whereas the salts lost, on average, 33% of their iodine after 12 months at 60% relative humidity in low-density polyethylene, salts from Canada, India, the Philippines, and Senegal lost less than 15% of their iodine after 6 months, even at 100% relative humidity in low-density polyethylene. Only the samples from China lost more than one third of their iodine after six months, yet the average iodine retention dropped

TABLE 1. Physical characteristics of salt samples

Sample no.	Source	Appearance of salt	% insoluble matter	Appearance of insoluble matter
1	Tanzania	Very hard crystals, some brownish-black impurity	2.5	Brownish, claylike substance
2	Bolivia	Very large (3–4 cm) pinkish crystals	0.7	Brown, sandy residue
3	Indonesia (P.T. Garam)	White crystals, some “dirt” sandy residue	1.6	Black, claylike substance with brown,
4	China (Beijing)	White, fine crystalline powder <1 mm	1.2	Fine, brown-black dust
5	Ghana	White crystals 2–5 mm	1.8	Black and brown, sandy material
6	India (Arumuganeri)	Fine white powder <1 mm	2.0	Fine to coarse, brown, sandy material
7	Philippines (code PHI-MI4)	Brownish crystals 2–4 mm	2.0	Black and yellow clay
8	Senegal	White crystals 2–8 mm	0.9	Yellow, sandlike material
9	Canada	White, fine, crystalline powder <1 mm	0.4	No visible residue
10	China repeat	White, fine, crystalline powder <1 mm	1.2	Brown and black dust particles
11	India (Kurkuch)	Brownish, sandlike, 2–4 mm crystals	2.8	Fine to coarse, dark brown, sandy material
12	Pakistan	Slightly brownish crystalline solids	2.5	Light brown, fine dust with white particles ~2 mm)
13	India (Phoda)	Very large, pinkish crystals 5–15 mm	0.7	Brown, claylike material
14	Guatemala	Brown, sandlike powder 2–4 mm	1.7	Black, clay-type residue
15	Indonesia (Central Java)	Yellow crystals 3–8 mm	2.0	Brown, black, clay-type substance
16	Philippines (code PHI-PCS)	White, clean crystals 2–4 mm	0.7	Brown, clay-type material
17	Thailand	White, crystalline powder <1 mm	1.9	Brownish-yellow, clay-type material
18	Bangladesh	White crystals 2–6 mm	0.7	Brown, clay-type and yellow sandy particles
19	India (Tuticorin)	White, crystalline powder <1 mm	2.3	Brownish-yellowish sand- and soil-like residue
20	India (“crushed” sign)	White to brown crystals 2–4 mm	1.9	Black, brown clay-type residue
21	Indonesia (Madura)	Yellow crystals 5–15 mm	3.3	Brown, black clay-type substance
22	Indonesia (West Java)	Yellowish-brown crystals 3–8 mm	0.7	Brown, clay-type substance
23	Philippines (code PHI-B2M)	White, crystalline powder <1 mm	1.7	Fine to coarse, dark, sandy material

TABLE 2. Chemical characteristics of salt samples

Sample no.	Source	pH	Moisture (%)	Carbonates (ppm)	Bicarbonates (ppm)	Total carbonates (ppm)	Calcium (ppm)	Magnesium (ppm)	Barium (ppm)	Potassium (ppm)	Iron (ppm)	Strontium (ppm)	Sulphur (ppm)
1	Tanzania	9.77	11.5	375	488	863	1,400	4,600	6.9	1,800	<50	48	3,500
2	Bolivia	8.48	2.1	10	443	453	2,600	380	<0.2	<500	<50	77	2,400
3	Indonesia (P.T. Garam)	8.78	6.0	35	442	477	1,100	3,300	<0.2	1,300	<50	57	2,500
4	China (Beijing)	8.58	0.2	23	361	384	910	260	<0.2	<500	<50	20	840
5	Ghana	8.32	9.5	5	430	435	2,500	1,700	<0.2	<500	<50	62	2,800
6	India (Arumuganeri)	8.28	2.1	2	454	456	3,800	540	2.3	<500	<50	260	3,200
7	Philippines (code PHI-MI4)	9.35	6.4	245	513	758	3,500	4,100	<0.2	<500	<50	71	4,700
8	Senegal	8.87	3.6	65	432	497	1,900	3,500	<0.2	1,400	<50	84	3,200
9	Canada	6.25	0.4	0	41	41	290	210	<0.2	<500	87	3	160
10	China repeat	8.58	0.2	23	361	384	910	240	<0.2	<500	<50	20	840
11	India (Kurkuch)	7.54	0.7	0	318	318	3,100	700	<0.2	<500	<50	37	2,700
12	Pakistan	9.08	6.2	83	1,396	1,479	5,800	4,300	<0.2	<500	75	180	12,000
13	India (Phoda)	7.86	0.8	0	287	287	2,600	690	<0.2	<500	<50	30	2,200
14	Guatemala	8.72	4.5	50	452	502	6,300	4,000	<0.2	1,600	<50	140	6,700
15	Indonesia (Central Java)	7.88	3.9	0	413	413	2,200	1,900	<0.2	<500	62	48	2,600
16	Philippines (code PHI-PCS)	9.07	3.2	118	671	789	3,100	4,000	<0.2	1,400	<50	85	4,600
17	Thailand	7.94	1.4	0	468	468	750	1,900	<0.2	<500	<50	45	1,600
18	Bangladesh	7.21	1.5	0	825	825	1,100	1,100	<0.2	<500	<50	32	1,300
19	India (Tuticorin)	8.62	3.6	19	363	382	3,000	3,000	<0.2	<500	<50	120	2,400
20	India (“crushed” sign)	7.48	1.8	0	379	379	3,700	740	<0.2	<500	<50	47	3,200
21	Indonesia (Madura)	7.78	5.0	0	1,256	1,256	1,700	3,400	<0.2	1,100	<50	66	3,000
22	Indonesia (West Java)	8.14	2.7	102	470	572	910	2,900	<0.2	<500	<50	42	2,200
23	Philippines (code PHI-B2M)	8.79	13.0	118	671	789	3,300	9,900	<0.2	2,700	<50	110	7,600

to 44% of the amount added at the end of one year of storage. The Tanzanian salt retained only 22% of its iodine after a year under these conditions.

The stability of the samples was significantly lower in high-density polyethylene bags. Whereas at low humidity the losses were, on average, reasonable after six months (18%), after a year the loss rose to 37%. At high humidity the losses were much more significant. Seven of the samples lost half of their iodine content after only one month, and the average iodine retention decreased rapidly to 37%, 10%, and 1% after 3, 6, and 12 months, respectively. The Indian Kurkuch and the Pakistani samples retained more than 90% of the original iodine at three months but only 61% and 28%, respectively, after six months. None of the samples retained more than 12% of the iodine after one year. The results are presented in tables 3 to 6.

There was no clear and consistent correlation between iodine stability and the presence of any impurity. Clearly there are many competing reactions and interactions between the salt impurities and the added potassium iodate. There is a trend towards lower iodine retention with increased magnesium and sulphur content, but the sparing effect of carbonates was not observed at the levels present in the samples. The stability dropped markedly in the first three months when samples were stored at high humidity and the magnesium content exceeded 1,000 ppm. After six months at high temperature and humidity, all samples lost most of their iodine independently of magnesium content, whereas at low humidity all samples were relatively stable (fig. 2).

The effect of pH was also not clear-cut. The data indicated that the stability was lower around pH 8.0, but this effect was not statistically significant. The effects of magnesium and pH are shown in figures 2 and 3.

Conclusions

The study clearly indicates that moisture plays a critical role in the stability of iodine. In particular, when salt is stored at a temperature characteristic of storage and distribution conditions in many developing countries, moisture absorbed by hygroscopic impurities contributes to the rapid loss of iodine. Although the loss of iodine cannot be clearly correlated with any specific impurity on the basis of the present study, it is clear that the use of highly purified salt would improve

TABLE 3. Iodine retention in low-density polyethylene film bags at 40°C and 60% relative humidity

Sample	Origin	% of original iodine remaining after storage for:			
		1 mo	3 mo	6 mo	12 mo
1	Tanzania	95.1	97.8	83.9	70.3
2	Bolivia	89.2	95.3	85.3	68.7
3	Indonesia (P.T. Garam)	98.9	93.7	96.5	79.0
4	China (Beijing)	13.5	3.2	0	0
5	Ghana	93.7	98.9	100.0	88.9
6	India (Arumuganeri)	100.0	98.7	99.1	87.4
7	Philippines (code PHI-MI4)	100.0	100.0	100.0	82.5
8	Senegal	93.8	93.2	93.8	76.1
9	Canada	95.6	94.2	94.9	77.3
10	China repeat (100 ppm)	57.1	54.3	44.5	39.5
11	India (Kurkuch)	100.0	100.0	91.5	69.6
12	Pakistan	89.2	79.4	76.4	69.6
13	India (Phoda)	100.0	87.3	76.1	69.8
14	Guatemala	100.0	88.6	79.3	74.9
15	Indonesia (Central Java)	85.6	71.4	65.6	60.9
16	Philippines (code PHI-PCS)	98.0	95.8	92.0	67.9
17	Thailand	100.0	100.0	91.2	63.6
18	Bangladesh	93.0	82.6	77.9	67.8
	Average	89.0	85.2	80.4	67.4

TABLE 4. Iodine retention in woven high-density polyethylene bags at 40°C and 60% relative humidity

Sample	Origin	% of original iodine remaining after storage for:			
		1 mo	3 mo	6 mo	12 mo
1	Tanzania	89.4	91.5	89.2	69.3
2	Bolivia	92.1	95.0	98.4	68.7
3	Indonesia (P.T. Garam)	95.9	94.3	98.2	78.5
4	China (Beijing)	5.4	8.3	0	0
5	Ghana	92.2	90.8	99.6	81.0
6	India (Arumuganeri)	100.0	99.1	98.0	75.7
7	Philippines (code PHI-MI4)	98.6	98.4	99.6	78.8
8	Senegal	91.8	90.5	90.3	77.1
9	Canada	100.0	94.9	94.9	76.4
10	China repeat (100 ppm)	55.3	51.2	41.1	37.2
11	India (Kurkuch)	100.0	100.0	95.8	67.5
12	Pakistan	86.7	81.0	74.0	67.4
13	India (Phoda)	98.2	93.6	88.9	71.8
14	Guatemala	100.0	97.5	85.2	59.1
15	Indonesia (Central Java)	80.9	68.9	62.0	37.0
16	Philippines (code PHI-PCS)	96.6	93.4	93.0	66.5
17	Thailand	94.9	88.7	87.4	58.5
18	Bangladesh	100.0	91.3	77.9	63.5
	Average	87.7	84.9	81.9	63.0

the stability of iodine in most cases. Unfortunately, this would not be technically or economically feasible in the short term in many developing countries.

By packaging salt in an effective moisture barrier, such as solid low-density polyethylene bags, iodine losses can be significantly reduced. With solid low-density polyethylene packaging, the losses of iodine from salt stored for up to six months can be kept in the range of 10% to 15%, but the losses generally increase significantly over the next six months of storage, and therefore the time required for distribution, sale, and consumption should be minimized to ensure effective use of the added iodine.

To retain the storage efficiency of low-density polyethylene films in a system of high mechanical strength and resistance to puncture, woven high-density polyethylene bags with a continuous film insert or laminate of low-density polyethylene should be investigated as an effective, low-cost packaging method for iodized salt.

The results indicate that the control of moisture content in iodized salt throughout manufacturing and distribution by improved processing, packaging, and storage is critical to the stability of the added iodine. In order to make allowances for the probable losses of iodine, countries must determine iodine losses from local iodized salt under local conditions, as these will be greatly affected by the quality of the packaged salt.

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TABLE 5. Iodine retention in low-density polyethylene film bags at 40°C and 100% relative humidity

Sample	Origin	% of original iodine remaining after storage for:			
		1 mo	3 mo	6 mo	12 mo
1	Tanzania	88.0	89.6	72.2	22.4
2	Bolivia	91.7	95.0	67.8	41.4
3	Indonesia (P.T. Garam)	93.2	91.2	77.5	46.2
4	China (Beijing)	14.7	9.9	12.5	0
5	Ghana	95.9	100.0	72.8	17.9
6	India (Arumuganeri)	100.0	100.0	91.5	56.8
7	Philippines (code PHI-MI4)	99.3	99.3	89.0	62.4
8	Senegal	92.5	93.4	87.6	63.8
9	Canada	100.0	96.0	92.0	66.6
10	China repeat (100 ppm)	56.0	54.8	55.4	45.6
11	India (Kurkuch)	99.6	91.9	73.8	44.0
12	Pakistan	84.3	77.0	64.7	59.0
13	India (Phoda)	95.8	78.1	70.0	52.3
14	Guatemala	97.9	82.7	65.0	33.7
15	Indonesia (Central Java)	75.7	71.9	66.3	33.2
16	Philippines (code PHI-PCS)	94.2	90.6	74.9	55.0
17	Thailand	88.9	88.0	69.0	37.1
18	Bangladesh	100.0	86.1	78.1	50.7
	Average	87.1	83.1	71.1	43.8

TABLE 6. Iodine retention in woven high-density polyethylene bags at 40°C and 100% relative humidity

Sample	Origin	% of original iodine remaining after storage for:			
		1 mo	3 mo	6 mo	12 mo
1	Tanzania	51.0	12.0	2.4	0
2	Bolivia	85.8	64.9	9.2	0
3	Indonesia (P.T. Garam)	91.3	27.1	7.2	0
4	China (Beijing)	26.6	14.5	7.5	0
5	Ghana	92.2	90.9	61.4	3.9
6	India (Arumuganeri)	98.7	93.3	28.1	1.1
7	Philippines (code PHI-MI4)	92.0	36.7	3.4	0
8	Senegal	91.2	14.1	1.6	0
9	Canada	89.7	72.2	4.2	2.0
10	China repeat (100 ppm)	48.8	40.1	16.0	12.2
11	India (Kurkuch)	87.9	29.0	8.7	0
12	Pakistan	37.0	6.5	4.0	0
13	India (Phoda)	20.1	5.4	3.0	0
14	Guatemala	92.2	58.0	12.3	0
15	Indonesia (Central Java)	13.4	12.7	7.1	0
16	Philippines (code PHI-PCS)	39.4	6.2	0	0
17	Thailand	78.6	71.7	7.1	0
18	Bangladesh	81.0	7.4	3.5	0
	Average	67.6	36.8	10.4	1.1

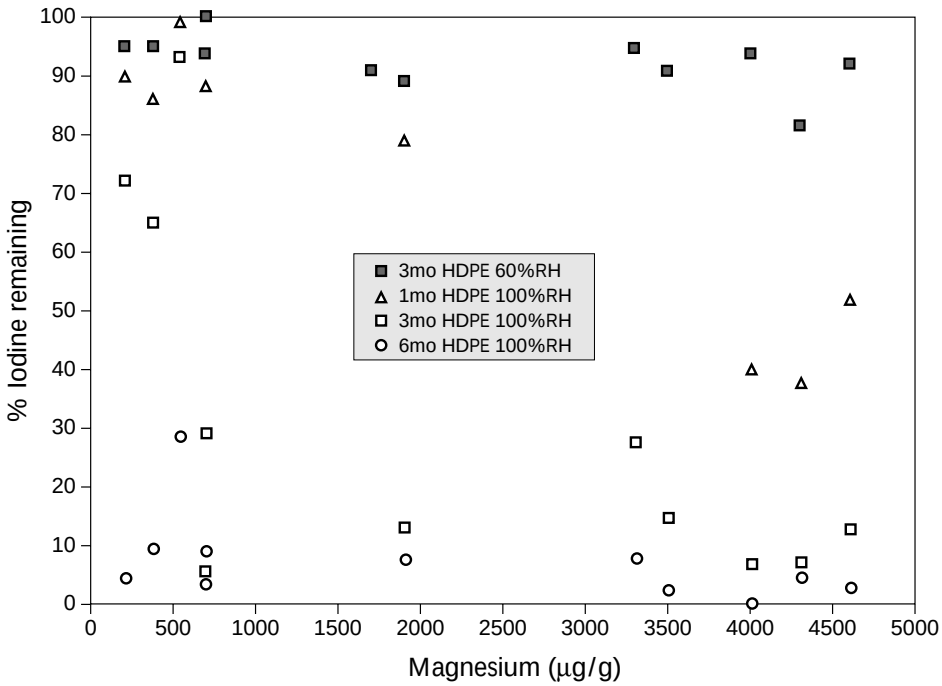

FIG. 2. Effect of magnesium on iodine retention in salt from India stored at 40°C. Abbreviations: LDPE, low-density polyethylene film bag; HDPE, woven high-density polyethylene bag; RH, relative humidity

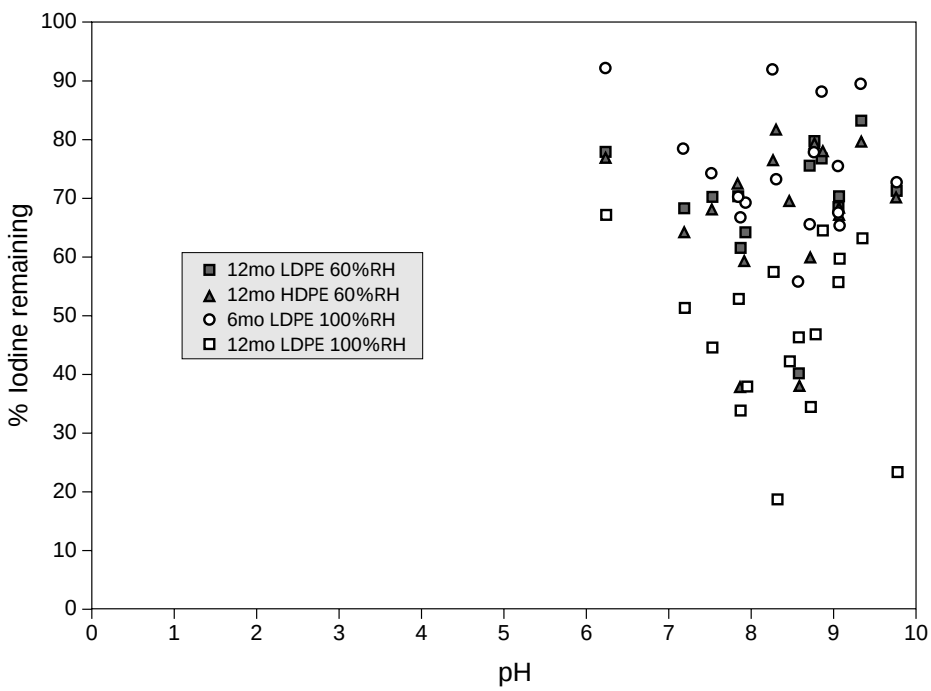

FIG. 3. Effect of pH on iodine retention in salt from India stored at 40°C. Abbreviations: LDPE, low-density polyethylene film bag; HDPE, woven high-density polyethylene bag; RH, relative humidity

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Dietary fat in developing countries

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Introduction

Dietary fat encompasses all the sources of lipids in foods, including those in plant and animal cellular membranes, as well as the readily recognized fats and oils. Fat is an important contributor of energy, which may be in short supply in some developing countries. As noted in the Food and Agriculture Organization/World Health Organization (FAO/WHO) report on fats and oils in human nutrition, there is a great disparity in the supply of this dietary component [1]. Data in 1990 from national food-balance sheets showed that the availability of total fat in developing countries was 49 g per person per day, equivalent to 440 kcal. Corresponding figures from national food-balance sheets for developed countries were 128 g of fat or 1,150 kcal per person per day. Within the two large economic groups, intake in individual countries varied from less than 20 g of fat (180 kcal) per person per day in Bangladesh, Cambodia, and Rwanda to more than 170 g (1,530 kcal) in Belgium, Denmark, Ireland, and Luxembourg. The difference between these two groups of countries in the supply of a major energy source was eight- to ninefold.

