Recent trends in malnutrition in developing regions: Vitamin A deficiency, anemia, iodine deficiency, and child underweight

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Introduction

Combined data on micronutrient deficiencies (and underweight prevalences) were previously assembled for the Micronutrient Report in 2001, published by the Micronutrient Initiative and the International Development Research Centre [1]. To update these data and understand recent trends, we carried out a global survey of national micronutrient programs and survey results from 2001 to 2003, mainly through e-mail contact with governmental, United Nations, and nongovernmental offices in some 100 developing countries (referred to below as the "country survey"). The published literature and unpublished material were searched by various means, including through on-line databases and web searching. The results described here were first used for the publication on "Vitamin and Mineral Deficiency" issued by Micronutrient Initiative and UNICEF in 2004 [2, 3], for which an early draft of the present results was provided.*

This document now presents the results on prevalences at the national, regional, and global (all developing countries) levels, with further detail. Here, the methods are recorded, and the estimates are provided in tables, figures, and annexes. The information from countries responding to the questionnaire in the country survey (49 replied with new data) are available on file, and certain of these have been transferred to the Web (http://www.tulane.edu/~internut/Countries/countrypage.htm).

The input data used here are very similar to those in other databases that have led to estimates by region and globally; these primarily give estimates of prevalences and numbers affected for one recent period (usually 2000 or 2003), without assessment of trend (see ACC/SCN [4], pp. 91—106, for iodine and vitamin A deficiencies; ACC/SCN [5], pp. 24—26, for anemia; and West [6] for vitamin A [7, 8]). Here the focus is on estimating trends from these data; the at-one-time regional prevalence estimates are of less concern, although, as would be expected, they are very similar to other calculations. Countries are differently aggregated into regions in various publications with different definitions used by, for example, the World Health Organization (WHO), UNICEF, and the United Nations. Here groupings based on those used by the United Nations are adopted, with China and India treated separately. Thus, while the totals across developing countries can be compared with other estimates, within-region estimates may differ somewhat depending on the countries aggregated. Underweight was also assessed, as background for interpreting trends in nutrient deficiencies.

Methods

General

The first step was to update the databases for vitamin A deficiency, anemia, iodine-deficiency disorders, and preschool child underweight prevalences. These procedures are described under the individual conditions. The data originate from sample surveys, either national or with samples defined at subnational (e.g., provincial) levels. Several processes of identifying and compiling these survey results were used. First, the previous database (Mason et al. [1]) contained most of the results available up to around 1998, and was built on. Newer

Additional research was done by Lindsey Madson, N'Della Njie, Leah Richardson, and Gillian Sheehy.

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survey results were sought from WHO, UNICEF, and Demographic and Health Survey (DHS) databases, plus searches of the literature for published surveys (usually subnational) that had not reached the agency databases. The major new effort to identify new and missing data was from a global survey that contacted 100 countries by email, to government departments and agency offices—especially UNICEF—with detailed questionnaires and instructions (questionnaires are available on http://www.tulane.edu/~internut/). Of these adequate responses were obtained from 49 countries, and the data extracted to provide prevalences. (The full data for 30 of these countries are available as country profiles on the website as given above.) The databases are described further under the individual nutrients below.

The database files were set up such that each case is at the level of country-year from a single source (i.e., if more than one survey was carried out in a country in the same year, the results are in the database as two separate cases, or rows). A case can be envisaged as a row in a spreadsheet, and a variable as a column. Each case can contain prevalence data for different biological groups, defined as new variables (e.g., anemia prevalences separately for nonpregnant and pregnant women). Data on programs, policy, and legislation are also included (from the questionnaire) but are not used in the analyses reported here. Selected independent variables (or predictors, used in regression models) are also included in the files. The specific independent variables used are described for each nutrient, many being common to the different deficiencies (e.g., infant mortality rates, education), but matched to the country-year for which the prevalence datapoint applies. The independent variable data were obtained from published sources for the applicable years, primarily UNICEF (State of the World's Children) [9], World Bank (World Development Reports) [10], United Nations Population Division (Demographic Yearbooks) [11], Food and Agriculture Organization (FAO) (Food Balance Sheet Data) [12], WHO (World Health Reports) [13], from printed material or accessed on-line.

This file structure means that the number of times a country appears (as a case or row) varies considerably: some countries have several repeated surveys over time and so are represented by multiple cases; other countries may have only one case with subnational data. The disaggregated datafiles are in the Statistical Package for the Social Sciences (SPSS) (version 11); calculations such as population-weighted averages for regions from country estimates used MS Excel.

Three methods were used to estimate trends:

First, where available, comparable national surveys at different times showed changes over arbitrary periods, depending on the timing of surveys. However, only a limited number of such comparisons are possible.

Second, survey estimates (defined by country-year) were simply averaged to the regional level for defined periods (e.g., 1990–95). A similar way of viewing the data is to scatterplot each datapoint against year and examine the apparent trend. Both of these methods—averaging and scatterplotting—have the serious drawback that the same countries are not necessarily repeated in different time periods, so the comparisons over time may be spurious: if a high-prevalence country appears in one time period and not in another, this will bias the estimate. However, they give some guidance as to what to expect. The results were not population-weighted, because large countries appearing in one period but not another would unduly affect the results.

The third approach was first to derive estimates of prevalences at the national level for every country, for defined years and biological groups ("country-year" estimates), by fitting the available prevalence data to regression models with widely available associated variables (e.g., gross national product, infant mortality rate, education, etc.). The reference years were 1990, 1995, and 2000, except for iodine, for which 1994 and 2000 were used (because of reporting of iodized salt, see the Methods section for iodine-deficiency disorders). Population-weighted aggregates to country group level were then made for the reference years.

"Best guess" estimates for each country were produced for the year 2000, to give a comparable list at one point in time; these were the estimates used in the Micronutrient Initiative/UNICEF publication "Vitamin and Mineral Deficiency" [2, 3]. The rules for these estimates are given below in the Methods section.

The methods and indicators are similar to those used in previous analyses, as described in the Micronutrient Report (Mason et al. [1], pp. 3–20). Based on data availability, the following prevalences were estimated:

- xerophthalmia (night-blindness plus Bitot's spots: XN + X1B) in children 0–72 months of age;
- vitamin A deficiency (VAD): prevalence of serum retinol less than 0.7 μmol/L or less than 20 μg/dl, in children 0–72 months of age
- anemia: prevalence of hemoglobin (Hb) less than 11 g/dl in pregnant women (15–49 years old)
- anemia: prevalence of hemoglobin less than 12 g/dl in nonpregnant women (15–49 years old)
- anemia: prevalence of hemoglobin less than 11 g/dl in children 0–59 months of age
- iodine-deficiency disorders (IDD): total goiter rates (TGRs) in overall population (all ages, M + F)
- underweight: prevalence of weight-for-age scores less than –2 SD according to National Center for Health Statistics (NCHS) standards in children 6–59 months of age (included as predictor of and check for other indicators; see text below).

To organize the data according to country and year and give a view of data availability, extended tables were constructed with years as the columns and countries as the rows, in which the survey results ("country-year"

values) were entered in the cells. This gives a clear picture of the data availability, and allows visual comparisons across countries at similar times and through time for the same countries. These compilations of all the datapoints that could be found and judged to be useable are given in Annex 1. The interpolated estimates for the reference years are also shown by country in Annex 1.

The terms "xerophthalmia" and "vitamin A deficiency" are used here to refer to the ocular manifestations of vitamin A deficiency—referred to previously as a sign of clinical vitamin A deficiency—and low serum retinol (previously termed "subclinical vitamin A deficiency") [14], which are a measure of vitamin A deficiency itself (and a surrogate for liver vitamin A stores). This follows the recommendations (as agreed in the Annecy Accords) fostered by the International Vitamin A Consultative Group [15, 16]. The concept of "vitamin A deficiency disorders" refers to the physiological disturbances caused by low vitamin A status [15]. The other terminologies are as used before, based on WHO recommendations (Mason et al. [1], p. 4).

Aggregating countries into regional groups generally followed the UN groupings, but where feasible adopted the World Bank practice of separating out India and China, as these two countries dominate any group due to their large population sizes, obscuring the situation for other countries they may be grouped with. A listing of the country groups used is given in **table 1**. Population estimates for children were taken from UNICEF State of the World's Children for the relevant years (UNICEF [9] 1992, 1997, 2002); for China and India the population estimates were from UN Population Division 2002 (UN [11] and website, accessed 2004: http://esa.un.org/unpp/index.asp?panel=2). This source was also used for all-age populations for the iodine-deficiency disorder weighting and estimates of numbers affected.