The percentage of energy content provided by fat in breastmilk from well-nourished women is expected to be 40% to 55% during the first six months and to decrease thereafter. According to FAO/WHO, the percentage of energy provided by fat should be at least 15% in adults and 20% in women of reproductive age [1]. On this basis, a minimum level of fat in a diet might be considered to be 20% of energy.

Globally, cardiovascular disease is the major cause of death [2]. This underscores the importance of dietary fat, a modifiable risk factor for cardiovascular disease. There is overwhelming evidence linking elevated plasma levels of total cholesterol and its principal carrier, low-density lipoprotein (LDL), to cardiovascular disease [3]. Over the past decades, diets designed for industrialized countries to reduce total fat and cholesterol and replace saturated fatty acids with polyunsaturated fatty acids have contained a large amount of linoleic acid. Subsequent studies have shown that large amounts of linoleic acid (>10 en%[energy percent]) can reduce not only LDL but also high-density lipoprotein (HDL) cholesterol. Apart from the effects on lipoproteins, dietary fatty acids modify platelet aggregation, vascular reactivity, and immune functions through their effects on the synthesis of eicosanoids in platelets and endothelial cells of the arterial wall. High intakes of *n*-6 fatty acids and saturated fatty acids increase platelet aggregation. Whereas the *n*-3 eicosapentaenoic and docosahexaenoic acids decrease platelet aggregation and bleeding time, they lower triacylglycerol and have hypolipidaemic, vasodilatory, anti-inflammatory, and hypotensive effects, as compared to *n*-6 arachidonic acid. In many developing countries, plant foods supply most of the essential fatty acids, and the ratio of *n*-6 to *n*-3 is the ratio of linoleic acid to α-linolenic acid. There are developing countries where fish supply eicosapentaenoic acid and docosahexaenoic acid. The balance between linoleic acid and α-linolenic acid should be maintained in developing countries at an *n*-6/*n*-3 ratio of 5:1 to 10:1. Saturated fatty acids do not contribute equally to hypercholesterolaemia or hyperaggregability of platelets, and further, their effects can vary with dietary levels of cholesterol and polyunsaturated fatty acids [4, 5].

This report describes the dietary fat consumed in two developing countries, Chile and India. Corresponding data were not available from impoverished countries in Africa. Other topics discussed are the nature

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of complementary foods for the young, the response of blood lipoproteins to saturated and *trans* fatty acids, and the role of vegetable oils in supplying vitamin A and carotenoids. It is assumed that the safety considerations of fatty foods intended for human consumption have been addressed through good manufacturing practices.

Consumption pattern of dietary fats in Chile

Chile, a country of 14.5 million, has experienced rapid economic growth and dramatic improvements in human and social development indices during the last two decades. Infant mortality presently stands at 12 per 1,000, illiteracy is less than 5%, and access to basic educational and health services is nearly universal. Poverty is decreasing markedly, and the per capita gross national product is growing at 6% to 7% per year. Unemployment is close to 5%, and projected inflation is less than 6% [6]. The nutritional status of children has improved; less than 1% of children are below 2 SDs in weight-for-age, and 5% are below 2 SDs in height-for-age. Mean per capita energy availability is close to 3,000 kcal per day, or 109% of the estimated need.

Chile's economic progress has been fuelled by exports amounting to 33% of the gross national product. Local oil production is based mostly on imported seeds and semi-refined oils. An exception in terms of manufactured products is the fish meal and fish oil industry. It is well developed in terms of overall production and quality; these products are technologically advanced and successfully compete in the international market.

Chile consumes both vegetable and animal fats and oils. Of the vegetable oils, soya bean oil, which is either imported from Argentina and Bolivia as such or produced from imported soya beans, is the most important contributor to the dietary fat supply. Rapeseed oil of the low-erucic-acid variety is the second most common vegetable oil consumed in Chile. It is also imported, although there is a limited local production. Sunflower oil is almost totally imported from Argentina and Brazil; more recently, imported canola oil has been introduced. There is a small consumption of olive oil locally produced and imported [7]. Animal fats are predominantly derived from beef and pork; a small proportion is obtained from sheep tallow. Fish oil products with different degrees of processing are highly consumed in Chile. Table 1 provides detailed information on estimated fat consumption in Chile for 1995 [8].

The improvement in the economic status of the country has been coupled to a change in the pattern of consumption of fats and oils. Over the past 20 years, there has been a steady rise in human consumption of oils and a decrease in the consumption of solid fats of animal origin, including butter. The consumption of margarine and solid vegetable fats (shortenings) has changed relatively little. The increased availability and use of liquid oils can be directly linked to the improvement in local buying capacity. In 1975 the per capita gross national product was US$2,800, whereas in 1995 it was US$4,800 in constant dollars [9]. The greatest use of liquid oils is for frying foods; they have replaced animal tallow and vegetable shortenings for this purpose. This trend has coincided with an increase in local consumption of fast foods and snacks. There has been an explosive growth of foreign and local fast-food chains promoted by aggressive advertising campaigns. Figure 1 illustrates the changes in the distribution of the types of fats consumed in Chile from 1975 to 1995 [8]. The estimated yearly per capita consumption of fats for 1995, 16.7 kg, is slightly above the average world per capita consumption of 15.2 kg for the same year.

Chile has a strong fishing tradition, although the local population does not consume a lot of fish or marine foods. Most of the fish catch in Chile serves as raw material for the production of fish meal and fish oil, and only a small percentage is used in canning. Pelagic fish, such as sardines, anchovies, and mackerel, constitute the main varieties caught along the long Chilean coastline [10]. There are over 50 fish meal factories distributed along the coast, which produce fish meal for export as well as internal consumption. Chile is the world's second largest producer of fish meal and fish oil, surpassed only by Peru. Table 2 shows recent information on the main world producers of fish oil. Within Chile fish oil is used in human foods and animal feeds and in the manufacturing of industrial products such as paints, varnishes, and leather tannery, Table 3 summarizes the main uses of fish oil in Chile; human consumption represents 36% of the total [11].

Human consumption of fish oil is largely in food products that are hydrogenated to various degrees to secure stability and prevent rancidity. Refined, deodorized, partially hydrogenated fish oil is mixed with vegetable oils of different origins to produce a low-cost

TABLE 1. Estimated fat consumption in Chile in 1995

Fat	Consumption (×1,000 metric tons)
Fish oil	91.7
Soya bean oil	77.5
Rapeseed oil	23.5
Sunflower oil	14.4
Butter	6.3
Tallow	5.7
Lard	0.15
Other oils (olive, canola, etc.)	0.05
Total consumption	219.3

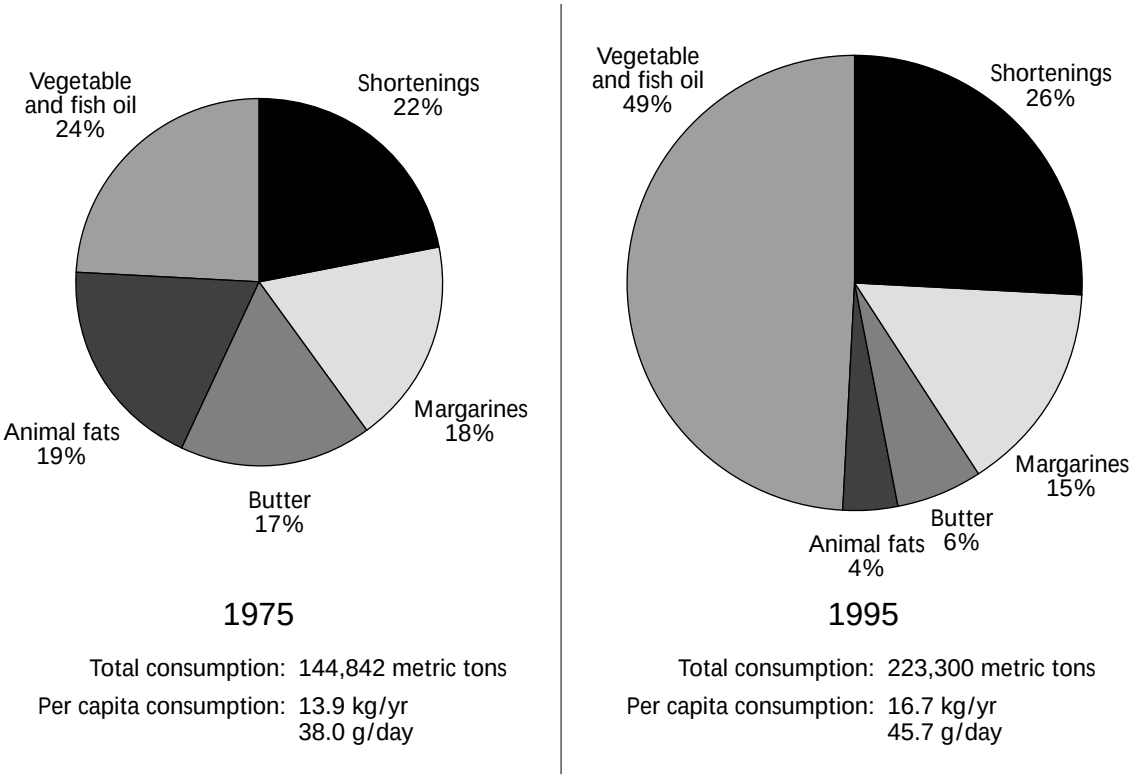

FIG. 1. Changes in distribution of types of fats consumed in Chile from 1975 to 1995

vegetable oil. These are generically called "combined oils" (containing up to 30% fish oil) and are sold by bulk in large metal drums. The commercial distribution to low-income consumers occurs in small grocery shops, which dispense the combined oil in small amounts according to the income of the customer. These combined oils are also packaged in one-litre or one-half-litre individual bottles under various trade names. Bottled oil is destined to replace oil in large metal drums, since local food regulations now prohibit the large containers. The combined oils are organoleptically satisfactory and acceptable, despite the non-standardized, variable fatty acid composition. The composition will change according to the source of the fish oil and vegetable oil used in the combination and the degree of hydrogenation. Combined oils do not constitute a good source of long chain *n*-3 fatty acids, since partial hydrogenation significantly reduces the content of eicosapentaenoic acid and docosahexaenoic acid to less than 2% of the total fat. These fatty acids are reduced mostly to isomeric mono- and di-enes by partial hydrogenation [12].

A significant proportion of fish oil in Chile is used in the manufacture of fat spreads for direct human con-

TABLE 2. Main producers of fish oil (×1,000 metric tons)

Country	Year		
	1990	1992	1994
Peru	185	244	488
Chile	130	148	286
Denmark	77	115	138
United States	126	82	110
Norway	50	110	100
Iceland	73	76	90
Japan	418	104	84
South Africa	11	16	12

TABLE 3. Uses of fish oil in Chile in 1994

Use	Consumption (×1,000 metric tons)
Industrial uses (paints, varnishes, etc.)	8
Aquaculture (salmon, trout)	15
Poultry feed	9
Human food	102
Pet food	1
Export	151
Total	286

sumption and solid fats used in processed foods (shortenings). Fish oil must be intensely hydrogenated to achieve a stable solid fat. The high-melting-point fats are very resistant to oxidation, do not become rancid with time, and are easy to handle in food processing, adding texture and flavour. The relatively low cost of hydrogenated fish oils as compared with vegetable oils makes them economical for use in margarine and industrial shortening. Up to 53% of the fat consumed in Chile is hydrogenated; of this 90% is hydrogenated fish oil [13]. Of the total margarine and shortening consumed in Chile, 80% and 95%, respectively, contain some proportion of hydrogenated fish oil [12]. The estimated consumption of fish oil in Chile, partially hydrogenated in combined oils or fully hydrogenated in margarine and shortening, is close to 7 kg per person per year. However, it must be emphasized that because of hydrogenation, most of the eicosapentaenoic acid and docosahexaenoic acid is lost. Therefore these products must be blended with vegetable oil to assure the presence of essential fatty acids.

The sources of *n*-6 and *n*-3 fatty acids in the Chilean diet are those described above, basically linked to the vegetable oils used. Nevertheless, additional sources of essential fatty acids, especially long-chain essential fatty acids, are present in pork, poultry, and eggs, since the animal feeds contain partially refined fish oil or free fatty acids as by-products of the fish oil used for human consumption. These free fatty acids are sold as a low-cost energy supplement for use during the early stages of poultry and pork production. To prevent the meat or eggs from having a fishy smell, the supplements are discontinued when the animals are close to completing their growth cycle, before they are sent to market. Because of this feeding practice, pork and poultry are important sources of *n*-3 fatty acids in Chile; the nutritional health impact of these non-traditional *n*-3 sources has not been fully studied. Figure 2 summarizes the *n*-3 fatty acid composition of beef, pork, chicken, and eggs in Chile [14].

Lipids in infant nutrition have been historically considered solely part of the exchangeable dietary energy supply. The main consideration was the amount of fat that could be tolerated and digested by infants and young children. The significance of the composition of the dietary fat has received little attention. Presently, there is a growing interest in the quality of the dietary lipid supply in early childhood as a major determinant of growth, development, and long-term health. Thus the selection of dietary lipid supply during the first years of life is now considered of greater significance (see next section). Lipids serve as structural components of all tissues and are indispensable for the synthesis of cell and plasma membranes. The brain, retina, and other neural tissues are particularly rich in long-chain polyunsaturated fatty acids. These lipids have been shown to affect neural development and function.

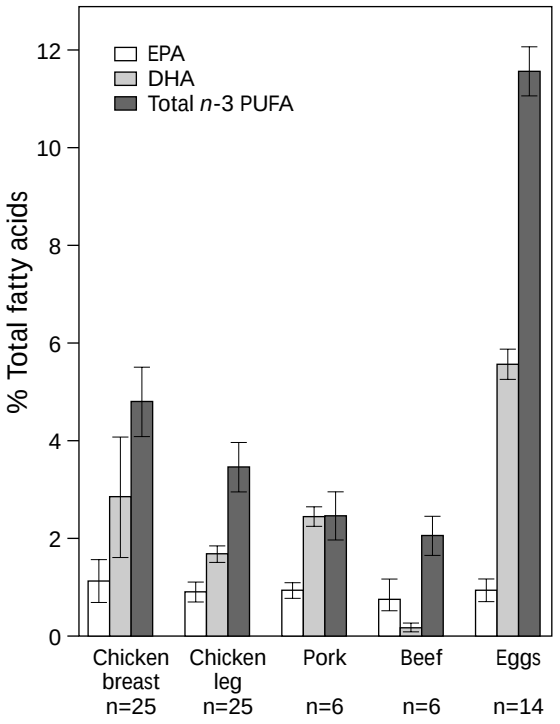

FIG. 2. Content of *n*-3 fatty acids in meat and eggs consumed in Chile. Abbreviations: DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; PUFA, polyunsaturated fatty acids

Information on the fatty acid composition of human milk from developing and developed regions of the world is summarized in figure 3 and contrasted with recent data obtained in Chile. It should be noted that milk from mothers in China and Nigeria and low-income mothers in Chile has significantly higher total *n*-3 and also higher docosahexaenoic acid (22:6 *n*-3) than milk from mothers in the United States and Germany. It is tempting to hypothesize that in Chile the consumption of docosahexaenoic acid-rich eggs, pork, and poultry may contribute to the high docosahexaenoic acid content of human milk. In addition, the small proportion of intact *n*-3 long-chain polyunsaturated fatty acids in the combined oil, which contains fish oil, may contribute to the overall supply of docosahexaenoic acid; the estimated total daily intake of docosahexaenoic acid and eicosapentaenoic acid may amount to 750 mg. Non-breastfed infants receive commercial formula, which usually provides the same *n*-6 and *n*-3 essential fatty acids that are found in breastmilk, but no long-chain polyunsaturated fatty acids, since new formulations that contain these have not yet been introduced in Chile (R. Uauy and P. Mena, personal communication, 1997). Older infants and even young infants of low socio-economic status fed powdered milk receive no long-chain *n*-3 and small amounts of *n*-6 from dairy fat. Cow's milk is also quite low in *n*-3 (18:3) and *n*-6 (18:2) es-

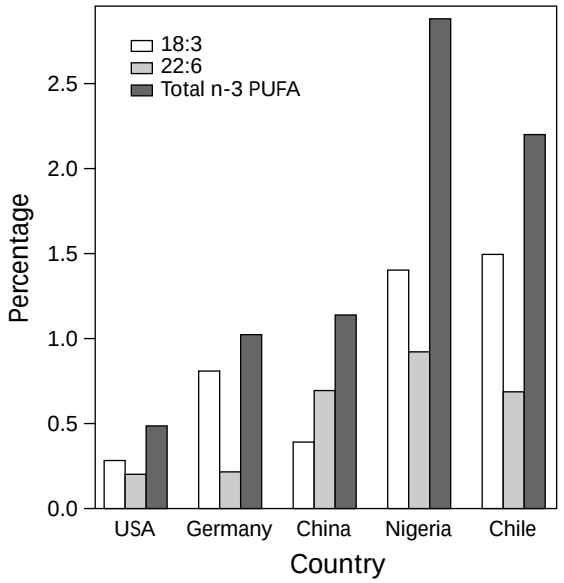

FIG. 3. Content of *n*-3 fatty acids in breastmilk of mothers in Chile and other countries

sential fatty acid precursors. Human milk in developing countries may represent the only way to secure appropriate *n*-6 and *n*-3 fatty acids in the right amount and balance; modern commercial formula is simply not affordable by most of the population. Unmodified cow's milk is a poor source of essential fatty acids and provides virtually no *n*-3 fatty acids.

In most developed countries, fats included in foods, even those given to young children, are products of one or many industrial processes. In the 1970s, hydrogenated fish oil was used in Chile for low-cost formula. When the fat was exclusively from hydrogenated fish oil and was fed to children recovering from malnutrition, faecal fat loss was as high as 20%; when this fat was mixed with equal parts of hydrogenated vegetable oil, fat loss was reduced to about 5%. In addition, the concern about the large amount of *trans* fatty acids formed during hydrogenation of fish oil posed two other potential problems: it may induce essential fatty acid deficiency and alter lipoprotein metabolism.

Trans fatty acids do not serve as substrates for synthesis of long-chain polyunsaturated fatty acids (*n*-6 20:4 and *n*-3 22:6), and thus more essential fatty acid precursors are needed [15]. The extent of essential fatty acid deficiency in developing countries is virtually unknown, especially since the clinical manifestations occur only in extreme deficiency. Thus this problem may go unreported, despite the potential effects on the development of the neural system. The other issue relative to the use of hydrogenated fats with large amounts of *trans* fatty acids is the effect they have on cholesterol and lipoprotein metabolism. High-*trans* diets increase LDL cholesterol, reduce HDL cholesterol, and possibly increase lipoprotein(a) [16]. All of these changes increase atherogenicity. Despite the urgency in improving the energy supply of infants in developing countries, we should avoid inducing problems in later life. The low price and long shelf life of hydrogenated products do not justify the risk of possible long-term effects of this type of fat [17].

Another example of safety concerns with fats used in developing countries is the need to avoid the use of high-erucic-acid rapeseed oil. If its use is not monitored, toxicity from erucic acid may occur, and this is difficult to diagnose clinically. If rapeseed oil is to be used, it should be derived from genetically selected low-erucic-acid varieties. Canada produces these varieties and markets them as canola oil. Unfortunately, cross pollination may lead to the production of phenotypes with an increasing level of erucic acid, and therefore certified seeds should be purchased. These may have a high cost, and farmers in developing countries may not use them unless forced to do so by appropriate quality control measures.

A critical safety issue is the stability of oils in terms of peroxidation. Highly unsaturated oils, such as processed fish oil used in human foods and as animal feed, require substantial amounts of synthetic antioxidants to preserve their structure and prevent rancidity [18]. The Chilean legislature has authorized the use of up to 0.01% BHT, BHA, TBHQ, and propyl or octyl gallate as total antioxidants. This is in accordance with the Codex Alimentarius, despite some concerns about the safety of synthetic antioxidants, which have led some countries to restrict the use of BHA. A specific issue in the use of processed fish oil for animal feed is the concern about the safety of ethoxyquine, which is utilized as an antioxidant in the product. This is a highly efficient antioxidant and anticombustion agent but is prohibited for use in foods for humans. The consumption of poultry or other animals fed fish meal or fish oil containing ethoxyquine has not been addressed by present regulatory efforts. Research is under way to find alternative antioxidants to replace ethoxyquine at reasonable prices.

Finally, there may be safety problems in the dispensing of oils. Large metal containers used to reduce costs in developing countries may facilitate adulteration of products and promote peroxidation because of the large volume and the long time before all the product is sold. Bottled oil ready for consumer purchases is undoubtedly safer but is also more expensive. Soft plastic (polyvinylchloride) containers using phthalic acid as a plasticizer can also create safety problems, since this agent is fat soluble and a known carcinogen. Rigid plastic or glass bottles are preferable. Brick containers have recently been introduced in some countries.

In Chile the recent food safety regulations promulgated in 1997 follow FAO/WHO Codex Alimentarius directives in terms of quality control, technical speci-

fications, safety of sources, use of additives and antioxidants, labelling, and nutritional claims.

Dietary fats in India

The major nutritional problem of India, a country of 940 million, is chronic energy deficiency associated with low fat intake [19]. The urban affluent and middle-income groups are increasing in number, with a corresponding increase in the prevalence of obesity, diabetes, and coronary heart disease in that segment of the population [20]. Fat intake in India is income dependent and highly skewed [21, 22].

The vegetable oils used in cooking represent 80% of the visible fat consumed in India [23]. Despite a yearly increase of 15% to 20% in the production of vegetable oil during the last few years, India has a shortage of oils. The average annual per capita consumption is 8 kg, as compared with 16 kg for the world and more than 40 kg for developed countries [24]. For many decades, 60% of the oil consumed was groundnut oil, followed by rapeseed and mustard seed oil, which accounted for 15%. The production of these seed oils has almost tripled [25].

A single oil is generally chosen for cooking, especially in rural areas. Groundnut oil predominates in the western and southern states, whereas mustard seed oil predominates in the northern and eastern states. In Karnataka and South Maharashtra, safflower oil is preferred. Sesame oil is produced and used all over India, but mostly as a second rather than the main oil. Coconut oil is popular in Kerala [26]. Sunflower and rice bran oils have been introduced, and sunflower oil has become popular. Palm oil, used over the last 15 years, is available through the public distribution system and is likely to become an important indigenous oil because of the introduction of palm cultivation [24]. Vegetable ghee (*vanaspati*), popular in the northern states, is used in confectionery, bakery, and ready-to-eat foods. Ghee, made from milk in the home or purchased, contributes to the high intake of fat in the urban affluent and middle-income groups [27].

Invisible fat in animal and plant foods was once poorly analysed because structural and tightly bound lipids were not extracted. More recent data on the fat content and fatty acid composition of Indian foods are shown in table 4 [28, 29]. Although cereal and millet contain only 1% to 3% fat, of which linoleic is a major fatty acid, as bulk items in the Indian diet they contribute significantly to the total fat intake. The fatty acids in commonly occurring visible fats vary according to the source. In safflower, sunflower, soya bean, and cottonseed oils, linoleic acid constitutes more than half of the total fatty acids. In sesame, rice bran, groundnut, and mustard oils, linoleic acid accounts for 20% to 40% of the total fatty acids; in palm oil it accounts for about 10%. Coconut and palm kernel oils have a high proportion of short- and medium-chain-length saturated fatty acids. Rapeseed, mustard, and soya bean oils contain *n*-3 linolenic acid and the first two also have long-chain eicosanoic (20:1) and erucic acids (22:1). Ghee, which has the fatty acids of milk fat, is high in saturated fatty acids, of which 40% are of short or medium chain length. *Vanaspati* contains long-chain saturated fatty acids and up to 55% *trans* fatty acids.

Dietary data from national surveys [19, 21] of the rural poor (an estimated 80% of the population) show that the average daily intake of cereal and millet is about 500 g, whereas the intake of visible fats and oils is less than 10 g per person. By using data on invisible fat and fatty acids in Indian foods [28, 29] and information on dietary intake of the rural population [21], it has been found that cereal and millet alone furnish about 70% of the total invisible fat in the diet. Pulses, milk, fresh coconut, whole oil seeds, and spices constitute the rest [28]. The daily intake of cereal, millet, pulses, and milk contains an average of about 16 g (7 en%) fat, 5 g (2 en%) linoleic acid, and 0.6 g (0.2 en%) *n*-3 linolenic acid. Thus, invisible fat from cereal and pulses alone furnishes two thirds of the requirement for linoleic acid [28]. Diets of urban high-income groups are low in cereal (200–300 g per person per day) but contain more legumes, pulses, vegetables, and milk (and also, for non-vegetarians, eggs and animal foods) [22]. Therefore, the invisible fat contributes 30 g (12 en%) to the diet [28]. The average daily intake of visible fat in the urban population is about 13 g in slum dwellers, 23 g in industrial labourers and low-income groups, 35 g in middle-income groups, and 46 g in high-income groups [22], but it is much higher in the top affluent group [31]. In the rural population, the lower limit of visible fat in Indian diets is about 20 g per person per day [28, 32]. Since chronic energy deficiency is a major problem in low-income groups, increasing dietary fat could help to remedy this situation.

In the urban high-income group, a daily intake of about 50 g per person (18 en%) would be the upper limit of visible fat (e.g., oil, ghee, *vanaspati*, and butter) [28, 32]. It was estimated that one third of all the fat in India was consumed by the 5% of the population who constituted the urban rich [26]. This segment of the population, which has a high prevalence of obesity and cardiovascular disease, could lower the consumption of fat and ease the pressure on the supply of edible oil elsewhere in the country.

During pregnancy and lactation, when the requirements of total fats and essential fatty acids are high, the invisible fat of cereals, pulses, and milk in Indian diets can meet 42% and 30% of the recommended level for linoleic acid of 3 en% as proposed by FAO/WHO [33] (4.5 en% in pregnancy and 6 en% in lactation). To furnish the additional amounts of linoleic acid recommended, the visible fat intake should be about 30 g in

TABLE 4. Invisible fat and fatty acids in Indian foods (g/100 g food)[a]

Food	Botanical name	Fat	16:0	18:0	18:1	18:2*n*-6	18:3*n*-3	18:2*n*-6/ 18:3*n*-3 ratio
Cereals and millets								
Rice	*Oryza sativa*	1.7	0.40	0.05	0.4	0.5	0.01	41
Wheat	*Triticum aestivum*	2.9	0.40	0.10	0.3	1.1	0.17	6
Maize	*Zea mays*	4.8	0.70	0.20	1.1	2.2	0.05	47
Jowar	*Sorghum vulgare*	3.3	0.50	0.07	1.0	1.5	0.05	32
Ragi	*Eleusine coracana*	1.5	0.30	0.02	0.7	0.3	0.05	5
Bajra	*Pennisetum typhoideum*	5.5	1.00	0.24	1.2	2.2	0.13	17
Legumes and pulses								
Black gram	*Phaseolus mungo* Roxb	1.7	0.20	0.05	0.20	0.1	0.70	0.2
Rajmah	*Phaseolus vulgaris*	2.2	0.30	0.04	0.20	0.5	0.70	0.7
Cowpea	*Vigna catjang*	2.9	0.60	0.10	0.20	0.8	0.50	1.7
Green gram	*Phaesolus aureus* Roxb	1.7	0.40	0.05	0.50	0.6	0.20	3.0
Red gram	*Cajanus cajan*	2.2	0.40	0.08	0.10	1.0	0.10	8.0
Lentil	*Lens esculenta*	2.0	0.20	0.04	0.40	0.8	0.16	5.0
Bengal gram	*Cicer arietinum*	6.9	0.50	0.07	1.20	3.5	0.20	17.0
Pea	*Pisum sativum*	2.1	0.20	0.06	0.40	0.8	0.15	5.0
Soya bean	*Glycine max* Merr	20.0	1.40	0.8	5.40	10.4	1.40	7.0
Vegetables								
Beans[b]		0.2	0.04	0.007	0.009	0.07	0.04	2.0
Green leafy vegetables[c]		0.4	0.05	0.007	0.025	0.04	0.15	0.3
Other[d]		0.2	0.03	0.008	0.016	0.06	0.03	2.0
Potato	*Solanum tuberosum*	0.6	0.15	0.002	0.150	0.08	0.06	5.0
Condiments and spices								
Dry chili	*Capsicum annuum*	17	2.20	0.34	1.8	9.1	0.26	35.0
Cumin seed	*Caminum cyminum*	9	0.30	0.08	4.7	2.1	0.48	4.0
Coriander seed	*Coriandrum sativum*	20	0.60	0.10	12.5	3.0	0.02	129
Fenugreek seed	*Trigonella foenumgraecum*	10	0.90	0.30	1.5	3.4	1.90	1.8
Nuts and oil seeds								
Coconut	*Cocos nuifera*	40	8.0	4.0	3.2	0.6	—	—
Groundnut	*Arachis hypogaea*	40	3.5	1.7	21.0	10.0	0.2	50
Sesame	*Sesamum indicum*	40	4.0	1.6	18.0	16.0	0.4	40
Mustard	*Brassica nigra*	40	0.4	0.2	5.0	5.0	3.5	1.4

Source: ref. 30, with permission.
a. Mean of 3 pooled market samples.
b. Mean of 3 different types.
c. Mean of 14 different types.
d. Mean of 5 different types.

pregnant women and 45 g in lactating women [28, 32].

In meeting the energy needs of children over two years of age by cereal–pulse diets, excess bulk is a problem. To prevent this, diets should contain a minimum of 25 en% fat. Widespread dietary energy deficiency in young children of low-income groups was attributed to an insufficient quantity of food [34], but re-examination of the intakes of energy and fat by preschool children belonging to different socio-economic groups in both rural and urban areas showed that increased energy intake was closely associated with increased intake of visible fat [35]. The data also showed that when the intake of visible fat was 15 en%, the energy intake was judged to be adequate [36]. These observations reinforce the importance of increasing the energy density of diets for young children.

In diets of the rural poor, invisible fat furnishes about 5 g of saturated fatty acids, 4 g of monounsaturated

fatty acids, 8 g of *n*-6 linoleic acid, and 0.3 g of *n*-3 linolenic acid; the ratios of polyunsaturated fatty acids to saturated fatty acids and *n*-6 to *n*-3 are about 1 and 13, respectively. In the urban high-income group, invisible fat furnishes about 13 g of saturated fatty acids, 6 g of monounsaturated fatty acids, 4 g of linoleic acid, and 0.6 g of *n*-3 linolenic acid; the ratios of polyunsaturated fatty acids to saturated fatty acids and *n*-6 to *n*-3 are 0.3 and 6, respectively [28].

Estimates of the various fatty acids in the total diet indicate that the levels of linoleic acid are generally adequate because of its high levels in cereals and many vegetable oils (table 5). The levels of *n*-3 linolenic acid, however, are low. To correct the quality of fat in Indian diets, *n*-3 polyunsaturated fatty acids should be increased [39]. Saturated and/or *trans* fatty acids are often needed in food products where a solid or semi-solid fat is desired. On their own, saturated fatty acids could fulfil the same functional requirements. Therefore, in countries where the consumption of *trans* fatty acids is high, solid fat formulations could be based on saturated fatty acids. In the high-income group, use of oils such as safflower, sunflower, sesame, or groundnut oil provides high ratios of *n*-6 to *n*-3 [30]. The levels of *n*-3 linolenic acid will be in the desirable range only when mustard, rapeseed, or soya bean oils are used [39]. Analyses of commonly consumed fish in India indicate that fish with high fat (>5 g/100 g), medium fat (1–5 g/100 g), and low fat (<1 g/100 g), respectively, furnish an average of about 1.2, 0.4, and 0.1 g of long-chain *n*-3 polyunsaturated fatty acids per 100 g of muscle [40]. The use of any single oil does not ensure the quality of fat (individual fatty acid levels, polyunsaturated fatty acids/saturated fatty acids, and *n*-6/*n*-3 ratios), as recommended for the prevention of cardiovascular disease [39].

The habitual diets of Indians contain a number of factors that are known to reduce the risk of coronary heart disease [3], including low fat intake (except in urban high-income and affluent groups, whose fat intake may exceed 30 en%), provision of essential fatty acids by invisible fat, high fibre, and provision of more than 60% of total energy intake by complex carbohydrates [19, 20]. Indian diets are also rich in spices and condiments, which may have antioxidant properties.

A series of metabolic studies was conducted in Indian subjects to determine the possible atherogenic effects of changing the cooking fat from groundnut oil to palmolein [30], ghee, canola oil [41], or mustard oil. The results showed that canola oil decreased LDL cholesterol, and mustard oil, with its high level of erucic acid, increased LDL cholesterol and triacylglycerol.