Vitamin A deficiency

Data compilation

Xerophthalmia prevalence was calculated as the sum of the prevalences of night-blindness (XN) and Bitot's spots (X1B). Data exist for multiple biological groups, and in extracting the data the age ranges for which prevalences were given were recorded. For xerophthalmia, the commonest groups were described as ages less than 60 months, 6 to 71 months, and "preschool." Age groupings were aggregated into 0 to 72 months (72%), nonpregnant women (12%), and others. The analysis focused on children 0 to 72 months of age, pooling prevalences of all preschool children, with age-based adjustment made for only a few cases, as described later.

Most data for xerophthalmia were reported as the standard XN + X1B—the sum of the prevalences of night-blindness (XN) and Bitot's spots (X1B). Some results were reported as the prevalence of either night-blindness or Bitot's spots. In these cases, previously established procedures were used (Mason et al. [1], p. 11): the estimate of the sum (XN + X1B) when only data for XN or X1B were available was calculated as (XN × 2) or (X1B × 1.5). A few countries reported X3A (corneal ulcerations), but these estimates, which were of low prevalence, were not included in the analysis. The total xerophthalmia rate (TXR), occasionally reported, was included as equivalent to XN + X1B.

The full set of data is shown in Annex 1, **table A1.1**. Prevalences of xerophthalmia greater than 4% (three of the national cases*) were considered possible outliers and were not used when developing the model; although these may indeed have been correct, they could not be fitted with the independent variables tested. Subnational xerophthalmia estimates were available for a further 40 cases, but these were not included in the analyses, as their applicability was not known, and with the low prevalences outlying cases would have substantial influence on the models. Other options would have been to make assumptions as to the populations to which survey results applied; however, in part as previous analyses had moved away from such correction factors (Mason et al. [1], pp. 9–10), subnational results were excluded altogether in these analyses. The classification of cases as either national or subnational was based on the following criteria: reporting countries indicated the data as national-level in the micronutrient questionnaires completed for this report; the data were consistently reported as national-level in multiple sources; and the data were evidenced by the multiplication factor [14]. Data meeting one or more of these criteria were considered national.

Vitamin A deficiency was reported in terms of serum retinol concentrations. Vitamin A deficiency was defined as serum retinol levels below 0.7 μmol/L, which were considered to indicate moderate plus severe deficiency. The cut points used for moderate deficiency were serum retinol levels below 0.7 μmol/L or below 20 μg/dl [14].

A wider range of age ranges than for xerophthalmia was recorded, with less than 60 months and 12 to 59 months the most common; the ages were again aggregated to less than 72 months (75%) being the group analyzed; no age adjustments were made.

The vitamin A deficiency database contained 52

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** Benin 1999, 70.2%; Burkino Faso 1986, 70.5%; Ghana 1990, 73.4%; Ghana 1997, 75.8%; Kenya 1999, 84.4%; Jamaica 1997, 58.8%; Brazil 1989, 54.7%.

TABLE 1. Country groups used in aggregating data

Sub-Saharan Africa	**Middle East and North Africa**	**Middle America and Caribbean**
Angola	Algeria	Belize
Benin	Egypt, Arab Republic of	Costa Rica
Botswana	Iran, Islamic Republic of	Cuba
Burkina Faso	Iraq	Dominican Republic
Burundi	Jordan	El Salvador
Cameroon	Kuwait	Guatemala
Central African Republic	Lebanon	Haiti
Chad	Libya	Honduras
Congo	Morocco	Jamaica
Côte d'Ivoire	Saudi Arabia	Mexico
Eritrea	Syrian Arab Republic	Nicaragua
Ethiopia	Tunisia	Panama
Gabon	United Arab Emirates	Trinidad and Tobago
Gambia	Yemen	
Ghana		**South America**
Guinea	**South Asia**	Argentina
Guinea Bissau	Afghanistan	Bolivia
Kenya	Bangladesh	Brazil
Lesotho	Bhutan	Chile
Liberia	Nepal	Colombia
Madagascar	Pakistan	Ecuador
Malawi	Sri Lanka	Guyana
Mali		Paraguay
Mauritania	**India**	Peru
Mauritius		Uruguay
Mozambique	**Southeast Asia**	Venezuela
Namibia	Cambodia	
Niger	Indonesia	**Eastern Europe and Central Asia**
Nigeria	Laos	Armenia
Rwanda	Malaysia	Azerbaijan
Senegal	Mongolia	Georgia
Sierra Leone	Myanmar	Kazakhstan
Somalia	Papua New Guinea	Kyrgyzstan
South Africa	Philippines	Slovakia
Sudan	Thailand	Tajikstan
Swaziland	Vietnam	Turkey
Tanzania		Turkmenistan
Togo	**China**	Uzbekistan
Uganda		
Zaire		
Zambia		
Zimbabwe		

national estimates and 47 subnational (classification criteria as above). Regional outliers and cases with a prevalence of moderate vitamin A deficiency greater than 70% (seven cases**) were not used in developing the models. Eighty-three cases were finally included in the analysis. For vitamin A deficiency, 28 of the final datapoints were subnational, and these were included in some of the analyses (see **table A1.2**), as they tended to be in line with the national estimates (similar results were obtained with and without the subnational estimates, in contrast to those for xerophthalmia, where this made a substantial difference).

Severe vitamin A deficiency is defined as serum retinol levels of less than 0.35 μmol/L or less than 10 μg/dl [14]. The database included 38 cases giving severe vitamin A deficiency prevalences, and although these

were generally not analyzed for this report, results from repeated national surveys are used.

First, for both xerophthalmia and serum retinol, individual country trends were examined from survey data where comparable results were available for a country at different times. Second, regression analysis using these survey data and a set of independent variables associated with the vitamin A deficiency prevalences was used to make interpolations for all countries, for the years 1990, 1995, and 2000. These results are shown in **tables A1.1 and A1.2**. Aggregating these by region then gave an estimate of the trends.

Age adjustment. The results from any subgroup within children 0 to 72 months old were treated as the same biological group. For example, if one survey assessed vitamin A deficiency in children 12 to 72 months of age, it was treated as comparable to children 0 to 59 months of age in the analysis, except when surveys within countries through time are compared, where small differences are important. This applied here in only three cases (shown later in **table 2**). For this purpose, an adjustment factor was derived from the relation between prevalences at different ages when these were reported in the same survey, by regressing the prevalences of the 0- to 4- and the 5- to 9-year groups from the same surveys. The formula was as follows:

> Prevalence at age range (x to y) adjusted to equivalent at age 0–59 months = Prevalence at age range (x to y) × (1.05/(0.225 + 0.33 (midpoint of (x to y) in years))).

For example, a prevalence of 1.7% for 5- to 9-year-olds is adjusted by $(1.05/(0.225 + (0.33 \times 7.0)) = 0.41$. Then $1.7 \times 0.41 = 0.7\%$, the equivalent for 0 to 4 years.

In practice, the age correction factor was needed to adjust the prevalence of vitamin A deficiency in only two cases (India 2001 and Nepal 1996), to correct for differences due to changing age groups in the samples when comparing surveys (see **table 2**), but not elsewhere. Age adjustments were not performed for vitamin A deficiency prevalence data, as insufficient age-differentiated results were available, but similar adjustments to allow aggregation of scarce data may be needed in the future, and a method such as this may be useful.

Database description

The vitamin A database is available as an SPSS file containing the results of vitamin A surveys and a set of independent variables. Cases are defined as country-year, with each case containing one survey result; thus, usually xerophthalmia and serum retinol survey results are different cases, unless the results were from one survey. Indicators by biological groups are recorded as new cases, including pregnant and nonpregnant women, children up to 72 months of age, older children, and men; thus, one survey could yield several rows distinguished as different age or biological groups. A code for survey type—national or subnational—is included. The database also contains information about policies and programs implemented to combat vitamin A deficiency, including information on capsule coverage, availability, and fortification of foods with vitamin A; these data are not used in the results reported here.

Each case has regional codes and indicators (for the survey year) used in interpolation models as independent variables, including infant mortality rate, female literacy rate, maternal mortality ratio, gross national product per capita, measles coverage, prevalence of underweight, percentage of population urbanized, and government expenditure on health and education. These data were primarily taken from a number of published (and Web) sources, mainly relying on editions of UNICEF's State of the World's Children (UNICEF, 1995–2001) [9] for the relevant years; other sources were based on data compiled from the World Development Reports (World Bank) [10] and the Human Development Reports of the United Nations Development Programme (UNDP) [17]. The underweight data were taken from the underweight database used for this report, as described later. The values for these variables were entered for the year of the vitamin A deficiency survey with which they were included; e.g., if the vitamin A deficiency result was for 1994, then the independent variables were for that year. Where the exact year was not reported, a linear interpolation was made from the nearest years reported.

Regional dummy variables, to represent different country groups (or countries, for India and China) were created, taking the value 1 if the country is in that region, otherwise 0. Interaction terms between independent variables (usually with the regional dummies) were created by multiplying the two interacting variables, for use in the regression analysis described later.

Analytical methods

Repeated national surveys

National surveys in the same country at different times were compared where these existed, as the first method of examining trends. There were 11 cases with national equivalent repeated surveys for xerophthalmia and 8 cases for vitamin A deficiency.

As a rule for guidance, a difference of 0.5% in xerophthalmia was considered likely to be meaningful. Sample sizes (n's) are not known for every survey, but we can estimate for a prevalence of 1% what the confidence intervals would be for different n's, reckoning that $n = 1000$ is fairly typical. The formula is: standard error equals [sq root $((p \times q)/n)$], where p is the prevalence as a proportion (0 – 1), and $q = (1 - p)$.

TABLE 2. Prevalence of xerophthalmia (XN + XIB) in preschool children: results from repeated national surveys

Country	Survey year	Prevalence (%)	Age group surveyed (mo)	Trend
Bangladesh	1983	4.5	0–59	
	1996	1.2	0–59	
	1997	0.9	0–59	
	1999	0.5	6–59[a]	Improvement
Ethiopia	1980	2.0	6–83	
	1996	1.5	6–60	Improvement
India	1988	1.4	0–59	
	2000	1.2	0–59	
	2001	1.7	24–72[a]	No change
Indonesia	1978	2.0	0–59/0–71	
	1995	0.3	0–59	Improvement
Laos	1995	1.1	24–71	
	2000	4.7	6–59	
	2000	0.1	0–59 (by exam)[b]	Unclear
Mongolia	1998	0.2	6–72	
	1999	0.8	6–72	Possible deterioration
Myanmar	1991	1.2	0–59	
	1994	0.8	0–59	Possible improvement
Nepal	1981	1.0	0–71[a]	
	1993	3.0	0–59	
	1996	1.5	6–35[a]	
	1998	0.6	0–59	Improvement
Niger	1988	3.0	0–71	
	1992	3.7	24–59	Deterioration
Philippines	1982	3.2	0–59	
	1987	0.9	0–59	
	1993	0.4	0–72	Improvement
Vietnam	1994	0.1	0–59	
	1998	0.3	0–59	Unclear

XN + XIB, Night-blindness + Bitot's spots.

a. For Bangladesh 1999, India 2001, and Nepal 1981 and 1996, the age groups surveyed are as shown, but the prevalences given have been adjusted to be equivalent to 0 to 59 months (see Methods).

b. The trend for Laos is unclear due to the different ways in which clinical signs were reported. When individuals reported night-blindness, the prevalence was much higher than that obtained from eye examinations.

Sources: see Annex 1, **table A1.1**.

Plus or minus two standard errors (SE) gives the 95% confidence interval. For $n = 100$, SE = 1.0%; $n = 1000$, SE = 0.3%; $n = 5000$, SE = 0.1%. Prevalences separated by 2 SE are likely to be significant at $p < .05$. As a guide, we take a difference of 0.5% (percentage points) in xerophthalmia as likely to be meaningful. A similar calculation for moderate vitamin A deficiency (serum retinol less than 20 μg/dl) suggests that a difference of approximately 4 percentage points, based on a sample size of 500, may be significant.

Unadjusted averages by region and time period

Averaging the prevalence data within regions and time periods provides a first view of possible regional trends, but these are crude because the same countries do not usually appear in each time period. Thus, if one period happens to contain one or more particularly high- (or low-) prevalence countries, the apparent trends may be spurious because of bias introduced by the differential reporting. Nonetheless, these averages were considered worth knowing, provided care is taken in interpretation. The survey results in the vitamin A deficiency database by region for the reference time periods (before 1990, 1990–95, and after 1995) were averaged to give a mean prevalence of vitamin A deficiency. For this calculation, the averages are not weighted by

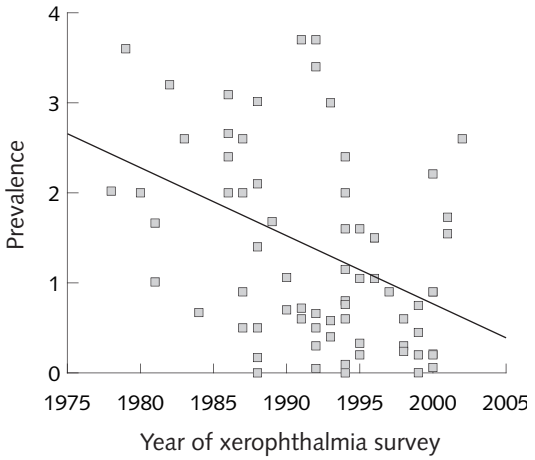


FIG. 1. Scatterplot of survey prevalences of xerophthalmia against year (national and subnational data for children up to 72 months of age)

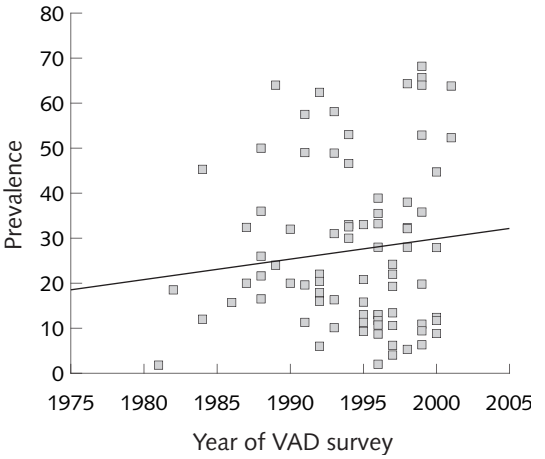


FIG. 2. Scatterplot of survey prevalences of vitamin A deficiency (VAD) against year by region (national only for children up to 72 months of age)

population (indeed, weights could introduce additional uncertainties). To increase the sample number, both national and subnational xerophthalmia data were included in these averages.

A similar view of the survey data for xerophthalmia and vitamin A deficiency prevalences was obtained by scatterplotting against time (**figs. 1 and 2**). A best-fit line and r^2 value were calculated to get a sense of the overall trend for each. The points were then distinguished by region. This adds to the interpretation when viewed alongside other evidence.

Interpolations of prevalences by country to reference years: xerophthalmia

Regression models for xerophthalmia were developed using a set of independent variables, to allow interpolation of available datapoints to reference years: 1990, 1995, and 2000. Models were examined including only national data, and another including both national and subnational data. The model using only national data produced the most robust results with larger and more significant coefficients. Moreover, results tended to have smaller sample sizes, with low proportions of positive cases, and with unknown (but likely) clustering of xerophthalmia subnational results were considered unlikely to be closely related to national levels. For these reasons, the final xerophthalmia regression models included only national data.

Prevalences of xerophthalmia greater than 4.0% (national) were considered outliers and were excluded. Based on this criterion, Laos 2000, Marshall Islands 1991, Bangladesh 1983, and Cambodia 1993 were excluded from the xerophthalmia model.

Variables tested in the development of the xerophthalmia models included survey year and different regional dummy variables. Survey year was not significant in the final model, which provided a useful indication that correlates of change had been included. Variables measuring infant mortality rates (IMR), women's education (as literacy), and measles immunization coverages were included after testing a wider range of possible correlates (or determinants) of xerophthalmia levels. Regional variables were not significant and were excluded. The interaction term for (IMR × measles immunization coverage) was found to be significant in some specifications; without it, the variables for IMR and measles immunization alone were nonsignificant; thus, this interaction term was included. A number of other variables were tested, including gross domestic product, and various food supply variables derived from food-balance sheets, which were found not to contribute to the model.