Improvements to the dietary fat in India could best be accomplished by:

» using oils with moderate levels of linoleic acid, such as groundnut, rice bran, or sesame oil;
» adding an oil or fat with a low level of linoleic acid, such as palm oil, to an oil with a high level of linoleic acid, such as safflower, sunflower, cottonseed, or soya bean oil;
» using a preferred oil along with mustard oil to increase the *n*-3 fatty acid content and moderate the intake of erucic acid from the mustard oil;
» combining soya bean oil with palm oil in equal proportions;
» using oils with minor components, such as antioxidants, which contribute to their nutritional benefits;
» consuming foods rich in *n*-3 linolenic acid, such as some vegetable oils and green leafy vegetables, and (for non-vegetarians) eating fish.

Since the requirements for *n*-3 polyunsaturated fatty acids increase with increased intake of *n*-6 polyunsaturated fatty acids, it is important to moderate linoleic acid and to increase the intake of *n*-3 polyunsaturated fatty acids. Use of more than one source of oil gives the added advantage of providing a greater variety of the minor components in the diet.

Fats and essential fatty acids in complementary foods for infants

Complementary foods are introduced when breastmilk can no longer satisfy all of the nutritional needs of an infant. Up to four months of age, a full-term infant fed by a well-nourished mother obtains sufficient energy and nutrients from maternal milk, the fat of which supplies 40% to 55% of the total energy and all of the *n*-6 and *n*-3 polyunsaturated fatty acids needed for growth and development [1]. As traditionally prepared in many developing countries, complementary foods have low energy and nutritional values [42, 43] and are often introduced earlier than the recommended age of four to six months. The prevailing situation in developing countries is that the fat content of breastmilk is too low and the wrong complementary foods are introduced too early. According to Butte [44], energy requirements may be 13% to 20% lower than those recommended by FAO/WHO/UNU [45], and breastmilk would be adequate up to six months if milk consumption reached at least 714 g/day up to two months and at least 784 g/day in three- to five-month-old infants [46]. Many infants under four months of age receive food supplements (fig. 4). There has been a consensus that complementary foods which would reduce breastmilk consumption should not be used before four months of age, and preferably should be used only after six months of age [47, 48].

Staple complementary foods are usually based on locally cultivated cereal crops, such as rice, millet, wheat, corn, and teff; roots and tubers, such as cassava, yam, taro, potato, and sweet potato; or starchy fruits, such as banana, plantain, and breadfruit. Other foods of vari-

TABLE 5. Fat and essential fatty acid content (g/100 g edible portion) of main traditional complementary foods in developing countries

Food	Data source			
	FAO[a]	Ref. 38 or unpublished data of the authors		
			Essential fatty acid content	
	Mean fat content	Mean fat content (range)	18:2 *n*-6	18:3 *n*-3
Staple complementary foods				
Cereals				
Rice	0.1–2.7	0.65 (0.5–1.0)	0.31[c]	0.01[c]
Barley	1.2–2.1	2.10 (1.80–2.25)	1.15	0.11
Maize	0.1–7.5	2.82 (1.56–3.90)	1.41	0.03
Sorghum	1.7–3.7	3.20 (0.10–5.80)	1.01	0.07
Wheat	1.0–2.4	0.90–2.30[b]	—	—
Oats	6.3–7.8	7.10 (6.80–7.50)	2.74	0.12
Teff (Ethiopian millet)	0.7–3.5	—	—	—
Millet	0.3–6.3	3.90 (2.00–5.00)	1.77	0.13
Roots and tubers				
Cassava	0.1–4.3	0.23 (0.20–0.35)	—	—
Yam	0.1–0.6	0.13 (0.10–0.20)	~ 0	0
Taro	0.1–0.4	0.25 (0.10–0.40)	—	—
Potato	0.1	0.10 (0.04–0.17)	0.03	0.02
Sweet potato	0.2–0.8	0.60 (0.40–1.00)	—	—
Starchy fruits				
Banana	0.1–0.4	0.18 (0.10–0.38)	0.04	0.03
Plantain	0.3	—	—	—
Occasional complementary foods				
Broad bean	1.5	—	—	—
Kidney bean	0.5	0.60	—	—
Lima bean	1.4	1.40 (1.10–1.60)	0.56	0.25
Mung bean (green gram)	0.8–1.0	1.10 (0.90–1.40)	—	—
Mungo bean (black gram)	0.6–2.6	1.20 (1.00–1.60)	0.14	0.57
African locust bean	22.9	—	—	—
Cow pea	0.9–2.0	1.40 (1.10–1.60)	0.44	0.26
Chick pea	5.3	3.40 (1.60–5.18)	—	—
Pigeon pea	1.3–3.0	1.40 (1.20–1.70)	—	—
Amaranth leaf	0.9	—	—	—
Gombo-okra leaf	0.3–1.0	—	—	—
Cassava leaf	0.2–2.9	1.64[c]	0.26[c]	0.67[c]
Spinach leaf	0.1–0.3	0.30 (0.20–0.41)	0.03	0.13
Soya bean flour	13.7–19.2	20.60 (19.80–22.10)	10.70	1.40
Pumpkin seed	41.5–53.7	50.64[c]	32.10[c]	0.05[c]
Shea-butter seed	48.0–50.0	—	—	—
Sesame seed	26.2–57.9	50.40 (48.40–52.80)	18.70	0.67
Roasted peanut	31.4–52.3	49.40 (48.10–50.90)	14.30	0.54
Vegetable oil	99.9	99.9	[d]	[d]
Condensed sweetened milk	—	8.8 (8.4–9.0)	0.18	0.07
Sweetening agent				
Sugar	0.0	0.0	0.0	0.0

a. In cases of multiple values, we reported the lowest and the highest means. See ref. 37.
b. See ref. 38.
c. Unpublished data of the authors.
d. Developing countries produce mainly peanut, palm, palm kernel, coconut, and soya bean oils of varying essential fatty acid compositions.

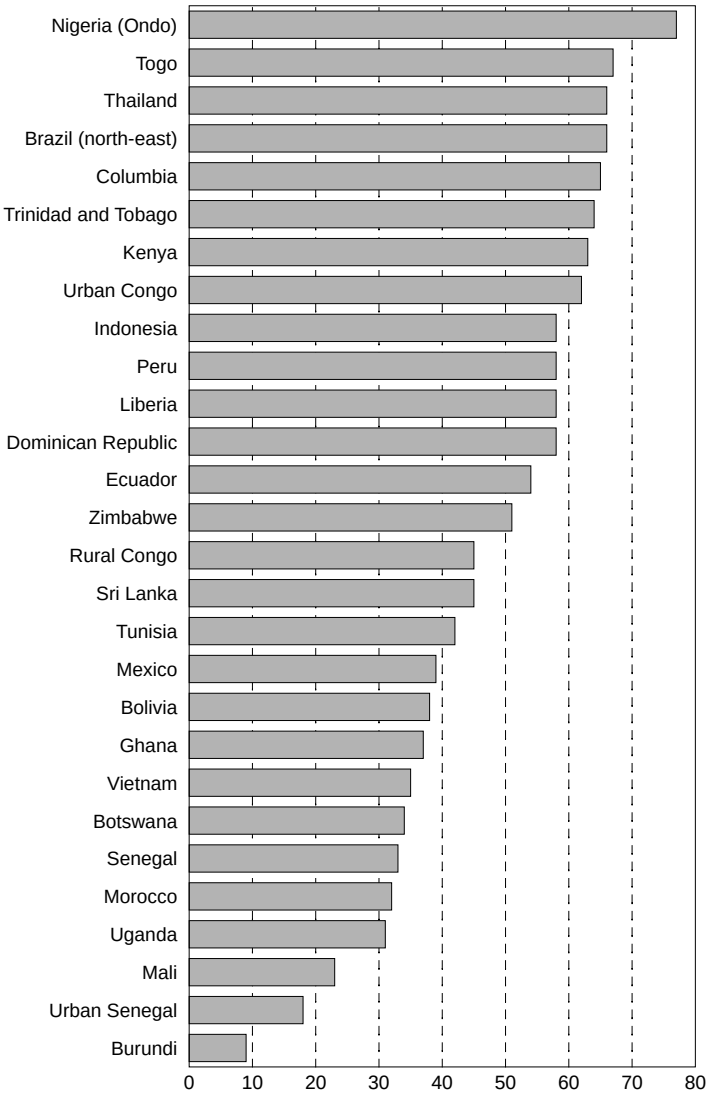

FIG. 4. Percentage breastfeeding + food supplements by infants 0 to 4 months of age in developing countries. Source: ref. 47 and unpublished data

ous origins and fat contents are occasionally added to the complementary foods [42, 43]. The complementary food, which is generally high in carbohydrate and low in fat, is fed to infants as a gruel of low energy density and nutritional value. In French-speaking African countries, such as Senegal and the Congo, the energy density of complementary foods has further decreased since 1994, with the devaluation of the currency and the poorer economic status of households [49]. Consequently, fat, essential fatty acids, and fat-soluble vitamins could be even more inadequate in these foods.

The concentrations of fat and essential fatty acids of staple and occasional complementary foods fed to infants in most developing countries of Asia, Africa, and Latin America vary with the sampling, the analytical methodology, and the source of data collected for food composition tables (table 5). Food from tubers, roots, and starchy fruits, all low-fat products, becomes even lower in fat when mixed with water in preparing gruel. The actual fat level in complementary foods is highly variable and is probably well below that of human milk.

Data on the content of essential fatty acids are relatively scanty and also vary greatly. Improved information would have to come from fatty acid analyses of the traditional gruels used in rural and urban areas of each developing country. Tubers, roots, and starchy fruits are low in total fat and in essential fatty acids, but most cereals contain significant amounts of linoleic acid (18:2 *n*-6), and some, such as barley, oats, and millet, also

have linolenic acid (18:3 *n*-3). Oilseeds are high in linoleic acid, and some of them have linolenic acid. These foods of vegetable origin lack the long-chain derivatives of linoleic and linolenic acids.

Table 6 lists examples of transitional foods of improved nutritional value and energy density, known as "weaning flours," that are prepared in small-scale production units. Sometimes imported sugar or skimmed milk is added. Two of the 22 transitional foods contain vegetable oils. The energy densities of these transitional foods are within a rather narrow range (342–444 kcal/100 g). Their fat content, although higher than that of traditional complementary foods, varies greatly (0.9–10.2 g/100 g), yet the fat content of gruel remains well below that of breastmilk from even malnourished mothers [50]. These features aggravate a deficiency of fat and essential fatty acids. The essential fatty acids in transitional foods are provided by cereals and legumes, and the long-chain polyunsaturated fatty acids are provided by eggs, dried meat, and yeast.

It is generally agreed that fat should not be restricted in the diet of infants and that it should constitute 40% to 55% of their energy intake. On the basis of the estimated fat content (28 g/L or 252 kcal/L) and energy density (0.59 kcal/g) of human milk in developing countries, fat provides 41% of energy [46]. When the fat content of human milk is low, the importance of complementary foods becomes more crucial. As shown in table 7, the energy supplied by milk fat is adequate for infants from 0 to 2 months of age, but at older ages there is a need for additional fat to supply 40% of the infant's energy intake from fat. The additional daily amount of fat required would be 6 g at 3 to 5 months of age, 12 g at 6 to 8 months, and 20 g at 9 to 11 months. Supplying this amount of fat with the complementary foods that are currently available would require the infant to consume an excessive bulk of food. Alternatively, enrichment of complementary foods with fat or addition of high-fat foods could enhance their nutritional value. Such enhancement would be necessary if fat were expected to provide 55% of the infant's dietary energy, because if maternal milk provided only 41% of energy and the fat content of the complementary food were not enhanced, the infant would have to consume an impossibly large amount of complementary food.

Some nutritionists consider that it might be sufficient, and more realistic for conditions in developing countries, for infants to obtain 30% instead of 40% to 55% of their energy from fat [46]. If this were so, infants aged 0 to 5 months would obtain enough energy

TABLE 6. Energy density and fat content of locally processed transitional foods in developing countries

Country	Name of product	Main ingredients	Energy density (kcal/100 g)	Fat content	
				g/100 g	% of total energy value
Algeria	Superamine	Wheat, chickpea, lentil, VMC, sugar, skimmed milk	414	4.5	9.8
Benin	Ouando 1	Maize, sorghum, rice, sugar	401	3.1	7.0
	Ouando 2	Maize, sorghum, kidney bean, peanut, sugar	366	4.0	9.8
Burkina Faso	Misola	Millet, soya bean, peanut, sugar, salt	430	11.5	24.1
Burundi	Musalac	Maize, sorghum, soya bean, sugar, skim milk, VMC	417	7.6	16.4
Cameroon	Boussiri	Maize, egg	410	0.9	2.0
Cape Verde	MICAF	Wheat, maize, bean	434	5.5	11.4
Congo	Vitafort	Maize or cassava, soya bean, sugar, VMC	342	5.8	15.3
	Maiso	Soya bean, maize, sugar, VMC	427	7.2	15.2
Guinea	Yéolac	Maize, sorghum, soya bean, sugar, milk	430	8.1	17.0
Morocco	Actamine	Wheat, soya bean, sugar, skim milk, VMC	357	ND	ND
Niger	Bitamin	Millet, cowpea, peanut, sugar	406	8.9	19.7
Rwanda	Sosoma	Sorghum, wheat, soya bean	400	7.7	17.3
Senegal	AGETIP	Millet, cowpea, peanut	440	7.9	14.2
	Ruy Xalele	Millet, skim milk, peanut oil, palm oil, monkey bread, cowpea, egg, sugar	421	5.2	11.1
Chad	Vitafort	Millet, maize, rice (or sorghum), cowpea, peanut, sugar	417–430	5.5–8.5	14.8
Togo	Nutrimix 1	Maize, sorghum, rice, sugar	426	2.8	5.9
	Nutrimix 2	Maize, rice, soya bean, sugar	444	9.0	16.2
	Viten1	Maize, rice, sorghum, sugar	385	3.4	8.0
	Viten2	Maize, rice, soya bean, sugar	400	7.6	17.1
Vietnam	FIRI	Rice, soya bean, mung bean, dried meat, beer yeast	439	10.2	20.9
Zaire	Cerevap	Maize, wheat, vegetable oil, soya bean, sugar, milk, VMC	430	9.2	19.3

Source: ref. 43.
Abbreviations: ND, not determined; VMC, vitamin and mineral complement.

from milk fat, and older infants would require 4 to 10 g of complementary fat daily, according to age. The important question is whether infants who obtain 30% of their energy from fat are adequately nourished.

Besides the fat needed for energy, breastmilk plus complementary food must supply adequate essential fatty acids. If total fat intakes are too low, essential fatty acids could be utilized for energy. The estimates for essential fatty acids in breastmilk and complementary foods in developing countries are given in table 8. Milk provides adequate linoleic acid for infants 0 to 8 months of age. Complementary food could provide additional linoleic acid (213 mg/day) for infants 9 to 11 months of age. It is more difficult to satisfy the requirements for *n*-3 linolenic acid, which appears not to be sufficient in partially or wholly breastfed infants. Staple foods, such as cereals, roots, tubers, and starchy fruits, are extremely low in linolenic acid, and only foods such as green leafy vegetables, some oilseeds, or soya bean oil could significantly increase the content of linolenic acid in complementary foods. Long-chain polyunsaturated fatty acids, which are lacking in current complementary foods, may be provided by fish, meat, and eggs or novel foods. Traditional complementary foods to supplement breastmilk should provide more energy from fat and contain sources of essential fatty acids.

Saturated and *trans* fatty acids

The intake of dietary fat is generally high in developed countries and low in developing countries. Although both the quantity and the quality of fat can influence the risk of cardiovascular disease, saturated fatty acids are in general hypercholesterolaemic [53, 54]. The various saturated fatty acids, however, behave differently. Evidence in 1991 showed that myristic acid had a greater effect in raising cholesterol levels than did palmitic acid [55]. On the basis of experiments in which the triacylglycerols were structurally modified, regression equations predicting the response of plasma cholesterol to dietary fatty acids indicated that total saturated fatty acids were twice as effective in raising cholesterol as polyunsaturated fatty acids were in decreasing cholesterol, and that monounsaturated fatty acids were neutral. Confounding effects came from the different species of triacylglycerol and the minor components in the fat or oil.

Several human clinical trials suggest that palm oil and palm olein do not raise total cholesterol and LDL cholesterol to the extent predicted from the fatty acid composition. In a normocholesterolaemic Malaysian population obtaining approximately 30% of their energy from fat, palm olein and soya bean oil had similar effects on plasma levels of total cholesterol and LDL cholesterol [56]. A switch from coconut oil (containing predominantly lauric and myristic acids) to palm olein (containing predominantly palmitic and oleic acids) lowered total cholesterol and LDL cholesterol; the switch to corn oil (containing predominantly linoleic acid) lowered it further [57]. Current evidence indicates that the cholesterolaemic effects of the various saturated fatty acids are not equal and that myristic acid is the most potent in raising plasma cholesterol [58]. This is of public health relevance, especially in populations in which coconut oil is the principal fat consumed.