The final model included the independent variables representing female literacy, measles immunization coverage, infant mortality rate, and the interaction between infant mortality rate and measles vaccination coverage, as follows:

Xerophthalmia (%) = 4.577 – 0.0387 (MEASLES) – 0.0147 (IMR) – 0.0099 (FEMLIT) + 0.00017 (INTIMRME)

$N = 35$

IMR: infant mortality rate ($p = .097$)

FEMLIT: female literacy rate ($p = .098$)

MEASLES: measles immunization coverage rate ($p = .004$)

INTIMRME: interaction between IMR and measles ($p = 0.170$)

Adjusted $R^2 = 0.486$

National estimates of xerophthalmia were then

generated by inserting the values for the independent variables in this equation. This provides a predicted prevalence of xerophthalmia for that specific country and year. It is assumed that the unknown prevalences have the same relationship as the known ones with these variables; thus, the unknown values can be predicted from them. The main assumption here is that the available survey data are an unbiased sample of the overall data. The country prevalences are then used to compute numbers of deficient children by country. Aggregating these by region then gives numbers by region; from this the prevalence by region (dividing by the child population) is calculated as a population-weighted prevalence. Estimates were made by country group (region) for the years 1990, 1995, and 2000, as population weighted means (see **tables 6, 7, and 8** and **figs. 1 and 2**).

Interpolations of prevalences by country to reference years: vitamin A deficiency

Procedures similar to those for xerophthalmia were used to derive vitamin A deficiency estimates. Subnational surveys were included here, increasing the number of cases from 49 to 93; the subnational datapoints were found to have similar residuals to the national values and were not considered to be increasing the errors; moreover, a dummy for subnational surveys was not significant. Survey prevalences of vitamin A deficiency higher than 70% were considered outliers and were excluded from the analysis. Regional variables, interaction terms, and survey year were first tested. Regional variables for Africa, India, Southeast Asia, and the Newly Independent States were kept in this model, as their inclusion contributed to the adjusted R^2. Significant variables ($p < .05$) were included in the model, along with variables whose coefficient was such that they improved predictions, even if $p > .05$. The cases excluded on this basis were Benin 1999, Ghana 1997 and 1998, Burkina Faso 1986, and Kenya 1999. Jamaica 1997 and Brazil 1989 were also removed, because they were significant outliers for the combined region of Latin America and the Caribbean. Costa Rica 1979, Indonesia 1978, and India 2001 were excluded because the data reported were incomplete. This reduced the final number of cases from 93 to 83. The final model was as follows.

Vitamin A deficiency (VAD) = 20.784 + 0.216 (IMR) – 0.147 (FEMLIT) + 0. 4829 (DAFR) + 27.267 (DINDIA) + 22.483 (DOTHER) + 9.519 (DSEASIA)

$N = 83$

IMR: infant mortality rate ($p = .000$)

FEMLIT: female literacy rate ($p = .081$)

DAFR: regional variable for Africa ($p = .182$)

DINDIA: regional variable for India ($p = .007$)

DOTHER: regional variable for Newly Independent States ($p = .100$)

DSEASIA: regional variable for southeast Asia ($p = .103$)

Adjusted $R^2 = 0.453$

This equation allows predicted prevalences to be generated for each country and reference year based on the values for the independent variables included in the regression model, as for xerophthalmia. National estimates for both xerophthalmia and serum retinol were calculated for the years 1990, 1995, and 2000. The results are given, by country, in the three columns (for 1990, 19995, and 2000) in Annex 1, **tables A1.1 and A1.2**.

Anemia

Data compilation

This analysis of anemia includes the data used in the previous Micronutrient Report [1] supplemented by additional data from various sources. A questionnaire was sent to UNICEF country offices in all developing countries where contacts could be found. In some countries, other agencies were also contacted, including Helen Keller International, World Vision International, the Pan American Health Organization, and others. Other information came from literature searches and published survey reports. The intended rule was to include only nationally representative data with sample sizes of at least 100. In some cases where only subnational data were available, the regional or subnational prevalences were compiled into a single, best guess of the national estimate. Moreover, descriptions of some surveys were incomplete, in which case a judgment was made from other information as to the value of including the data.

The three biological groups most commonly used to measure the extent of anemia in a population are nonpregnant women of reproductive age (15–49 years), pregnant women, and children under five years of age. For these three groups, anemia is defined using the cut points given earlier, of 12 g/dl for non-pregnant women, and 11 g/dl for pregnant women and children. Only surveys reporting prevalences using these cut points were included in the analysis. (Many surveys used different cut points, and the information from these was included in the database but excluded from the statistical analysis.) The available results are laid out by country and year of survey in Annex 1, **tables A1.3–1.5**. For each biological group, the numbers in parentheses represent survey results that were not included, either because a different cutoff was used in the survey, or because the value was far from that expected from correlations with other variables (flagged by having a

residual greater than 2 SD in the models). Some surveys also included hemoglobin results from adult men, adolescents, and school-age children, but the number of these surveys was too small to analyze statistically, so the results are not dealt with in this analysis.

Database description

The data files were set up in the same way as for vitamin A deficiency, described earlier. The anemia database consists of 485 cases (results for a country-year), containing a total of 520 survey results, of which nearly 350 were considered national. This breaks down as follows: nonpregnant women, *n* (survey results) = 180 (of which national = 118); pregnant women, *n* = 243 (national = 169); children under five years old, *n* = 97 (national = 60). A single country-year case may contain results for different groups, e.g., pregnant and nonpregnant women (defined as different variables) from the same survey, and hence the total number of surveys is more than the total cases.

Analytical methods

Repeated national surveys

National surveys considered to be comparable at different times in the same countries were identified, for nonpregnant women (21 countries), pregnant women (27 countries), and children (9 countries). As for vitamin A deficiency, which has similar prevalences, differences of 4% were considered likely to be significant. When several estimates at different times for one country are available, where feasible trends for separate periods are assessed on this basis.

Unadjusted averages by region and time period

The principle used to assess the unadjusted regional averages for anemia is similar to that for vitamin A deficiency, with the same caution that the averages are not between comparable countries, as the same countries do not appear in all time periods. For anemia, the periods were before and after 1990, differing from vitamin A deficiency because of the distribution of available results by year.

Interpolations of prevalences by country to reference years

The variables tested were prevalence of underweight, infant mortality rate, maternal mortality ratio, low birthweight, measles vaccination coverage, female literacy, percentage of government spending on health and education, gross national product (and log of gross national product), reported cases of malaria per 100,000 population, total fertility rate (TFR), total calories per person per day, calories from meat per person per day, calories from pulses per person per day, percentage of calories from meat per person per day, percentage of calories from pulses per person per day, and percentage of calories from animal sources per person per day. When available, all independent variables were included for every country in each year of a national anemia survey. In cases where values for these independent variables were unavailable, points were either interpolated between two years or assigned the value for a close year (within two years). Several of these variables had strong correlations with the prevalence of anemia in developing countries. Regression models were built for the three biological groups. The best models for each group consisted of a combination of independent and regional variables.

A small number of values considered outliers were excluded from the models, flagged primarily when the difference between the observed value and the predicted value (i.e., the residual) was more than 2 SD; although this was not automatic, it prompted a more careful examination of the survey result and exclusion of the value if corroborating data or explanation could not be found (e.g., comparing with prevalences from other biological groups, or from earlier or later surveys; this was facilitated by the disaggregated format in Annex 1).

A number of interactions (based on logical likelihood) were tested in all models. Only one was found to be significant: in the regression model for pregnant women, a significant interaction was found between gross national product and percentage of calories from meat. This was included in the final model, as described below.

The coefficients from the regression model were then used to calculate predicted prevalences, by substituting the independent variables for the country and reference year in the equation. This used Excel, and then allowed calculation of numbers affected, hence aggregation to the country-group level. Several cases might have been excluded because of missing independent variables (i.e., maternal mortality ratio and low birthweight for the country and reference year). These values were, however, assigned using the regional means for missing data. However, it should be noted that the countries with missing data for maternal mortality ratio and low birthweight are also some of the worst-off countries (e.g., Angola, Liberia, Ethiopia, and Afghanistan), so the assignment of the mean value for the region to these countries may bias the estimate downward for the country, since the values of the independent variables may actually be much worse than the regional mean.

Regression model for anemia in pregnant women:

$$\text{ANEMIA} = 58.188 - (2.22 \times \%\ \text{calories from meat}) - (8.174 \times \text{regional variable for China}) + (21.987 \times \text{regional variable for India}) - (0.01583 \times \text{GNP}) + (0.001794 \times \text{the interaction between \% calories from meat and GNP})$$

$N = 129$

Percentage of total calories from meat ($p = .020$)

Regional variable for China ($p = .291$)

Regional variable for India ($p = .003$)

GNP, gross national product ($p = .006$)

Interaction between % calories from meat × GNP ($p = .057$)

Adjusted $R^2 = 0.254$

Regression model for anemia in nonpregnant women (15–49 years):

ANEMIA = 42.606 + (10.687 × regional variable for south Asia) + (18.414 × regional variable for India) + (0.548 × low birth weight) + (0.01092 * MMR) – (8.143 × log GNP) + {0.395 × (survey year –1970)} – (0.03456 × % calories per day from meat)

$N = 69$

Regional variable for South Asia ($p = .143$)

Regional variable for India ($p = .008$)

Prevalence of low birthweight in survey year ($p = .75$)

MMR, maternal mortality ratio ($p = .012$)

Log GNP, log gross national product ($p = .033$)

Survey year –1970 ($p = .038$)

% calories per person per day from meat ($p = .046$)

Adjusted $R^2 = 0.657$

Regression model of anemia in children under five years of age:

ANEMIA = 124.562 + (22.3 × regional variable for India) + (25.65 × regional variable for South America) – (27.622 × regional variable for China) + (15.49 × regional variable for Sub-Saharan Africa) – (0.299 × female literacy) – (22.412 × log GNP)

$N = 51$

Regional variable for India ($p = .100$)

Regional variable for South America ($p = .000$)

Regional variable for China ($p = .041$)

Regional variable for Sub-Saharan Africa ($p = .002$)

Female literacy rate in survey year ($p = .002$)

Log GNP, log gross national product ($p = .000$)

Adjusted $R^2 = 0.623$

Correlations among prevalences for different biological groups

The prevalences of anemia among nonpregnant women, pregnant women, and children under five years of age are highly correlated with each other. One way of estimating trends and predicting prevalences (where observed values are unknown) is to predict for one group on the basis of known prevalences in another group. By the use of regression analysis, a set of predicted prevalences for the three biological groups was calculated. These are included in the disaggregated matrix shown in Annex 1, **tables A1.3–5**, and were used to check the likelihood of predicted values when "best guess" estimates were made at the country level.

The equations were as follows:

Prevalence in nonpregnant women = 6.0 + 0.75 (prevalence in pregnant women)

[Regression: $n = 76$, adjusted $R^2 = 0.584$; $B = 0.75$, $t = 10.32$, $p = .000$]

Prevalence in pregnant women = 14.6 + 0.79 (prevalence in nonpregnant women)

[Regression: $n = 76$, adjusted $R^2 = 0.584$; $B = 0.79$, $t = 10.32$, $p = .000$]

Iodine-deficiency disorders

Estimating trends in iodine-deficiency disorders presented issues different from those for other micronutrients; although there were considerably more national data, the simple comparisons by regional averaging at different times were showing little progress in reducing iodine-deficiency disorders (Mason et al. [1], p. 34; 18, 19], which conflicted with repeated survey data from individual countries where salt iodization was proceeding. This was presumably due to reporting bias, whereby as awareness of iodine-deficiency disorders increased, more surveys were undertaken, and these found a more extensive problem. (For example, endemic goiter rates for countries without iodized salt averaged 25.0% ($n = 24$) for 1980–89, compared with 33.3% ($n = 33$) for 1990 and after ($p = .09$), which illustrates likely reporting bias.)

The goiter rate estimated seemed likely to depend on the endemic rate—prior to iodization, in turn dependent on factors such as soil iodine content—and the extent to which iodization had proceeded. To begin with, therefore, data were compiled on goiter rates with reference to salt iodization status, classifying countries according to the underlying (pre-iodization) prevalence. This allowed trends to be seen with respect to iodization status, stratified by endemic prevalence. Second, since not all countries had pre-iodization data, estimates were made of likely pre-iodization status for

those missing by using factors such as soil characteristics. These could then be linked to data on iodized salt coverage, which are available for most countries in recent years, to estimate national prevalences for reference years, and hence regional trends, analogously to the method for vitamin A and anemia.

A question arises concerning the choice of indicators, where the tradeoff is between availability of time-series data and interpretation. Urinary iodine would provide a better estimate of current iodine status than goiter. However, data on iodine reach back further in time, so if the aim is to track trends over a decade or more—over the time in which iodized salt has been expanding in coverage—then at present goiter provides the only practical choice. But in the future, it should be feasible to shift toward use of urinary iodine, as WHO has done in recent reports [7]. A further consideration is that although reduction in iodine-deficiency disorders is reflected in reduced goiter prevalence, both the rate at which this occurs and the possible persistence of residual goiter (from previous deficiency) need to be considered in interpreting the data. Finally, improved training of survey personnel has probably increased the sensitivity of goiter detection.

The steps, in sum, were:

1. To estimate national endemic, pre-iodization goiter levels from survey data for those countries with suitable surveys, and to use these to stratify and then relate post-iodization survey results to iodization coverage (overall and according to region); in a second iteration (after step 2 below), additional countries were assigned to pre-iodization categories;
2. To estimate endemic goiter rates for countries without suitable pre-iodization data, from other factors;
3. To establish associations between endemic goiter, current (post-iodization) goiter, and salt iodization coverage, to predict goiter rates for all countries for reference years (1994 and 2000);
4. Hence, to re-estimate trends by region.

Data compilation

The indicator used for iodine-deficiency disorders was the total goiter rate (TGR), which is defined as the sum of grade 1 goiter (palpable, not visible) and grade 2 goiter (visible when the neck is in the normal position) [20]. The prevalence in the school-age population was used where available (in 81% of cases), but TGR when reported for all ages, or for the adult population, was included to increase the number of datapoints; as discussed previously (Mason et al. [1], p. 12), variations because of age differences were considered minor compared with other sources of error, and age adjustments were therefore not made. The data for iodine-deficiency disorders were compiled in a matrix by country and region (see Annex 1, **table A1.6A–B**). The matrix includes country-level data on the year of iodine-deficiency disorder legislation and on salt iodization progress as reported by the percentage of households consuming iodized salt, from the country surveys and published sources. Data on urinary iodine levels were far less frequently available, and were not included in these analyses.

The database built on that used previously (see Mason et al. [1], pp. 78–79), which had 82 cases. Of the total of 225 country-year estimates of TGR initially compiled for this analysis (including the 82), 81 were from the country surveys (36%), 57 (25%) were from WHO (1993) [19], 21 (9%) from workshop reports from Asia [21], 19 (8%) from the ICCIDD database (www.people.virginia.edu/~jtd/iccidd/), and the remainder from individual publications. Each case was a single TGR estimate (i.e., by country-year), and other variables in each case were matched to this year; in addition this database contained the program and policy information from the country surveys. The iodine-deficiency disorder matrix (Annex 1, **table A1.6A–B**) contains data on 116 countries arranged by region (in two parts due to the extent of data).

The ICCIDD website and results from the country surveys in 2002 were the primary sources of information concerning iodine-deficiency disorder legislation. Iodized salt consumption data were obtained from UNICEF's State of the World's Children 1997/2000/2002, from the country surveys, the ICCIDD website, and from reports synthesized in Deitchler et al. [22]. In some cases interpolation to the required year was done in the usual way.

Analysis (1): endemic and post-iodization TGR in relation to iodized salt coverage

The analytical file included the available TGR data from 88 of the 116 developing countries investigated (see Annex 1, **table A1.6A–B**). The case was defined as country-year. Cases were excluded from this initial trend analysis if there were no TGR data available for that country or if only subnational TGR data were available. Thus, 159 cases, or separate survey results, were included. Based on these criteria, the following countries were excluded: Afghanistan, Malaysia, Korea, Papua New Guinea, Jamaica, St. Kitts and Nevis, Trinidad and Tobago, Guyana, Congo, Equatorial Guinea, Mauritius, Sierra Leone, Somalia, Swaziland, Kuwait, Libya, Pakistan, Palestine, Saudi Arabia, United Arab Emirates, Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Slovakia, Tajikistan, Turkey, and Turkmenistan.

Countries were categorized according to an estimate of the underlying or pre-iodization TGR. This was based on the estimated TGR before salt iodization began. The categories were: 1 = TGR < 20%; 2 = TGR 20–40%; 3 = TGR > 40%. The period before iodization was defined in practice as when the household consumption of iodized salt was reported as less than or equal to 25%. When more than one value for pre-

iodized TGR existed for a country, the prevalences were averaged. This applied in the cases of Ecuador 1969 and 1980, Ethiopia 1980 and 1985, Guatemala 1979 and 1987, Guinea 1988 and 1992, Indonesia 1980 and 1982, Iraq 1992 and 1993, Laos 1988 and 1993, Myanmar 1990 and 1994, Nicaragua 1966 and 1977, Senegal 1992 and 1993, Sri Lanka 1986 and 1989, Tanzania 1981 and 1985, Thailand 1982 and 1989, Paraguay 1976 and 1990, Peru 1968 and 1987, and Turkey 1988 and 1995.