In an Indian population obtaining 27% of its energy from fat, partial replacement of groundnut (peanut) oil by palm olein did not affect total cholesterol or lipoprotein cholesterol levels [30]. Australian men and women obtaining 30% of their energy from fat and ingesting less than 200 mg of cholesterol per day showed no difference in their plasma and lipoprotein levels resulting from a 5% exchange of energy between palm oil and olive oil [59]. These investigators also reported similar results from a human study comparing palm olein and canola oil [60]. Also, diets containing palm olein and canola oil, and the step 1 diet of the American Heart Association, all of which provide about 31% of their energy as fat and less than 200 mg cholesterol per day, had similar effects on levels of total cholesterol, very low-density lipoprotein (VLDL) cholesterol,

TABLE 7. Energy needed from fat in complementary food to provide 40% or 55% of total daily energy from fat

Age group (mo)	Breastfed	Required energy (kcal/d)[a]	Fat calories		Energy from milkfat[b]		Energy (kcal) needed from fat in complementary food	
			40%	55%	kcal	%	40%	55%
0–2	Exclusively	404	162	222	180	41	0	42
	Partially	404	162	222	155	41	6	667
3–5	Exclusively	550	220	303	198	41	22	105
	Partially	550	220	303	167	41	53	135
6–8	Partially	682	273	375	166	41	106	209
9–11	Partially	830	332	457	155	41	177	301

a. According to Butte [44].
b. Assuming a breastmilk fat content of 28 g/L and energy density of 0.59 kcal/g.

TABLE 8. Essential fatty acids needed from complementary foods to meet minimum or optimal infants' requirements

Age (mo)	Breastfed	Average body weight (kg)[a]	Required energy (kcal/d)[b]	Average milk intake (g/d)[c]	EFA supply by milk intake (mg/d)[d]	Minimum EFA requirement (mg/d)[e]	EFA needed from CF to meet minimum requirement (mg/d)[f]	Optimal EFA requirement (mg/d)[g]	EFA needed from CF to meet optimal requirement (mg/d)[f]
18:2 *n*-6									
0–2	E	4.2	404	714	2,630	1,212	0	2,520	0
	P	4.2	404	617	2,280	1,212	0	2,520	240
3–5	E	6.4	550	784	2,890	1,650	0	3,840	950
	P	6.4	550	663	2,450	1,650	0	3,840	1,390
6–8		8.0	682	660	2,439	2,046	0	4,800	2,361
9–11		9.2	830	616	2,277	2,490	213	5,520	3,243
18:3 *n*-3									
0–2	E	4.2	404	714	99	202	103	210	111
	P	4.2	404	617	86	202	116	210	124
3–5	E	6.4	550	784	109	275	166	320	211
	P	6.4	550	663	93	275	182	320	227
6–8		8.0	682	660	92	341	249	400	308
9–11		9.2	830	616	86	415	329	460	374
20:4 *n*-6 and associated *n*-6 fatty acids									
0–2	E	4.2	404	714	159	U	—	168	9
	P	4.2	404	617	138	U	—	168	30
3–5	E	6.4	550	784	175	U	—	256	81
	P	6.4	550	663	149	U	—	256	107
6–8		8.0	682	660	148	U	—	320	172
9–11		9.2	830	616	138	U	—	368	230
22:6 *n*-3									
0–2	E	4.2	404	714	79	U	—	84	5
	P	4.2	404	617	69	U	—	84	15
3–5	E	6.4	550	784	87	U	—	128	41
	P	6.4	550	663	74	U	—	128	54
6–8		8.0	682	660	74	U	—	160	86
9–11		9.2	830	616	69	U	—	184	115

Abbreviations: E, exclusively; EFA, essential fatty acid; CF, complementary food; P, partially; U, unknown.

a. According to WHO [51].

b. According to Butte et al. [44].

c. According to WHO/UNICEF [46].

d. Assuming an average content of 13.2% of 18:2 *n*-6, 0.5% of 18:3 *n*-3, 0.8% of 20.4 *n*-6 and associated *n*-6 fatty acids, and 0.4% of 22:6 *n*-3 [52], and a milkfat content of 28 g/L.

e. 300 mg 18:2 *n*-6 and 50 mg 18:3 *n*-3 per 100 kcal.

f. Optimal (or minimum) EFA requirement = EFA supplied by milk.

g. 600 mg 18:2 *n*-6, 50 mg 18:3 *n*-3, 40 mg 20:4 *n*-6 and associated fatty acids, and 20 mg 22:6 *n*-3 per kilogram of body weight according to WHO [1].

and LDL cholesterol; only the step 1 diet increased HDL cholesterol and altered the LDL/HDL ratio beneficially [61]. The studies conducted in humans obtaining about 30% of their energy from fat in a mixed diet showed that vegetable oils, such as palm oil, palm olein, olive oil, canola oil, and soya bean oil, behave similarly with respect to blood cholesterol and lipoproteins.

Partial hydrogenation of vegetable oils results in the formation of isomers of monounsaturated fatty acids and sometimes polyunsaturated fatty acids. *Trans* monounsaturated fatty acids are the most common of these isomers, and their physico-chemical properties are similar to those of saturated fatty acids. Their effects on blood cholesterol and lipoproteins, however, are different when compared to the most common *cis* monounsaturated fatty acids. Relative to oleic acid, *trans* fatty acids raise the atherogenic LDL and probably lipoprotein(a) and lower the beneficial HDL [16, 62–65]. In a comparison between two diets providing 32% to 34% of their energy as fat, one with 8.7% of total energy from *trans* monounsaturated fatty acids and the other with 9.3% of total energy from stearic acid, the diet containing *trans* monounsaturated fatty acids had a more adverse effect on lipoproteins [66]. As compared with the other diet, the diet containing stearic acid lowered LDL levels, and the diet containing *trans* monounsaturated fatty acids lowered HDL levels and also significantly increased lipoprotein(a) levels. These studies were conducted in industrialized countries where the fat intake was high (providing 36%–40% of total energy), but a study conducted in Malaysia (with 32% of total energy from fat) showed that *trans* fatty acids had a greater adverse effect than saturated fatty acids [67]. Generally, *trans* fatty acids tend to worsen the LDL/HDL ratio.

Food products requiring a solid or semi-solid consistency have traditionally been formulated with saturated and/or *trans* fatty acids. In view of the growing knowledge of *trans* fatty acids and their health implications, formulations should aim to reduce or eliminate the use of partially hydrogenated fats. Saturated fatty acids on their own could fulfil the same functional requirements. This may be an important consideration in some developing countries where the consumption of solid fats containing *trans* fatty acids is high. Although stearic acid has been reported to be neutral with respect to its effects on blood cholesterol and lipoproteins, questions remain about its possible thrombogenicity. In any case, it is best to avoid high levels of *trans* fatty acids in the diet.

Fats and oils as sources of vitamin A and carotenoids

Palm oil is by far the most important source of carotenoids. Total carotenoid levels have been reported between 300 and 3,000 ppm. On average palm oil contains 500 to 700 ppm of carotenoids [68]. The major carotenoids in palm oil are α- and β-carotenes, but more than 10 others have been detected. Ratios of α- to β-carotene have been reported between 1/2 and 1/10 [68], but commercial crude palm oil normally has a ratio of 7/10. Corn oil (90 ppm), rapeseed oil (<100 ppm), and olive oil (5 ppm) have been reported as having lower carotenoid levels.

The purpose of refining palm oil is to remove undesirable odour and colour compounds, but at the same time refining removes all carotenoids. It has been observed that heating can transform carotenoids completely into hydrocarbon-type derivatives [69]. These compounds will not have the physiological effects of carotenoids. Refining of the world production of palm oil (13.5 million tons in 1996) destroys approximately 6.8 tons of carotenoids. Improved technologies are being developed to preserve the carotenoids in palm oil.

Vitamin A values (retinol equivalents or RE) for palm oil between 3,600 and 21,700 RE/100 g have been reported, using the NAS-NRC conversion factor of 1 RE to 6 mg trans β-carotene [64]. This makes palm oil a very significant contributor to vitamin A needs, especially in developing countries.

Fat-based products may contain β-carotene (e.g., for colour in spreads) or be fortified with vitamin A. The latter is a legal obligation in a considerable number of countries. Most developing countries do not have such legislation, but when fat is fortified in developing countries, the range is 5 to 10 mg/kg (table 9). Both vitamin A and carotenes are well absorbed from fat-based products.

Summary and recommendations

» Data on the composition and intake of dietary fat are scarce in developing countries. Collection of reliable data should be encouraged.
» Updated knowledge on dietary fat should be available. Analysts and local analytical capacity are needed to examine these constituents of the diet.
» In determining the intake of dietary fat, the sometimes large differences between population groups have to be taken into account.
» Energy deficiency is normally associated with a low-fat diet. To reach FAO/WHO recommendations, an increased fat intake may be necessary. In most cases, for the general population the fatty acid composition is less critical than the amount of total fat.
» In general, dietary guidelines should not be automatically adopted from industrial countries but should take into account local health issues and positive features of the local dietary situation.
» For groups in developing countries who have a *high-fat* intake, dietary guidelines similar to those of in-

dustrialized countries are applicable.
» Where *n*-3 fatty acids are in short supply, consideration should be given to the *n*-6/*n*-3 balance of fatty acids. Special attention should be given to women of reproductive age, infants, and children.
» High concentrations of *trans* fatty acids in food products should be avoided.
» Infants should be breastfed. Complementary foods, produced locally whenever possible, should contain more energy from fat and provide essential fatty acids with a balanced *n*-6/*n*-3 ratio.
» Fortification with vitamin A through concerted efforts of governments, international organizations, and industry is recommended to overcome critical vitamin A deficiency. Where unrefined palm oil is used, its continued use should be encouraged. Alternatively, red palm oil rich in carotenoids should be included in the total dietary fat to enhance vitamin A activity.

TABLE 9. Vitamin A in margarines in developing and emerging markets

Country	Brand	Vitamin A type	Quantity (g/kg)	Quantity (IU/kg)
Central and East Europe				
Czech Republic	Flora	A[a]	7,650	26,250
	Rama	A	6,120	20,200
Hungary	Liga light	A	6,010	16,630
Poland	Bono	Palmitate + D_3	9,000	29,700
	Kasla	Palmitate + D_3	9,000	29,700
Turkey	Almost all	Palmitate (1 mIU/g)	63,000	207,900
Latin America				
Brazil	Becel CV	Palmitate 1.7 mIU/g	4,950	16,330
	Clayborn Sabor & Saude	Palmitate 1.7 mIU/g	9,690	31,980
	Doriana Light	Palmitate 1.7 mIU/g	4,950	16,330
Chile	Doriana (Sabor) (kitchen)	Palmitate + D_3	9,000	29,700
	Doriana (Sabor) soft	Palmitate + D_3	9,000	29,700
Venezuela	Blue Band[b]	A	9,640	31,800
Netherlands Antilles	Blue Band Packets	A	9,090	30,000
	Blue Band Tins	A	9,090	30,000
Peru	Astra	Palmitate 1.7 mIU/g	102,000	36,660
		Vitamin A + D_3	11,700	38,610
	Dorina Potae 454 g	Vitamin A + D_3	7,500	24,760
Chile	All	Vitamin A + D_3	900	2,970
Panama	All	Vitamin A + D mix	6,430–6,930	
Africa				
Côte d'Ivoire	Blue Band	A	6,300	30,790
South-East Asia				
Malaysia	Dorina[b]	A	7,570	25,000
	Plarta[b]	A	7,570	25,000
Sri Lanka	Astra[b]	A	1,000	33,000
Indonesia	Astra[b]	A	1,000	33,000

a. The type of vitamin A used was not specified in the database.
b. Information from Golden Yellow Fats database, Food Applications Unit, URL, and from margarine labels.

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Guidelines for the development of research proposals following a Structured, Holistic Approach for a Research Proposal (SHARP)

Rainer Gross, Darwin Karyadi, Soemilah Sastroamidjojo, and Werner Schultink

Abstract

SHARP (a Structured, Holistic Approach for a Research Proposal) is a structured method for developing a research proposal that can be used either by individuals or by teams of researchers. The eight steps in SHARP are (1) setting up a causal model, (2) establishing a fact–hypothesis matrix (FaHM), (3) developing a variable–indicator–method matrix (VIM), (4) selecting the study design, (5) defining the sampling procedure and calculating the sample size, (6) selecting the statistical methods, (7) considering the ethical aspects, and (8) setting up an operational plan. The objectives of the research proposal are to help the researcher to define the contents and to plan and execute a research project, and to inform potential collaborators and supporters about the topic. The proposal that is produced during the process can be submitted to agencies for possible funding.

Introduction

The following guidelines for writing a research proposal have been developed on the basis of experiences at academic institutions providing advanced training in nutrition. We have noted that students who plan and conduct their first research projects often have difficulty orienting themselves within the vast field of scientific information and tend to focus their proposals on a minimum of relevant issues, ignoring many essential items. Therefore, a structured method has been developed as an orientation tool to help guide young researchers into scientific research. Furthermore, the method has also been found useful for the development of research proposals by a team. This is especially important in interdisciplinary sciences such as nutrition, when individuals with different experiences and expertise have to be brought together. This instrument and procedure has been named SHARP: Structured, Holistic Approach for a Research Proposal.

SHARP should be implemented in eight consecutive steps:

1. Set up a causal model;
2. Establish a fact–hypothesis matrix;
3. Develop a variable–indicator–method matrix;
4. Select the study design;
5. Define the sampling procedure and calculate the sample size;
6. Select the statistical methods;
7. Consider the ethical aspects;
8. Set up an operational plan.

SHARP is an instrument and a process. It defines and standardizes scientific requirements that are needed for the development of a research project. Furthermore, SHARP encourages the bringing together of different types of scientific expertise and can be used to guide the development of a research proposal by a team.

Objectives of these guidelines

The objectives of these guidelines for the development of a research proposal are to:

» improve, standardize, and maintain research quality and performance;
» stimulate the orientation and training of scientific personnel;
» facilitate comparisons among research projects;
» facilitate the development of proposals that can be submitted to agencies for research funding.

The target group of the guidelines is primarily students, but the guidelines will also be useful to senior researchers who guide and coach students or who plan to carry out their own research projects in the field of nutrition.

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Objectives of a research proposal

A research proposal has two main objectives:
» to help the researcher to define the contents and to plan and execute his/her research project;
» to inform potential collaborators and supporters about the topic and the expected quality of the research.

In addition, the proposal can be submitted to one or more agencies for consideration for funding. In particular, a research proposal should:
» justify the chosen research project;
» describe the current state of knowledge on the research topic, considering all important relevant literature;
» formulate the hypothesis or research question;
» define the research strategy and methodology to be used to test the hypothesis or research question;
» discuss ethical considerations about the research methodology;
» define realistic, feasible, operational planning, based on the research methodology and general conditions;
» inform potential collaborating institutions and persons about the research project and enable them to identify the kind of support they can give;
» serve as an important tool for monitoring the research.

The research proposal may be an educational as well as an examination exercise. The proposal should be lucid, direct, selective, and critical.

Contents of a research proposal

The presentation of a research proposal follows a logical sequence according to the following steps:
1. introduction to the research topic, formulation of the problem, and justification for its selection;
2. development of the causal model;
3. formulation of the hypothesis;
4. definition of all variables and their indicators;
5. selection of the study design;
6. description of the population to be studied;
7. description of the sampling procedure;
8. selection of measurement methods and statistical methods;
9. development of the operational plan, including time schedule, human resources, equipment, material, and budget.

Each of the following sections describes a component of a research proposal.

Title page

The purpose of the title page is to present a concise statement of the subject of the research and to identify the responsible researchers. The title page is the "main gate" of the research proposal, which invites the reader to enter the research proposal.

The title should:
» express the main message of the research topic;
» be relevant;
» be short;
» be clearly and precisely formulated;
» be exciting;
» be appealing.

The title page should contain the following information:
» title of the research project;
» name of the principal researcher;
» date of submission of the research proposal (month and year);
» name and address of the institution of the principal researcher;
» telephone number, fax number, and e-mail address of the principal researcher.

The title page should also contain the:
» name(s) of the scientific collaborator(s) (e.g., supervisors and promoters);
» name(s) and address(es) of the institution(s) of the scientific collaborator(s).

The *curriculum vitae* of the principal researcher should be included in the appendix of the research proposal.

Table of contents

The table of contents outlines the structure of the research proposal. An example is shown in table 1. The headings and subheadings are structured and numbered, and the appropriate page numbers appear at the right-hand margin. The headings of the table of contents are identical to those in the body of the report.

Abstract

The purpose of the abstract is to summarize in less than 200 words all important parts of the research proposal.

The abstract should:
» describe the general objective of the study (justification);
» define the central hypothesis;
» describe the site and population to be studied;
» summarize the total time and budget necessary to carry out the research.

Introduction

Purpose of the introduction

The introduction should justify the hypothesis of the proposed research. In particular, it should:
» summarize the relevance of the topic;
» give an overview of the status of international research in related areas;

TABLE 1. Table of contents of a research proposal

Title Page

Table of Contents

0 Abstract

1 Introduction
- 1.1 Relevance of the topic
- 1.2 Current state-of-the-art
- 1.3 Causal model
- 1.4 Fact–hypothesis matrix (FaHM)
- 1.5 Objectives of the research project
- 1.6 Hypothesis of the research project

2 Methodology
- 2.1 Variable–indicator–method matrix (VIM)
- 2.2 Study design
- 2.3 Population under survey
- 2.4 Sample size and sampling procedure
- 2.5 Measurement methods and statistical analysis
- 2.6 Ethical considerations

3 Operational Planning
- 3.1 Time schedule
- 3.2 Human resources
- 3.3 Equipment and material
- 3.4 Budget

4 Appendices
- 4.1 Literature cited
- 4.2 Draft of questionnaire
- 4.3 *Curriculum vitae* of proposer

» finally, lead to the objectives and hypotheses of the proposed research topic.

Relevance of the research topic

In the introduction, the research topic is placed in the general framework of current knowledge. The proposed research is justified, and after the general framework has been described, the topic is narrowed down. Research submitted for a doctoral thesis must be original; it must be substantially new.