Iodization is therefore defined here as beginning in the year when iodization was estimated to reach 25% of households (see Annex 1, **table A1.6A–B),** where the cells are shaded/highlighted after this time. In a few countries iodization dropped from higher levels (> 25%) back to pre-iodized levels (≤ 25%). This was occasionally seen mainly in Latin America where large-scale salt iodization first began in the mid-1940s, but later decreased again, usually temporarily. Guatemala and Paraguay are examples with fluctuating levels iodized salt consumption. In such cases, the most recent year that iodized salt consumption surpassed 25% was used as the basis for pre-iodized TGR categorization.

Household consumption of iodized salt was categorized into five groups (*rectypes*), matching TGR survey data. The five categories for household consumption of iodized salt were as follows: 1: household iodized salt less than 25% (i.e., pre-iodization); 3: transitional iodized, 25%–50%; 5: fully iodized, early > 50%; 6: fully iodized, later > 50% (when second or more post-iodization value was available, usually 5–10 years after first [which was coded 5]). (Rectype 2 was deleted because only one pre-iodized TGR was defined in order to categorize a country by its endemic prevalence.)

In the dataset, organized into cases by country, year, and TGR (n = 159), the majority of the TGR prevalences were from national surveys, with a few subnational surveys only also used in those analysis where associations (rather than trends) were studied. When data for household consumption of iodized salt were unknown for a given year and TGR, they were assigned a percentage that was from the closest year reported, or interpolated using known percentages from two different years. Additional variables were later added for the endemic goiter predictions as described later.

The analysis of trends in TGR, stratified by pre-iodization (or endemic) TGR (*var = ptgrcat*), in relation to level of salt iodization coverage (*var = rectype*) initially included 59 cases; 30 cases were added when pre-iodization categories were estimated by the procedures in step 2.

Analysis (2): estimating pre-iodization (endemic) goiter for countries with missing data.

Since goiter is determined primarily by iodine intake, and has persisted over centuries, it is probable that there is not much underlying trend in the absence of intervention to increase iodine intake in any affected area. Large differences in deficiency are known to persist between areas—mountainous regions and floodplains in particular have high iodine-deficiency disorder prevalences—in the absence of intervention. Initial inspection of data, with some focus on the older results (see Annex 1, **table A1.6 A and B**) seemed to support the hypothesis that goiter prevalences (called total goiter rate [TGR], meaning visible plus palpable goiter) at any one time were determined principally by three variables:

» The level of household consumption of iodized salt;
» The amount of time iodized salt has been consumed;
» The level of endemic goiter in the country.

Endemic TGR here means the TGR before the introduction of iodized salt. It is assumed that in the absence of intervention, the level of goiter does not show much of a trend through time.

The eventual aim was to fill in the gaps by country and year, estimating TGR for reference years, here 1994 and 2000. A major problem in the past had been that while for individual countries goiter can be seen to decrease, this improving trend does *not* appear when regional estimates are made, as more data come in (reporting bias), in fact as noted earlier, WHO estimates for 1990 and 1998 showed an apparent slight *increase* (WHO [19], table 5; Mason et al. [1], table 8), from 12.5% to 13.6%. This is because repeated data from the same countries were not used; rather estimates from different countries at varying times were averaged by region for the reference years (1990 and 1998 in this case).

A procedure to address this is to make estimates for every country (in each developing region) for the reference years, then aggregate these and compare. This should give an unbiased estimate of the trend. To do this we needed to develop a model that would interpolate or predict the national prevalences for the reference years. This was done in three stages:

» Estimate the endemic (pre-intervention) TGR for each developing country;
» From this, establish the relationship between the current TGR data, the endemic TGR, and levels and duration of salt iodization;
» Apply this relation to all countries to predict the estimated TGR for 1994 and 2000.

In order to create this model to predict current TGRs by country, the data on pre-intervention TGRs and the timing of the introduction of iodized salt were used. These country-level data include an estimate of the year that household iodized salt consumption first reaches 25% for most countries (certain assumptions were made in the rare cases when it passed 25% and fell again). TGR prior to iodization, however, is only reported for 59 countries. This necessitated the construction of a regression model to predict country-level

endemic TGR for the missing countries; this model was also used to check for possible errors and outliers in the reported pre-iodization TGR.

Endemic TGR is known to depend on the levels of iodine present in the local environment. There are no direct data reporting this in detail on a global level, so several associated independent variables were used to predict endemic TGR.

In developing the model, the dependent variable is TGR as reported prior to iodization (*endtgr*). This value was averaged in cases where there were more than one reported pre-iodization TGR value. Four countries' values were excluded from the data used for the model. Cameroon, which gave a level of 70% in 1984, reported a level of only 26.1% in 1991 (after the introduction of iodized salt). This rapid change is unlikely, making both datapoints unreliable. Mozambique had a reported value of 76% in 1992, which is unusually high, and due in part to the conflict up until 1992, this value was judged to be unreliable, or at least atypical. Malawi reported a value of 12.7% in 1989, which is unusually low, and because of the several higher reported values in neighboring countries this datapoint was judged to be unreliable. Finally, Syria reported a value of 73% in 1992, which was also determined to be unrealistically high based on the levels of surrounding countries.

First, a variable for percentage of land with low cation exchange capacity (CEC%) was created, from FAO data [23]. CEC measures the ability of soil to hold nutrients; a low CEC indicates soil unable to hold nutrients, often sandy soil. Due to a large number of zero values, this continuous variable was transformed into two dummy variables: for countries with 0% of land with a low CEC (*cec.d.0* = 1), and countries with a percentage of land with CEC greater than zero and less than 10(*cec.d.10* = 1); countries with 10% or greater of land with low CEC were the comparison group (*cec.d.0* and *cec.d.10* both = 0).

Second, a continuous variable for the percentage of a country's population living within 200 km of the ocean was included (*p.p.ocn2*). Data were available for both 100 and 200 km; however the 200 km data showed a higher association with pre-iodization TGR (*endtgr*), and were finally selected. This variable was expected to be useful since an important natural source of iodine is seafood, and in poor societies the trading is limited—thus, proximity to the coast was considered a possible determining factor.

Third, three variables were created based on a map of areas of the world with depleted soil iodine levels [24]. These data were summarized into two dummy variables, indicating some of the country (>0%, less than 100%) mapped as having low soil iodine levels (*dumsoil1* = 1), all of the country has soil deficient in iodine (*dumsoil2* = 1), with the comparison group being countries that have no area with low soil iodine levels.

Fourth, regional dummies for South Asia (*d.reg.1*), South America (*d.reg.4*), and the Middle East/North Africa (*d.reg.5*) were included in the final model (others were tested and not significant).

Finally, a continuous variable was created as the average of the reported endemic TGRs of neighboring countries (*nbrtgr*), where these existed. Each neighboring TGR value was weighted by the amount of border shared with that country over the total amount of border shared with all countries having a reported endemic TGR. For island nations and near island nations (more than 90% surrounded by ocean), the average of pre-iodization TGRs was calculated and this value (17.8%) applied as the *nbrtgr* value to all islands, on the assumption that islands have more physical similarities to each other related to iodine than to the countries they are nearest to.

These variables led to model 1:

ENDTGR = 31.514 – (8.623) CEC.D.0 – (11.989) CEC.D.10 + (8.225) DUMSOIL1 + (10.951) DUMSOIL2 + (16.393) D.REG.1 + (8.412) D.REG.4 + (13.530) D.REG.5 – (.15) P.P.OCN2 + (0.187) NBRTGR

CEC.D.0 = dummy for 0% of land with low cation exchange capacity ($p = .117$)

CEC.D.10 = dummy for 0.1% to 10% of land with low cation exchange capacity ($p = .026$)

D.REG.1 = dummy for South Asia ($p = .006$)

D.REG.4 = dummy for South America ($p = .074$)

D.REG.5 = dummy for Middle East/North Africa ($p = .083$)

DUMSOIL1 = dummy for some of soil mapped as having low iodine ($p = .093$)

DUMSOIL2 = dummy for all of soil mapped as having low iodine ($p = .075$)

NBRTGR = Weighted average of endemic TGRs of neighboring countries ($p = .172$)

P.P.OCN2 = % of population living within 200 km of the ocean ($p = .021$)

This model has an $n = 46$, an adjusted R^2 of 0.649, a standard deviation of the residuals of 9.296, and overall $p < .001$. This parameter of the SD of the residuals was used in this and other models developed, as it shows the expected error of any predicted estimate: the value of 9.3 means that 68% of predicted TGR values are expected to be within ± 9.3 percentage points of the real value, if that were known. (The average predicted error is zero.)