Current state-of-the-art

The review of literature should focus on the knowledge required to test the hypotheses. Literature citations should be used to support factual statements. It is necessary to filter out ideologies, unsubstantiated dogma, open questions, and untested hypotheses. Rambling on, mentioning uncritically everybody who ever said anything related to the topic confuses more than contributes to the analysis of information available about the topic. The selection and discussion of the literature strongly indicates the intellectual capacity of the researcher and the time spent in preparing the research proposal. This requires careful review and analysis of the literature.

Modern computerized systems allow for the collection of an enormous number of literature citations. It may be difficult for a less experienced researcher to judge the relevance of a citation. The establishment of a causal model (see below) facilitates the decision of relevance.

Causal model

During the development of a causal model (frame of thinking), all important variables are defined and their relationship to the central hypothesis is identified. The causal model is based on conclusions drawn from the literature. An example of a causal model is shown in figure 1.

The causal model helps to identify all relevant variables that contribute to a hypothesis and define the expected cause–effect relationships of the variables. In particular, a causal model helps to:
» select relevant literature for reading;
» identify all necessary variables that have to be controlled by the study, including confounding factors;
» identify hypothetical relationships between variables.

A cause–effect relationship can be identified as a direct

IF → THEN

relationship

The development of the causal model starts with the concise definition of the core situation or problem (e.g., nutritional inadequacy) that results from the central hypotheses (diseases, inadequate intake, and low birthweight contribute to nutritional inadequacy). The model is then constructed as follows:
» A concise statement of the core situation is written down and enclosed in a box.
» Each direct (proximate) cause (variable) that could influence the core situation is identified and written down in a box *below* the box containing the core situation. The box(es) containing the direct cause(s) of the core situation are connected to the box containing the core situation with directional arrows.
» Each box should be consecutively numbered for later identification.

If a research proposal is developed by a team or group, the construction of a causal model should be carried out using the Metaplan technique as described in the Appendix. At the end of the exercise, the hierarchy of the causal model has been developed that contains all core problem-related variables. The causal model will form the basis of the fact–hypothesis matrix (FaHM) (table 2) and the variable–indicator–method matrix (VIM) (table 3).

Facts and hypotheses

The fact–hypothesis matrix is a systematic way to organize causal relationships proposed in the causal model

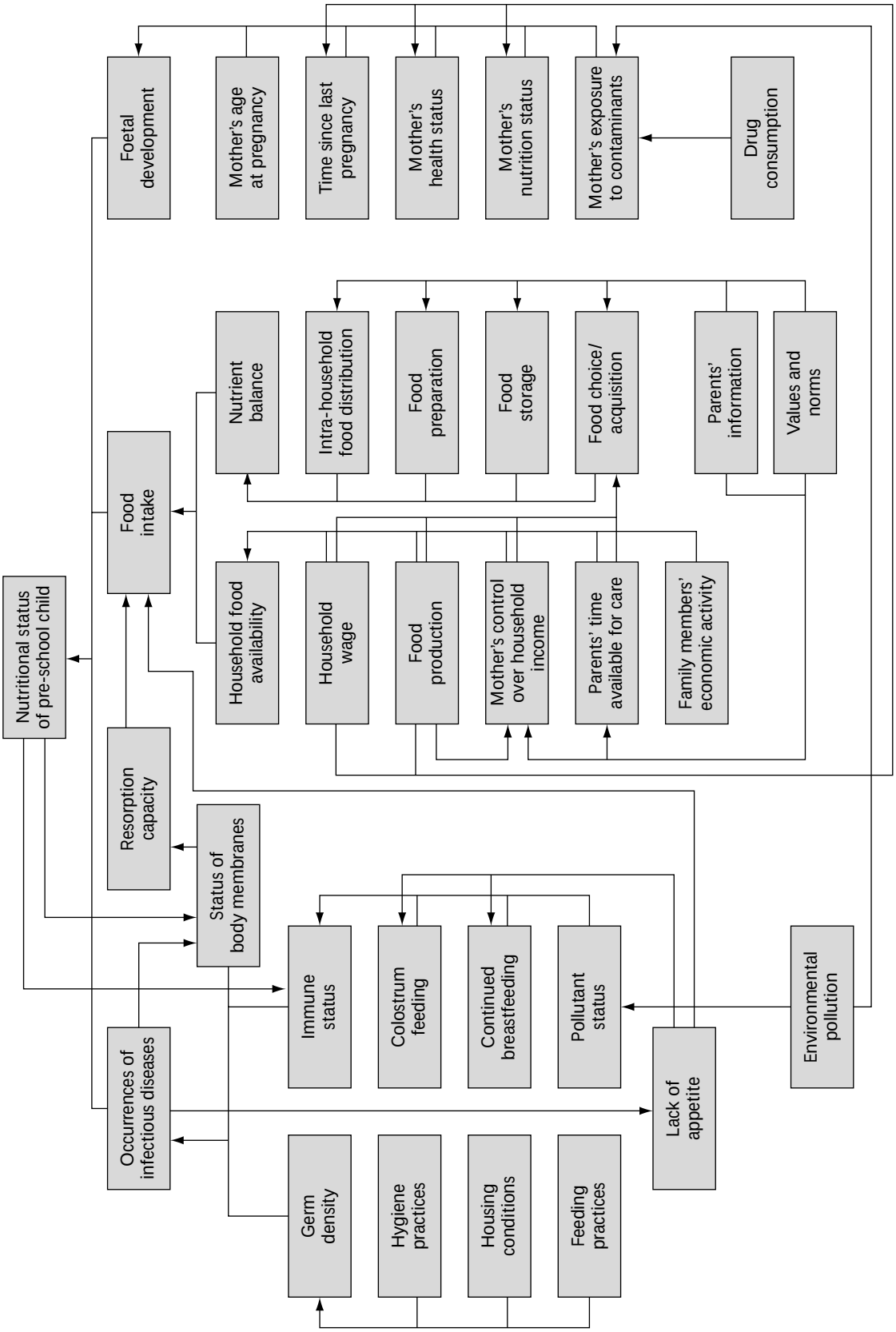

FIG. 1. Example of a causal model

TABLE 2. Fact–hypothesis matrix (FaHM)

Letter	Effect	Cause	References
A	Stunting	Energy intake	H
A	Wasting	Energy intake	H
A	Stunting	Vitamin A intake	H
B	Stunting	ARI	Neuvianz et al. (1990)
B	Stunting	Diarrhoea	Black et al. (1984)
B	Stunting	Helminths	Stephenson et al. (1980)
C			
D			
E			
F			
F			
G			

(table 2). Each relationship is identified as either hypothetical or proven. In the first three columns of the matrix, each causal relationship of the model is summarized. Each direct cause is identified by a letter, and the respective dependent (effect) and independent (cause) variables are listed in the second and third columns.

In the fourth column, the literature citation that confirms that the stated variable is a cause of the core situation is cited. If no literature source can be found, an H for a hypothetical cause–effect relationship is entered in the fourth column. A causal model with many hypothetical cause–effect relationships indicates a very uncertain frame of thinking, which makes the outcome of the research work very unpredictable and planning more complex.

Formulation of the objectives of the research project

The general objective of a research project is defined as the purpose of the project. It states what the project intends to accomplish or develop in relation to observed problems or situations. The following criteria should be considered when formulating the general objectives of the project. An objective must (1) be applicable to the situation, (2) be achievable and measurable, (3) not be ambiguous, and (4) be harmonious with societal and institutional goals and constraints.

Sometimes after the single, general objective has been stated, it is convenient to list a series of component objectives or specific objectives. These state specific research results and sequential goals to be achieved during the study. They are concrete, attainable results that can be measured and are readily identified when they have been reached. Specific objectives must be necessary *and* sufficient to reach the general objective of the research project.

Formulation of the hypothesis of the research project

The hypothesis of a research project is an educated guess, or a prediction of causal relationships that can be tested; an unanswered question that arises from a literature review of a topic leads to such predictions. Data are then gathered and analysed to test the hypothesis.

If a hypothesis refers to the relationship between two variables, the formulation should indicate clearly the direction of their relationship. The relationship stated in a hypothesis should be tested by measuring appropriate variables and judging whether the values of these variables could have occurred by chance. If the observations could have occurred by chance, then the researcher concludes that the null hypothesis is true and that the hypothesized relationship does not explain the data. To prove a relationship, the null hypothesis must be proven to be wrong.

A hypothesis should be:

» based on a known fact or theory,
» testable,

TABLE 3. Variable–indicator–method matrix (VIM)

No.	Variable	Indicator	Method	Reference
0	Nutritional status	wt/age, wt/ht, ht/age	Anthropometric measurement	WHO (1983)
	Nutritional status	MUAC/age	Anthropometric measurement	UN (1986)
	Nutritional status	Hemoglobin status (g/L)	Cyanide	INACG (1985)
1	Infectious/invasive diseases	Period prevalence ARI	Questionnaire	WHO (1985)
	Infectious/invasive diseases	Period prevalence diarrhoeal disease	Questionnaire	Black et al. (1984)
	Infectious/invasive diseases	Period prevalence ascariasis	Stool examination	Brown et al. (1980)

Abbreviations: ARI, acute respiratory infection; MUAC, mid upper arm circumference.

» specific,
» brief, but clear.

The proposal for research intended to contribute to new scientific knowledge must always have a hypothesis. A *main hypothesis* should be supported by *specific hypotheses*, which state relationships between variables that are part of, or complement, the interpretation of the main hypothesis.

Definition of methodology

The purpose of the methods section is to identify and justify the research methods selected for the research. The choice of methods depends on the variables to be measured and the cause–effect relationships among them. One method for developing a community nutrition research project is the causal model approach, as defined above.

Variables and indicators

A variable is a characteristic of the study subjects (e.g., nutritional status), and an indicator is a measurement collected during research that is assumed to reflect the variable (e.g., blood haemoglobin level).

The variable–indicator–method matrix (VIM) is a systematic way to organize the relationship between variables of interest and potential indicators of these variables. The VIM should:

» relate every variable (cause) of the causal model to at least one indicator;
» describe the methodology by which each indicator will be surveyed;
» cite the literature source of the methodology selected.

An example of a VIM is presented in table 3. Each variable of the causal model is listed in the first two columns of the VIM and identified by the box number. (Because of the hierarchical nature of the box numbering, the numbers will not be consecutive.)

Indicators of variables are specified in the third column. Each variable should be related to at least one indicator, which defines the variable precisely (e.g., variable: nutritional status; indicator: Z-score of weight/height index according to the NCHS reference population). The indicators should be selected according to the following criteria:

» Validity
  – Does it measure (quantify or describe) what we assume it measures? For example, does the indicator we have chosen to show obesity indeed measure the fatness of a person?
» Feasibility/appropriateness
  – Is the cost realistic?
  – Is the equipment available?
  – Is the methodology appropriate, and can data be obtained?

The method of measuring each indicator is listed in the fourth column. The methods should be selected according to the following criteria:

» Accuracy (getting the correct answer). This includes:
  – sensitivity
  – specificity
» Precision (reliability, reproducibility, repeatability). There are several kinds of precision, including:
  – instrumental (precision of analytical instrument on same sample on different occasions);
  – biological (precision of same subject on different occasions);
  – intra-observer (precision of same tester on different occasions on same subject);
  – inter-observer (precision of different testers on the same subject at same occasion).

Literature references validating each method are cited in the fifth column, when available. If the method has not been validated, a separate validation activity must be carried out before the major portion of the research project can be undertaken.

Study design

After variables to be surveyed have been identified and indicators related to each of the variables have been defined, the study design has to be selected and presented in the text and as a diagram. Common types of study designs include the following (fig. 2):

» Observational study
  – prospective study (prospective cohort study)
  – retrospective study (case-control study)

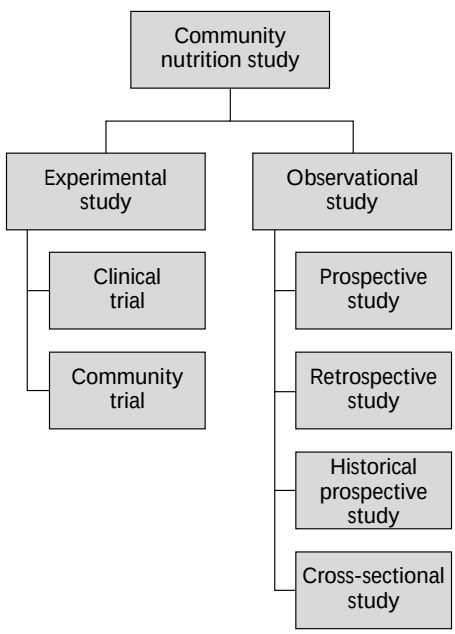

FIG. 2. Common types of study design

  - historical prospective study (retrospective cohort study)
  - cross-sectional study
- Experimental study
  - clinical trial
  - community trial

The criteria of the selection of the most appropriate study design should be listed and advantages and disadvantages of the design should be discussed. Special attention should be given to possible confounding factors related to the selected study design.

It is highly recommended that whenever possible, double-masked tests (formerly called double-blinded) be used in intervention studies. "Double-masking" implies that neither the researchers nor the participants in the intervention are aware of the assignment of the treatment. This eliminates evaluator bias on the part of the researcher and behavioural bias on the part of the participant.

Population under survey

The proposal needs to define the criteria to be used in selecting the population to be surveyed and needs to distinguish the selection criteria from the descriptive data that will be collected to characterize the sample. For example, the selection criteria for a study might be women with two children under the age of five years—all other women and all men would be excluded. The study population would then be characterized by maternal age, number of dependent children, geographic area, etc.

Ideally, the sample selected from a population is representative of the entire population, and therefore the characteristics of the study sample describe those of the entire population.

Sample size and sampling procedure

After identification of the variables and their indicators and the selection criteria for the population to be surveyed, the sample size and sampling methods must be defined. Obviously the selection of the population, the sampling method, and the sample size must be coordinated. By convention, *N* represents the number of individuals in the population and *n* the number of individuals in the sample.

It is important that the sample size be large enough that statistically significant differences will be identified if they exist. The calculations concerning sample size depend on:

- the primary question that the researchers want to investigate;
- the way in which it is to be answered.

The probability of detecting a specified difference is called the power of the study. A powerful study is one with a high probability of detecting an important treatment difference. It is a waste of resources to conduct a study with insufficient power to reach valid conclusions. A biostatistical or statistical textbook should be consulted before the final sample size is selected. The population must be sufficiently large so that an adequate sample can be obtained in a reasonable amount of time using the methods chosen.

The following sampling methods are applicable to community nutrition research:

Probability sampling methods rely on formal random techniques to identify the units to be included.

- *Simple random sampling.* A fixed percentage of the population is selected using a formal random process, such as a random number generator or random number table.
- *Systematic random sampling.* The *n* sampling units are selected from the sampling frame at regular intervals (e.g., every fifth house). When systematic methods are used, the starting point in the first interval is selected on a formal random basis.
- *Stratified random sampling.* Before selection, the sampling frame is divided into strata based on factors likely to influence the variable being estimated (e.g., variable: nutritional status; factor: income). Then a simple random or systematic random sample is selected within each stratum.
- *Cluster sampling.* Primary sampling units are defined, which are logical groups or clusters (e.g., classrooms) of secondary sampling units (e.g., individual children). The clusters can be selected by systematic, simple, or stratified random methods, and *all* individuals within the primary sampling units (or clusters) are selected to participate in the research.
- *Multistage sampling.* This method is similar to cluster sampling, except that sampling takes place at all stages. As an example of two-stage sampling, one would begin as in cluster sampling by selecting a sample of the primary units (e.g., classrooms) listed in the sampling frame. Then within each primary unit, a *sample* of secondary units (e.g., individual children) is selected. This procedure differs from cluster sampling, in which all of the secondary units within each selected primary unit are taken.

Non-probability sampling methods do not rely on formal random techniques to identify the units to be included.

- *Judgement sampling.* Representative units of the population are selected by the investigator.
- *Convenience sampling.* The sample is selected because it is easy to obtain. Using convenience or judgement sampling often produces biased results, regardless of whether the researcher believes he/she can select representative samples. Therefore, these samples should rarely be used for survey purposes.
- *Purposeful sampling.* The selection of units is based on known exposure or disease status (for example, children with severe diarrhoea admitted to the hospital). Purposeful sampling is often used to select units for analytic observational studies, but it is in-

adequate for obtaining data to estimate population parameters.

Statistical analysis

The purpose of statistical analysis is to allow the researcher to draw conclusions from the data obtained. Therefore all aspects of the research proposal should be formulated so that valid statistical conclusions can be drawn.

Appropriate statistical methods should be selected based on the study design and the sampling techniques. Before analysing the data with a certain statistical test, it is essential to determine some characteristics of the data.

Research data are differentiated into at least three categories:

» Frequency or nominal data. Each value represents a characteristic or group membership (e.g., sex: male=1, female=2; place of origin: south=1, central=2, north=3).
» Ranking or ordinal data. The values imply a relative rank of the characteristic, but not the magnitude of differences between ranks (e.g., formal education: none =1, can read and write =2, completed primary school =3, completed secondary school =4).
» Measurement value or fixed interval data. Values are from a scale with constant intervals and known size (e.g., size, weight, age, haemoglobin level).

The choice of statistical test depends on several aspects of the hypothesis being tested:

The values recorded for each variable included in the statistical test. Variables with values recorded in either frequency or ranking categories will be analysed by a non-parametric statistical test. Variables with values in the measurement category are usually analysed with parametric tests. However, the values of variables in the measurement category may be very skewed or irregular in distribution. In this case, non-parametric tests are used in analysis of the data. Therefore, a necessary part of data analysis is checking the distributions of data values for patterns that differ from the normal distribution. Descriptive statistics, such as the rate of progression (skewedness) and excess (kurtosis), are useful in this determination.