Seven countries did not have values for *nbrtgr*, so a second model was estimated omitting this variable, allowing the use of the 46 countries in the previous

model with reported neighboring endemic TGRs, and the additional 7 countries without. This caused the dummy variable for South Asia (D.REG.1) to become insignificant, so it was also removed. This resulted in model 2:

ENDTGR = 41.029 – (11.650) CEC.D.0 – (15.503) CEC.D.10 + (4.74) DUMSOIL1 + (12.354) DUMSOIL2 + (10.902) D.REG.4 + (11.732) D.REG.5 – (.133) P.P.OCN2

CEC.D.0 = as above ($p = .038$)

CEC.D.10 = as above ($p = .007$)

D.REG.4 = as above ($p = .041$)

D.REG.5 = as above ($p = .049$)

DUMSOIL1 = as above ($p = .316$)

DUMSOIL2 = as above ($p = .030$)

P.P.OCN2 = as above ($p = .013$)

This model has an $n = 53$, an adjusted R^2 of 0.455, an SD of the residuals of 11.3, and overall $p < .001$.

These coefficients and constant from these equations were entered into Microsoft Excel. The independent variables (as 0–1 dummies: cation exchange capacity, soil mapping for iodine, neighboring TGR, region) were determined from the same sources used to set up the models, for each country for 1994 and 2000, and the equations were used to impute the levels of endemic TGR in each developing country. The first model equation was the standard. The second model was used only where there were no bordering countries to provide a *nbrtgr* value. The imputed values of pre-iodization TGR were then used to estimate TGRs for 1994 and 2000, as described in the next section.

It is important to note that the *year* of pre-iodization TGR (*endtgr*) was tested and found not to be significantly related to the pre-iodization TGR itself, either alone or when included in any model. This lends some support to the hypothesis of no underlying trend in endemic TGR.

Analysis (3): estimating national TGRs at reference years (1994 and 2000)

The data used to construct this model to estimate TGRs for 1994 and 2000 (in most cases, post-iodization) consisted of all observed values of TGR (TGR, dependent variable) that have a corresponding value of percentage of households using iodized salt (*hhiod*), for that country and year. Countries were included if they had reported values of household iodization coverage (*hhiod*) and TGR with no more than two years separating them. Iodized salt coverage was interpolated if necessary when values were reported before and after, but not on, the year for TGR. All countries had an estimated endemic TGR (*endtgr*), either as observed or from the previous model, as described above.

The amount of time that the country had had iodized salt coverage above 25% was not significant in the model. This may have several causes. First, the percentage of households using iodized salt appears to be positively correlated with the amount of time above 25% salt iodization (which makes sense). That is to say, countries with high levels of iodization are likely to have been above 25% for a longer period of time than countries with moderate or low levels of iodized salt coverage. So, the time component is included to some degree in the iodized salt coverage variable (*hhiod*). Second, the time-related data are subject to some uncertainty, which may make the data unreliable. A significant interaction observed between *hhiod* and *endtgr*, further discussed in the Results section, was kept in the model. No regional dummy variables were significant (implying that these differences were accounted for by the endemic TGR and the salt iodization variables).

Model 3 was:

TGR = .988 + (.946) ENDTGR + (.113) HHIOD – (.00108) ENDTGR * HHIOD

ENDTGR = imputed endemic TGR ($p = .000$)

HHIOD = % of households using iodized salt ($p = .193$)

ENDTGR × HHIOD = interaction term between endemic TGR and % of households using iodized salt ($p = .000$)

This model had $n = 79$, an adjusted r^2 of 0.621, a mean square residual of 96.7 giving an SD of the residuals of 9.8, and a $p < .001$.

The implications of the model are difficult to interpret by inspection alone because of the interaction term. However, they can be visualized as confirming that the slopes shown in **figs. 9 and 10** are significantly different. (When run without the interaction term and with *hhiod*, it has a lower adjusted r^2 value, and a higher mean square residual, but remains significant. The *hhiod* term has a negative coefficient, and *endtgr* has a positive coefficient near one, indicating that TGR only changes in the presence of iodized salt.)

The predicted TGRs using the coefficients and constant from this model were calculated, inserting values for the independent variables. The 1997 and 2003 reported values for percentages of households using iodized salt were taken from UNICEF's State of the World's Children [9]. The 1997 values represent information gathered between 1992 and 1996, averaged to 1994. The 2003 values represent data gathered between 1997 and 2002, averaged to 2000. The pre-iodization TGR was taken from the estimates described earlier. Population data were taken for 1995 and 2000. This procedure gave the estimates of TGR for 1994 and 2000.

The country-level TGR estimates were then used to calculate the weighted regional averages, based on total country populations. The weighted regional averages were also calculated for predicted endemic TGR, and for household iodization for 1994 and 2000. The population data for 1995 and 2000 were taken from State of the World's Children [9]. The 1995 population data were used for calculating the endemic TGR weighted regional estimates. The country-level data are included in **table A1.6** and Annex 2.

Estimates for India are of particular concern here because of their uncertainty and the large population. The value for endemic goiter, from the model, was 25.3% for India; however, this does not use neighboring country values, since these countries are considered ecologically different (mountainous, noncoastal, flood-prone). No national data on pre-iodization prevalence are available, but an estimate can be made from WHO (1993) [19]: here (pp. 68–69), disaggregated values (n = 106) for the 1970s and 1980s are found to have a mean (unweighted) of 23% (25th centile = 9.7, 75th centile = 32.3), lending credibility to the 25% estimate. This report is also the source of the widely quoted 9% TGR (for 1991, p. 42), [19] which is presumably post-iodization, as the policy of universal salt iodization was declared in 1986, and iodized salt production was substantial by 1992. The estimates here for post-iodization TGR, of 14% in 1994 and 17% in 2000, seem reasonable in this perspective. The figure of 25.3% pre-iodization TGR is used for India in the calculations here.

Underweight

Underweight prevalence data for children provide probably the most available and robust information on general nutrition conditions. For estimating and understanding trends in micronutrient deficiencies, it had previously proved extremely useful to include underweight trends [1]. As it would be expected that these would tend to be in similar directions, checking against underweight trends proves valuable in evaluating data on micronutrient deficiencies. Putting together the four estimates—vitamin A deficiency, anemia, iodine-deficiency disorders, and underweight—gives a useful overall picture. Finally, the population affected by multiple deficiencies can be calculated, updating previous estimates. The database for underweight already existed from previous work and therefore was updated and reanalyzed for the present purposes.

Data compilation

The results of 318 national surveys from 101 developing countries from 1975 to 2001 were available, building on the data compilations previously used for the Micronutrient Report [1], and prior to that for the ACC/SCN Reports on the World Nutrition Situation [4, 5, 25, 26]. This was a considerable increase in the number of datapoints, from 173 estimates from 77 countries. The new results were taken from DHS (http://www.measuredhs.com/) and UNICEF Multiple Indicator Cluster Surveys (MICS) (http://www.childinfo.org/index2.htm), accessed through the websites, and in some cases from government results identified through the country survey. The complete set of survey results is recorded by country and year in Annex 1, **table A1.7**.

A number of variables were used in developing the regression model to interpolate missing data to reference years. Those used in the final model were enrollment of girls in secondary education (%: *femsec*); urban population (%: *urbanpop*); percentage of government expenditure on health and education (*pedheal*); infant mortality rate; gross national product for previous year (*lnlagnp*); and percentage of kilocalories from animal products (*anmprodx*). The primary data sources for the independent variables were UNICEF's the State of the World's Children (UNICEF 2002 and earlier [9]). Other sources were FAOStat (http://apps.fao.org/), the World Bank's World Development Reports (World Bank 2002 and earlier [10]), and the United Nations Development Programme's Human Development Reports (UNDP 2002 and earlier [17]).