The nature of the research question. The hypothesis can ask for a comparison between proportions of observations or between the mean values of two groups, or it can predict group membership based on the values recorded for several variables. There are many types of research questions, and table 4 shows which tests are appropriate for common types of questions.

Ethical considerations

Each study and survey conducted on human beings and animals needs approval from an official committee of a research institution. This committee evaluates the research proposal according to the following criteria:

» maximizing benefit
» avoiding harm and minimizing discomfort
» confidentiality
» conflict of interests.

For epidemiological research, the guidelines of the Council for International Organizations of Medical Sciences (CIOMS, 1991) are highly recommended as a source of detailed information for ethical considerations. It is the function of the ethical committee to

TABLE 4. Selected statistical tests

Factors	Sampling	Data category			
				Measurement values	
		Frequency	Ranking	Non-normal distribution	Normal distribution
Tests for 2 factor steps	Independent sampling	χ^2 test	Siegel-Tutzey test U test	Kolmogoroff-Smirnoff test	*F* test *b* test
	Joint sampling	Tests for indications	Wilcoxon test Spearman rank-order correlation coefficient		*t* test Product-moment correlation Linear regression
Tests for >2 factor steps	Independent sampling	χ^2 test	H test		Variance analysis Student-Newman-Keuls test
	Joint sampling	*Q* test	Friedman test Multiple comparison between Wilcoxon and Wilcox		Variance analysis Multi-various methods

monitor and control the implementation of ethical standards of the researcher.

The research proposal should provide information on how the individuals will be directed for treatment in case health problems are identified during the study. Subjects allocated to a control group should be able to benefit from the treatment after ending the study. For example, if in an iron-supplementation study anaemic individuals have been identified who are not allocated to the treatment group or who are in the treatment group but are still anaemic at the end of the study, adequate treatment has to be provided for them at the end of the study.

A copy of the declaration of informed consent that should be signed by the subjects or their caretaker must be available in the appendix of the research proposal.

Operational planning

The purpose of operational planning is to synthesize all research activities into a working plan. The research activities include additional activities that are not directly linked to the scientific work. For example, during the selection of the study population, individuals with diseases need to be treated, and at the end of the study, the community needs to be informed of the results of the study, which should lead to interventions, if relevant. The plan includes a time schedule, a summary of the human resources, equipment, and material needed to complete the plan, and a budget. The plan needs to be checked carefully to determine whether it is feasible and whether it will indeed allow the researcher to test the stated hypothesis.

If methods have not been validated, the plan needs to include a provision for a validation procedure. In studies in which more than one person takes measurements, carries out tests, or makes observations, provisions for training the research team are essential.

Time schedule

The length of time needed to complete each part of the research project needs to be clearly identified. It is very important that the estimates be realistic, because the allocation of resources (human resources, equipment, etc.) may need to be coordinated with other projects. All aspects of the project must be included: planning, validating survey instruments, training in data collection and analysis, providing information to the community and to institutions, follow-up treatment, etc. **A balance needs to be reached: usually, the longer a project takes, the more expensive it becomes; however, a hurried project may not yield reliable results.**

Figure 3 provides an example of a time schedule for a Master of Science research project. It shows how to represent the time required for each activity and indicates which portions of the project can be conducted simultaneously. The schedule starts after the acceptance of the research proposal. The literature research for the development of the proposal must begin before the schedule starts. However, literature study is not finished with the acceptance of the research proposal.

Much time can be saved if the researcher has met with and explained the activities to all parties involved in the research, such as local representatives of governmental offices, non-governmental organizations, and the individuals and the community to be studied.

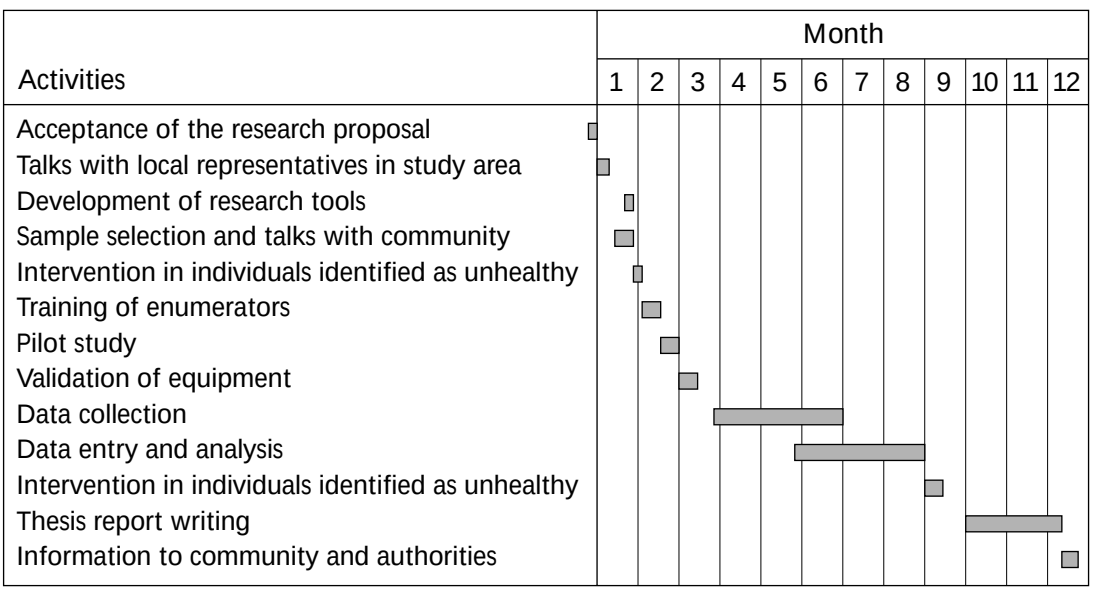

FIG. 3. Example of an operational plan for a Master of Science research project

Research tools such as equipment, material, and questionnaires have to be checked and validated. It may therefore be necessary to carry out a reconnaissance or pilot study before beginning the main study.

Sufficient time and resources must also be available for the treatment of subjects who are diagnosed with health problems. Treatment should also be available for those individuals not chosen to participate in the study. Additionally, treatment must be organized for subjects who participate in the study and still have health problems at the end of the trial. The same issues must be considered in cross-sectional studies.

Research that takes more than one year, such as doctoral research, needs special attention from supervisors. At certain phases of a research project, the principal researcher must inform all those involved about the progress of the research activities. Important reporting times are:

» after a reconnaissance or pilot study, before the main study is to start, so that the collaborators will have a chance to influence the research design and implementation;
» every six months during the research work.

This does not mean that these are the only times that the research is monitored. The researcher should continuously monitor all aspects of the research.

Human resources

All human resources needed to complete the project must be identified. Individuals are not usually named in the research proposal. Human resources include:

» technicians
» consultants
» drivers
» translators
» data entry personnel.

The following information should be included in the proposal:

» How many of each type of person will be needed;
» Whether they will be needed full-time or part-time;
» How much each person will be paid;
» How long they will be needed;
» When they will be needed.

Equipment and material

All equipment and material needed to complete the project must be identified. Expensive or specialized items must be precisely specified. Other items can be listed in general categories (for example, office supplies). Rented, leased, or shared equipment should be considered expensive items and should be precisely specified.

Some or all of the following may be needed:

» paper for reproducing questionnaires
» equipment to be used in the field
» equipment to be used in the laboratory
» transport
» computers, fax machine, and copy machine
» postage and communication costs

With regard to equipment and materials, the proposal should state:

» What is needed;
» How much it will cost, including tax and shipping, etc.;
» When it will be needed.

Budget

The budget should include all projected expenditures. Generally, a budget is stated on a yearly basis. Within each year, the budget is divided into sections such as:

» personnel (salaries, wages, fringe benefits)
» equipment
» materials and supplies
» printing and publication
» travel
» rental or lease of facilities
» other (utilities, phone, insurance, advertising)
» overhead
» contingency

Overhead (indirect costs) covers the cost of administering the project, such as office space, administrative personnel, etc. It is often a set percentage of the entire cost of the project, based on an agreement between the sponsoring organization and the project. If the research project will take more than one year, an adequate inflation rate has to be factored into the budget planning.

Statement of assumptions

The statement of assumptions identifies external influences that are risks to successful implementation of the research project. This demonstrates how the research project is or can become dependent on its environment and facilitates the evaluation and reduction of any risks that threaten the success of the project. The proposal should discuss any implicit assumptions that may not be readily accepted by the potential collaborators or research supervisors of student projects.

Examples of assumptions that might be important in nutrition research projects during implementation include the following:

» Enough qualified interviewers can be hired locally;
» The population will accept research methods (e.g., blood sampling).

Other assumptions are out of the control of the researcher. These include the following:

» The political and economic situation will remain stable;
» The health system will continue its current immunization schedule;
» The schools will continue to serve lunch to the children.

If the statement of the objectives of the research proposal is based on an assumption that may turn out to

be invalid, the proposal should anticipate the problem by having one or more alternatives.

Monitoring

Monitoring is an important tool for guaranteeing the success of a research project. It needs to be done continuously, with particular attention at the beginning and end of each stage of the research. Monitoring helps inform all research workers about the situation and possible problems of the research project. In doctoral research, monitoring is carried out by supervisors and proposers. The research proposal is the basis upon which the programme is monitored.

Reporting is an essential part of monitoring. Appropriate reporting by the person responsible for the research is needed for monitoring the activities carried out. The report should consist of the following topics:

» Implementation
  – overview of activities carried out during the report period
  – institutional affiliations, contacts, and collaborations
  – organizational set-up (e.g., personnel hired, logistics)
  – collaboration with individuals and population to be studied
  – evaluation of implementation (if relevant, reasons for changes)
» Changes of research design (if relevant)
» Preliminary results
  – main results of data analysis
  – reasons for not achieving the objectives (if relevant)
» Assumptions not directly related to programme
» Plans for the next reporting period
» Finances
  – budget spent
  – budget planning for the next report period

The research coordinator and the proposers of the research must receive the report within one month of the end date of the reporting period defined in the time schedule of the research proposal. The report should not exceed eight pages. The written report is only a small part of monitoring. Research must be monitored continuously and necessary modifications made immediately.

Appendices

The appendices contain background documentation that provides additional detail on any aspect of the proposal. The detail should complement the proposal text.

Literature cited

The list of cited literature is an important indication of the quality of the research proposal because it shows the thoroughness of the literature search and the understanding of the technical background needed for the project. The cited literature verifies:

» the relevance of the proposed research topic;
» the originality of the hypothesis;
» the validity, accuracy, and precision of the proposed research methodology.

Literature has to be used critically. Any of the references can be used to explain and expand the theoretical discussion of the topic. In general, primary literature sources should be used. If secondary literature is used, in which authors quote information published by others, the references must clearly reflect this.

Specific formats for citation in text and in the literature cited section of a research proposal will be dealt with below.

Draft of questionnaire

Questionnaires are an important tool of epidemiological and operational research. Given the nature of original research, a unique survey form must be developed for each research project. The nature of the study and the setting in which the data will be collected will influence the design and structure of the data-recording form or questionnaire; however, the following general principles should be considered:

» The title of the study should appear at the top of the survey form and should be clear and sufficiently detailed to inform collaborators of the general purpose of the survey.
» Questions must be clearly worded, straightforward, and necessary. Initially, it is useful to list all of the variables about which information is required; then structure the questions so that the answer(s) to each question provide the appropriate data.
» Questions should be grouped according to subject matter or another logical basis, such as the temporal relationship of events, to facilitate communication with the respondent.
» It is desirable to record the answers as measurements or continuous variables (e.g., the actual age). Data can be grouped later, if necessary.
» The layout of the questionnaire should assist the analysis and/or computer entry of data. Copying data by hand should be avoided, because each time a number is written down the probability of introducing an error increases.
» Asking questions correctly is as much an art as it is a science. Nonetheless, certain principles should be followed:
  – Avoid asking leading questions that suggest a right answer to the respondent.
  – Make sure that there is an obvious answer to each question.
  – The terminology used in the question should be tailored to the way the respondents use the words and names.

There are three distinct types of questionnaires or survey forms used in community nutrition projects:

» surveys of individual data
» surveys of household data
» surveys of structural data (data on the village, city, suburb, district, etc.)

Data that are unique for each individual are recorded on surveys of individual data. Data that apply equally to each individual in the household, such as the size of the family or the amount of living space, should be recorded on a separate form for that household, not on the form for each individual in the household. Similarly, observable variables applying equally to all households in a village, such as climatic data, should not be recorded on a household survey form, but should be recorded on a form for each village or city suburb (survey of structural data).

The survey forms for each project should be standardized to simplify recording and later reading of the data. For this purpose the following rules should be observed:

1. Each survey form should have a header that provides the following information:
   » title of the study
   » name of the responsible institution
   » type of form (e.g., household form, individual form)
   » household number
   » individual number (if relevant)
2. Each household must be assigned a unique household number. This number should be entered in the header of the survey form BEFORE commencing the survey. In this way if the pages of the survey become separated, the identity of the household will be clear, and also no two households will receive the same identification number (household number).
3. In case more than one individual of a household is assessed (for example, more than one child below five years of age), besides the household number each individual must be assigned a unique individual number. Consequently, each page of the individual survey form should have both the household number and the individual number, which should be filled in BEFORE commencing the survey.
4. Each variable must have a sequence number.
5. The text of each variable is fully written out, so that the surveyor has no doubts in his/her mind during the interview. This means that the questions on the survey form should be short but specific.
6. The answer categories for closed questions are coded and the codes identified on the survey form (e.g., male = 1; female = 2). For size measurements (such as height, age, and weight), the appropriate unit (such as cm, months, or kg) is shown on the survey form.

INSTITUTION, NUTRITION SURVEY **Household number** ☐☐☐
Household **Page 7**

35) Question: If you were to have another child, would you prefer a boy or a girl? ☐
1) Boy
2) Girl
3) Boy or girl, it does not matter
8) Don't know
9) No answer

36) Measurement: Weight of the mother (00.1 kg) ☐☐.☐

37) Measurement: Height of the mother (cm) ☐☐☐

38) Observation: Could you please show me which kind of salt you use currently in cooking and as table salt? ☐
1) Packaged iodized salt
2) Packaged salt, without label about iodination
3) Coarse, rock, or brick salt
8) Don't know, not sure
9) No observation made

39) Measurement: Presence of iodine in tested sample ☐
1) No colour change
2) Blue colour change occurs
8) Don't know, not sure
9) No observation made

40) Question: During the last 7 days, how often have you frequented a meeting with more than 10 persons? ☐

FIG. 4. Example of a template for a questionnaire sheet

7. A box is available on the right-hand side of the form for each variable to provide an identified space for coded answers.
8. All possible responses to a closed-category question are assigned to a number (including categories for "other" and "unknown," if appropriate). There should be no opportunity to record unique answers, because these add considerably to the workload of data entry and analysis, and where several data collectors are engaged, it is impossible to maintain adequate standardization. The reconnaissance or pilot study is an important stage to convert open questions into closed ones.
9. To reduce errors, answers such as "no answer," "don't know," or "others" should always have the same code (e.g., 99 or 9, 88 or 8, and 77 or 7).
10. If no exact answer can be expected in certain cultural contexts, the question should be omitted. It is better to obtain less, but accurate, information than large quantities of erroneous or ambiguous information.
11. The respondent should not read the questionnaire in advance. This will maintain the spontaneity of the answers.
12. Each variable should have its own unique code name that should consist of not more than eight digits. All code names should be listed in the Description of the Variables (a list of all variable codes and their description). For example:

    Variable code: ELECTRIC house has electricity. However, since the variable codes are only important for the data analysis and have no further implication for the enumerator, the code need not be stated on the form.
13. Some data needed for analysis are based on further manipulation of the information obtained by the interviewer. For example, to ensure that the question "How many people are there in the household?" is accurately answered, it is best to ask for the name of each member of the household. The interviewer writes down the names and later sums up the total. The variables that are not asked directly are marked on the questionnaire by square brackets [ ].

Samples of survey forms are presented in the Appendix. These are divided into the household level on one hand and the individual level (child) on the other. The household-level sample forms are further divided into samples adapted to urban and rural households, as there are some important differences in socio-economic and ecological descriptions of the two environments.

The sample forms are provided to show appropriate layout and structure. The content and language of the forms used must always be adjusted to the circumstances of the survey area and the respondents.

Curriculum vitae *of the proposer*

The research proposal finishes with the *curriculum vitae* of the proposer. The following information should be included in the *curriculum vitae*:

» full name and academic degrees
» place and date of birth
» office and rank
» higher education degrees
» work experience
» scientific publications
» awards

Writing the research proposal

The form of the research proposal is particularly important, because:

» Often it is possible to draw conclusions about the quality of the content of the proposal from the quality of the form of the research proposal. For instance, an unstructured presentation may be a sign of conceptual problems in the logical framework of a research project.
» A well-structured and attractively presented document facilitates reading and understanding the proposal, even if the subject is complex and complicated, as is the case for many research proposals.

It is necessary to present the proposal in a form as structured and attractive as possible.

The research proposal starts with the title, a very condensed and general explanation of the research, which is followed by a more expanded presentation in the abstract, and continues with the details of the planned research project. The proposal ends with the most specific information in the appendix—a draft of the questionnaire and a list of the literature cited in the proposal. This form of presentation should invite the reader to study the proposal but should also quickly alert him/her if the subject of the proposal is not within his/her scope of interest.

Miscellaneous

Abbreviations are usually used for generic names, but the full generic name should be given when the insect (or other animal, bacterium, or plant) is first mentioned anywhere in the proposal. Thus the mosquito would be referred to first as *Anopheles hyrcanus* var. *sinensis*, and later as *A. hyrcanus* var., or *A. h. sinensis*, or simply *A. sinensis*.

Several mosquitoes belong to genera having the same initial letter, and confusion is therefore possible if initials are used for them all. For instance, if *Anopheles*

and *Aedes* are named in the same paper (as often happens), it is wise to refer to both genera in full throughout, even at the expense of much repetition. Similarly, if both *Entamoeba coli* and *Escherichia coli* were named in the same paper, it would obviously be wrong to use the contraction *E. coli*. In general, all Latin words should be written in italic letters.

Names of diseases derived from proper names should *not* be written with initial capital letters once they have become generally accepted: e.g., brucellosis, bilharziasis, leishmaniasis.

Measurements should always be given in metric units. Abbreviations of metric units should be written according to international standards.

Tables

Tables must be self-explanatory, although interpretations need to be explained in the text. Each table should begin with a heading consisting of the table number followed by the title. The table number must be referred to in the text. Tables should be numbered sequentially through the research proposal.

The title should summarize briefly the information in the table. Each column has to have a heading. Immediately beneath the column headings, the precise units of measurement of the data should be shown, if applicable (e.g., "%" or "years"). Units of measurement should be enclosed in parentheses. Longer units (e.g., "number of infant deaths per 1,000 live births and stillbirths") should be put in a footnote to the table. In these cases, footnotes should be placed beneath the lower boundary of the table. However, the footnote should be at least two double-spaced lines above the following text to distinguish it clearly from the text.

If possible, the column headings should be concise so that they can be written horizontally. They may contain abbreviations. Although different table layouts can be chosen, with lines separating columns, rows, or headings, the same style should be maintained throughout the document.

As a rule, tables are presented vertically on the page, although wide tables may be presented sideways (landscape). If a vertical table is too long to fit on one page, it should be continued on the next page. At the bottom of the first page, the word "continued" should appear. The second should begin with the words "Table X continued," and the column headings should be repeated. Such larger tables should probably appear in an appendix because they will contain more detail than is necessary for the points made in the text.

Figures

Various types of illustrations may accompany the research proposal, such as line drawings, graphs, maps, and photographs. Drawings should be presented clearly with india ink on the same white paper used for the text. Graphs that are developed by computer software should be printed with ink jet or laser printers. Photographs should be printed on glossy paper. All figures should be separated from the text and include the following elements:

» a heading, consisting of a sequence number in arabic numerals (preceded by "Figure") and the subject heading or title;
» the figure itself;
» where necessary, footnotes or explanatory notes.

Similar to the table heading, the subject heading (title) of figures should be clear and concise, enabling the reader to understand the figure without reference to the text. If necessary, more detailed information may be given in a footnote below the table. If an illustration is taken from another publication, the source must be given.

Citation of literature

In the text, references should be cited by author and year of publication. For more than two authors, use *"et al."* For multiple citations in one year from the same author(s), use 1992a, 1992b, etc. If two or more references have authors with the same last name, use first and middle initials to identify them.

Common formats for citations in the text include the following:

> Miller *et al.* (1992) investigated…
>
> Other investigators (McColm *et al.*, 1989; Rahmadalan *et al.*, 1992) found…
>
> A combination of iron status indices offers better accuracy in detection of iron deficiency than the use of a single assay (Cook *et al.*, 1976b).

In the literature cited section, references should be listed alphabetically, without numbering. Journal or book titles should not be italicized and should be abbreviated according to standard conventions or spelled out in full. Words in titles of books should be capitalized (except for articles and prepositions), but only the first letter of the first word in the title of an article within a journal or chapter within a book should be capitalized.

Styles for different types of citations in the literature cited section are as follows:

Article in journal

Weiser, N.W., Sumhadi, W. & Chen, R. (1992) Title of article. Journal 11:111–113.

Book

King, J.C. (1992) Title of Book. Publisher, City, State (or Country).

Chapter in book

Brown, K. & Dewey K.G. (1992) Title of chapter. In: Title of Book (Finley, D.A., ed.), vol. 2, pp. 1–20. Publisher, City, State (or Country).

Abstract or letter to the editor

Lembke, J.G. (1992) Title of abstract. Journal 11:111 (Abs. or Letter).

Thesis

Haskell, M. (1992) Title of thesis. Doctoral thesis, University Name, City, State (or Country).

Once the list of literature citations has been established, it should be rechecked against the citations in the text *and* vice versa. This check will not only confirm the completeness of the list but also identify references that should be deleted because they are not cited in the text.

It is advisable to use a computer programme to manage the references. These programmes store details of references and generate bibliographic citations, footnotes, or endnotes from the text file in over 1,000 different publishing styles. The programmes allow references cited in the research proposal to be included in the subsequent scientific article without retyping if the citation style is different from that described above. In addition, these programmes will sort references and copy information from other bibliographic sources.

Selected readings

Beach DP, Alvager TKE. Handbook for scientific and technical research. Englewood Cliffs, NJ, USA: Prentice-Hall, 1992.

Beghin I, Cap M, Dujardin B. A guide to nutritional assessment. Geneva: World Health Organization, 1988.

CBE Style Manual Committee. Scientific style and format: the CBE manual for authors, editors, and publishers. 6th ed. New York: Cambridge University Press, 1994.

CIOMS. International guidelines for ethical review of epidemiological studies. Geneva: Council for International Organizations of Medical Sciences, 1991.

Kirkwood BR. Essentials of medical statistics. Oxford: Blackwell Scientific Publications, 1988.

Lefèvre P, Beghin I. Guide to comprehensive evaluation of the nutritional aspects of projects and programmes. Health and Community Working Paper No. 27. Antwerp, Belgium: Institut de Médicine Tropicale "Prince Léopold," 1991.

Locke LF, Spirduso WW, Silverman SJ. Proposals that work: a guide for planning dissertations and grant proposals. Newbury Park, Calif, USA: Sage Publications, 1987.

Martin SW, Meek AH, Willeberg P. Veterinary epidemiology: principles and methods. Ames, Ia, USA: Iowa State University Press, 1987.

Mauch JE, Birch JW. Guide to a successful thesis and dissertation: conception to publication: a handbook for students and faculty. 2nd ed. New York: Marcel Dekker, 1989.

Meador R. Guidelines for preparing proposals. 2nd ed. Chelsea, Mich, USA: Lewis Publishers, 1991.

Sultz HA, Sherwin FS. Grant writing for health professionals. Boston, Mass, USA: Little, Brown & Co, 1981.

Appendix. Metaplan technique

If SHARP is implemented by a team, the Metaplan technique should be used. The key approach of this technique is *participation, visualization, and documentation*. The objective of this technique is to allow input from all individuals on the team.

During a brainstorming time of 10 to 20 minutes, every participant writes ideas on several cards, one idea per card. During this time no discussion is allowed and everybody works by themselves. The specific steps of the process are as follows:

» Write an idea on a card;
» Formulate only one idea per card;
» Use a thick pen to write on the card;
» Write in printed letters as large as possible;
» Write no more than three lines on each card.

After this session:

» All cards are collected;
» The written text of the first card is read aloud to all participants;
» After it has been read, the card is pinned to a board;
» The second card is read and pinned to the board, and so forth.

If a card contains the same idea as one already on the board, it is discarded. This procedure should be continued until all cards have been presented. These ideas can then be used to formulate the causal model, the fact–hypothesis matrix (FaHM), and the variable–indicator–method matrix (VIM).

Books received

Amino acid metabolism and therapy in health and nutritional disease. Edited by Luc A. Cybnober. CRC Press, Boca Raton, Fla., USA, 1995. (ISBN 0-8493-8962-3) 459 pages, hardcover. US$210.00.

It is becoming increasingly clear that amino acids, including the dispensable ones, have metabolic and regulatory functions beyond their incorporation into proteins. This book is the first to focus on the overall metabolic and therapeutic roles of individual amino acids. Fifty-six authors from 11 countries contribute authoritatively. The first 14 chapters review amino acid metabolism and its control of and by amino acids, and advances in knowledge of amino acid requirements. One of these deals specifically with the role in the central nervous system of nitric oxide produced from the terminal guanido N of L-arginine. Seven chapters deal with quantitative and qualitative aspects of amino acid supply in disease. The last four chapters deal with experience with amino acid formulas in the management of catabolic illnesses, cancer, acute renal failure, and gastrointestinal disorders. This book is highly recommended for those concerned with the role of protein and amino acids for normal maintenance and in various disease states.

Flavonoids in health and disease. Edited by Catherine A. Rice-Evans and Lester Packer. Marcel Dekker, New York, 1998. (ISBN 0-8247-0096-1) 541 pages, hardcover. US$195.00.

The potential health benefits of dietary phytochemicals are a rapidly expanding area of research. The protective effects of diets rich in fruit and vegetables against cardiovascular disease and certain cancers have been attributed partly to the antioxidants they contain, particularly vitamin C and carotenoids. The flavonoids, phenylpropanoids, and phenolic acids contribute this activity through their antioxidant and other properties. This volume is the seventh in a series on antioxidants in health and disease that have dealt successively with vitamin A, biothials, vitamin C, and lipoic acid. It deals with flavonoids in medicinal plants, phenolic acids in fruits, and their chemical and biochemical properties, with five chapters on their antioxidant activities. It also has chapters on flavonoids in grapes, wine, gingko biloba extract, fruit juices, and extracts from the bark of the French maritime pine. The final chapters explore the actions of flavonoids against cardiovascular disease and cancers. Current activity in this promising field is well represented by the contributions of leading researchers to this volume.

Food allergy issues for the food industry. Edited by Maurice Lessof, Leatherhead Food RA, Surrey, England, 1997. (ISBN 0-905-748-21-2) 110 pages, hardcover. £85.00.

Almost any food can pose the threat of an allergic response in a susceptible individual. Problems arise for the food industry when manufactured foods contain varying or undeclared ingredients of a type that can cause problems for sensitive individuals. When the major ingredients of a product are indicated on the product labels, this provides useful nutritional information but cannot satisfy the need of the food-allergic shopper who may have a reaction to minor, unidentified components, or even traces carried over from food previously produced on the production line. The potential liability of the manufacturer and distributor are daunting. Reactions to peanuts and other nuts are the most serious, but more consumers are allergic to milk, eggs, and other common staples, and they also are also in need of accurate labels. Since catered food does not usually come with ingredient information, it can pose problems. Catering staffs need to be trained to answer accurately the questions of concerned consumers. This simple and clearly written short treatise provides useful guidance to food manufacturers and distributors in helping them to understand the problem.

Handbook of nutritionally essential mineral elements. Edited by Boyd L. O'Dell and Roger A. Sunde. Marcel Dekker, New York, 1997. (ISBN 0-8247-9312-9) 691 pages, hardcover. US$195.00.

Although this handbook is designed primarily for students and professionals in all aspects of nutrition, it is also a valuable source of information for professionals in all areas of biology. Authoritatively written individual chapters on each of 22 minerals cover the full range of these minerals' biological functions in animals and, where appropriate, in plants and microorganisms. Practising physicians may need to supplement this handbook with more comprehensive clinical examinations, but they will find this book invaluable for the basic information it provides on what is known about the metabolism of all the minerals of established or potential biological significance. This book should be available, at the very least, in every academic and medical library.

Improvement of crop-livestock integration systems in West Asia and North Africa. Edited by Nasri Haddad, Richard Tutwiler, and Euan Thomson. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria, 1997. (ISBN 92-9127-065-2) 572 pages + 40 in Arabic, hardcover.

This volume is based on a 1995 workshop in Amman, Jordan, at which agricultural scientists reviewed research achievements and discussed strategies for increasing the productivity of barley, pastures, and sheep in the critical rainfall zones of Iraq, Jordan, and Syria. The multiple-authored chapters in the volume cover both the promises and the constraints for improved crop and livestock productivity among the dry and farming systems and agro-ecological environments concerned. The information provided will be useful for agriculturalists in arid zones in other parts of the world.

Nutrient and gene expression. Clinical aspects. Edited by Carolyn D. Berdanier. CRC Press, Boca Raton, Fla., USA, 1996. (ISBN 0-8493-9485-6) 216 pages, hardcover. US$110.00.

Modern molecular genetic techniques are bringing rapid increase in our knowledge of nutrient–gene interactions. They are providing increasing evidence of the ways in which the phenotypic expression of genotype can be modified by nutritional factors. As this volume demonstrates, this applies to all human conditions and not just recognized genetic disorders. Chapters deal with gene–nutrient interactions, gene expression of the branched-chain keto acid dehydrogenase complex, genetic approaches to obesity and energy balance, diet–gene regulation of lipogenesis, mitochondrial DNA mutations in diabetes, and lipid peroxidation in human aging. This volume is an authoritative but not exhaustive treatment of this important topic.

Nutrition during infancy. Principles and practice. Reginald C. Tsang, Stanley H. Zlotkin, Buford L. Nicols, and James W. Hansen. Digital Education Publishing, 700 Walnut St., Suite 450, Cincinnati, Ohio, USA (e-mail: info@DEPinc.com), 1997. (ISBN 0-932883-09-5) 521 pages, hardcover.

This is an unusually reliable textbook, not only because the chapter authors are recognized authorities, but also because each chapter was reviewed in detail by two other listed chapter authors as well as the editors. The tables and illustrations are excellent and the focus is practical. Most chapters include global perspectives that reflect worldwide practices and applications. Appendices are provided on nutrient composition of infant formulas, growth charts, arm circumference and skinfold tables, growth tables and growth velocity, and skinfold charts. An unusual feature of the volume is the historical perspective on each nutrient accompanied by vignettes and photographs of physicians who have made outstanding contributions to the understanding of infant nutrition in this century. For those needing authoritative and practical information on infant feeding, this book is highly recommended.

News and notes

In Memoriam—Joaquin Cravioto

Joaquin Cravioto, one of the hemisphere's pioneer paediatric nutritionists, died in Mexico City on April 9, 1998. He was born in Mexico on September 12, 1933. His seminal observations of the relationship between growth retardation in rural Mexican children and impaired intersensory integration, while an investigator in the Children's Hospital of Mexico, provided the first convincing evidence that malnutrition influenced learning and behaviour. The findings, graphically presented in his famous lecture "Children of the White Dust," stimulated the research that has now confirmed the relationship in dozens of studies from all parts of the world. Variations in growth among children in middle- and upper-income families bore no relationship to differences in intersensory integration.

Cravioto also described the relationship between marasmic kwashiorkor and reduced cognitive performance. This work complemented the significant concurrent work of Fernando Mönckeberg in Chile showing a similar and lasting effect of marasmus in infancy. Cravioto was a charismatic teacher who inspired generations of paediatricians and nutritionists to understand and take into account the impact of malnutrition on the physical and mental growth of children.

Between 1961 and 1966 he left Mexico to serve as Associate Director of the Institute of Nutrition of Central America and Panama (INCAP). While there he replicated his famous landmark study of undernutrition in children and demonstrated his outstanding influence on students as a leader of the summer course in Public Health Nutrition. He also had responsibility for INCAP's relationship with its member countries to assist them in the application of its research findings and formulation and implementation of national nutrition policies.

Upon returning to Mexico, he became the Director for the next 16 years of the National Programme for Integrated Family Development of the National Institute of Science and Technology and continued active field research. At the time of his death, he was on the faculty of the National Institute of Human Communication of the Autonomous University of Mexico, still conducting research on nutrition, growth, and development.

From 1966 to 1971, he was Director of Training in the Children's Hospital of Mexico. He also served for several years as Assistant Director of the Applied Nutrition Division of the Food and Agriculture Organization in Rome. He was a visiting professor at Cornell University, Massachusetts Institute of Technology, and the University of Washington in the United States and at universities in the United Kingdom and Sweden. He received honors and awards from many countries and was a member of 25 national and foreign scientific societies.

In addition to his wife, Maria Cristina, he is survived by a son, Alejandro, and a daughter, Patricia, both of whom worked with him in his research, as well as three grandchildren. With his death the world has lost one of the last of the remarkable founders and leaders of modern paediatric nutrition.

New Director of the UNU Food and Nutrition Programme

The former Director of the Division of Nutritional Sciences of Cornell University, Cutberto Garza, an internationally recognized paediatric nutritionist, is the new Director of the Food and Nutrition Programme of the United Nations University. He will also serve part-time as Vice-Provost of Cornell University. He succeeds Nevin Scrimshaw, who has directed the programme since its inception in 1975 and will continue to serve it as Senior Advisor.

A coordinating center for the UNU Food and Nutrition Programme will be established on the Cornell University Campus, and several new initiatives have already been added by Dr. Garza, including a cooperative study with WHO to develop new growth standards and plans for a series of workshops for the development of nutrition leaders on different continents.

Dr. Scrimshaw will continue to serve as editor of the *Food and Nutrition Bulletin* in Boston, whose editorial office will be shared with the International Nutrition Foundation.

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.

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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.

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Références. Les références doivent apparaître à la fin de l'article, en double interligne également. Les documents non publiés ne doivent pas figurer dans les références pas davantage que les documents présentés à des fins de publication mais qui n'ont pas encore été acceptés.

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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.

—*auteur d'une société:*

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

—*éditeur, compilateur, président en tant qu'auteur:*

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

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Los editores del *Food and Nutrition Bulletin* agradecen el envío de contribuciones pertinentes al tema de la revista (vea la política editorial de esta revista en el interior de la tapa anterior). La presentación de un artículo no es garantía de su publicación, la cual dependerá del criterio de los editores y evaluadores en lo que respecta a su pertinencia y calidad. Los manuscritos con posibilidades de ser aceptados serán sometidos a evaluación por pares. Se ruega a quienes deseen colaborar que consulten números recientes de *Food and Nutrition Bulletin* para cerciorarse de su contenido y estilo.

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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.

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