Underweight prevalence in children from 0 to 59 months of age was the outcome indicator. This is the most frequently reported age group, and where only other age groups were reported, these were adjusted. Using data from children 36 months old and younger may overstate the prevalence for those 0 to 59 months old by a factor of about 1.15 to 1.3 [26]. Adjustments were made to survey results that gave prevalences among children 0 to 36 months old as follows. A conversion factor of 1.3 was used to convert the prevalences to the 0- to 59-month-old equivalent. In all, 25 survey reports were adjusted, the majority of which were DHS surveys. These countries were Afghanistan (1997), Benin (1996), Bolivia (1994), Cameroon (1998), Central African Republic (1994), Côte d'Ivoire (1994, 1998), Eritrea (1995), Ghana (1993), Kazakhstan (1995), Kenya (1998), Kyrgyzstan (1997), Madagascar (1997), Mali (1995/96), Mozambique (1997), Myanmar (1995), Niger (1998), Nigeria (1999), Togo (1998), Uganda (1995), Uzbekistan (1996), and Zimbabwe (1994).

For Nepal and India, after comparing surveys for these two countries that had prevalences of underweight for both 0- to 36-month-olds and 0- to 59-month-olds available, it was found that the prevalences were higher for 0- to 59-month-old children. The prevalence was 1.08 times greater in India, and 1.02 times greater in Nepal. Prevalences that were reported only for 0- to 36-month-olds for these two countries were adjusted according to these findings.

Database description

The database was set up with each country survey result as a case; thus, there were 318 cases (or rows). The independent variables were entered for the same years as the underweight results. The analytical files for underweight were thus set up in the same way as for vitamin A deficiency, anemia, and iodine-deficiency disorders.

Analytical methods

Repeated national surveys

The methodology used to compare repeated national surveys is straightforward and similar to that for micronutrients. A country was included when more than one national prevalence estimate was available for that country. The difference between two consecutive estimates was calculated and divided by the number of years between the datapoints, to give the change in percentage points per year for the period between the two surveys. For more than two surveys, the rate was calculated for each interval. Using the same calculation as for vitamin A deficiency, but estimating the sample sizes as likely to be around 2000, a difference of 2 percentage points between surveys was considered likely to be significant; less than this was noted as static. This assessment was made regardless of the number of years between surveys.

Unadjusted averages by region and time period

This was calculated by computing an unweighted mean for all the prevalence datapoints for a particular region and time. The time periods used to calculate the means were before 1983, 1983–87 (centered on 1985), 1988–1992 (centered on 1990), 1993–97 (centered on 1995), and 1998–2001 (centered on 2000). The regions are the same as those used throughout this report.

Analysis by country-year: Interpolations

To develop country prevalence estimates for the reference years 1990, 1995, and 2000, multivariate regression analysis was utilized. The purpose of the regression model was not to explore causality, but to explore factors that had the best predictive values for underweight. Therefore, the variables used may or may not relate to potential causal contributions. The model was similar to that derived for the Micronutrient Report (Mason et al. [1], p. 85). The logit function for underweight prevalence was used as the dependent variable (as before), as this reduced the error (increasing R^2, reducing SD of the residuals). [Logit prevalence (p, as proportion, i.e., 0 to 1) = ln $(1/p - 1)$] [27].

The final model was derived from fitting a linear regression to the 318 national estimates of underweight prevalence, with the final $n = 293$; 25 cases were missing due to unavailability of one or more independent variables (mainly estimates of percentage of kilocalories from animal products, or percentage of expenditure on education and health). The prevalences were standardized to 0 to 59 months and represent those weighing less than 2 SD below the mean weight for age. The final model is as follows:

Regression model for underweight:

Ln $(1-p/p) = 0.0608 + (0.00974 \times \text{FemSec}) + (0.00742 \times \text{UrbPop}) + (0.01236 \times \%\text{EduHlth}) + (-.0021 \times \text{IMR}) + (0.0959 \times \text{LnGNPlag1}) + (.01266 \times \text{anmprodx}) + (-2.856 \times \text{DSAsia}) + (0.288 \times \text{DSAsiaGNP}) + (-3.310 \times \text{DSAmer}) + (0.499 \times \text{DSAmerGNP}) + (-0.804 \times \text{DSEAsia w/outChina}) + (0.408 \times \text{DNewIndSt}) + (.224 \times \text{DMeastNAfri})$

N = 293

p = prevalence of underweight (%)

FemSec = ratio of girls enrolled in secondary school ($p = .000$)

UrbPop = % of urban population ($p = .005$)

%EduHlth = % of government budget spent on education and health ($p = .002$)

IMR = infant mortality rate ($p = .083$)

LnGNPlag1 = ln GNP (in constant prices) for the previous year ($p = .105$)

anmprodx = % of total calories from animal products ($p = .013$)

DSAsia = regional variable for south Asia ($p = .021$)

DSAsiaGNP = interaction term for South Asia and GNP ($p = .190$)

DSAmer = regional variable for South America ($p = .001$)

DSAmerGNP = interaction term for South America and GNP ($p = .000$)

DSEAsia = regional variable for Southeast Asia, not including China ($p = .000$)

DNewIndSt = regional variable for Newly Independent States ($p = .033$)

DMeastNAfri = regional variable for Middle East and North Africa ($p = .041$)

Adjusted $R^2 = 0.767$

Methods applying to vitamin A deficiency, anemia, iodine-deficiency disorders, and underweight

Calculating regional prevalences from interpolated country-year estimates

After determination of the regression models, the

countrywise and regional predicted prevalences for underweight, vitamin A deficiency (both xerophthalmia and subclinical), and anemia were calculated by Microsoft Excel. The different independent variables included in the regression model were entered into the spreadsheets on a countrywide basis for each of the micronutrient deficiencies and for underweight. Different spreadsheets were created for underweight, xerophthalmia, vitamin A deficiency, anemia among pregnant women, anemia among nonpregnant women, and anemia among children less than five years of age. These spreadsheets were further divided into the three years being examined: 1990, 1995, and 2000.

Most of the country-level independent variables for 1990, 1995, and 2000 were taken from the State of the World's Children published annually by the United Nations Children's Fund [9]. Several variables, however, were not included in these annual reports, and thus other sources were used. Most notably, the independent variable, population of women of reproductive age, was taken from the United Nations Population Division [11]. Likewise, the independent variables, percentage of calories from animal products and meat, were taken from the Food and Agriculture Organization's Food Balance Sheets [12].

The coefficients of the regression models were then entered into the spreadsheets, and the regression equations were solved using the calculation functions available in Excel. Once the countrywide predicted prevalence was determined for each of these nutritional deficiencies, the weighted regional averages were calculated. The regional averages were then plotted to provide a graphical illustration of the prevalence and trends according to region. The regional averages were used to estimate the numbers of malnourished and the trend in percentage points of change per year. Large matrices were also constructed that displayed the observed countrywide and regional prevalences in relation to the predicted values. This facilitated the examination of trends among the observed and predicted values to determine whether the predicted values were indeed good estimates of the true values.

Estimating "best guess" of prevalences by country

Prevalences were calculated for each country for reference years, leading to estimates at the regional level and hence trend assessment, as described above. The data were potentially useful also to give a picture of relative prevalences by country at one time, 2000 being the most recent estimated. There is demand for such rankings—here for use in the Micronutrient Initiative/UNICEF Vitamin and Mineral Deficiency publication [2], and more generally in line with common practice in such publications as State of the World's Children (UNICEF, annual) [9]. Caution is needed for country-level data, compared with regional aggregates where random error will cancel out at least to some extent. Here the estimates for 2000 for each of the seven indicators for 107 countries were compared with the survey data—conveniently viewed as in the matrices in Annex 1—and decisions were made as to the most likely value by developing and applying rules systematically. These are referred to as "best guess" estimates. Note that these best guesses apply *only* to the country data in Annex 2, and do not affect the regional results.

Although the country-level estimates were not necessarily accurate individually, laying them out as in the Annex 1 tables allowed an assessment of how close they were in countries with surveys near the reference years. For individual country data, where there was a recent survey, it was felt better to use that survey result if it appeared credible, or to adjust it to the likely value if it was a few years away from 2000. The rules were as follows:

1. For vitamin A deficiency, underweight, and anemia, since it had been seen in developing the interpolation models that approximately 70% of predicted values were expected to fall within 10 percentage points of survey values (i.e., the SD of the residuals was about 9 percentage points), instances where a predicted value differed by more than 10 percentage points from a recent survey value were flagged for further investigation. If the survey result had already been excluded as an outlier, the predicted value was used. Otherwise the rules as given below applied.
2. For underweight prevalences, if the observed value (for the year 1995 or later) was *not* a DHS/MICS datapoint, or there was no recent survey (for 1995 or later), the 2000 predicted value was used. Otherwise, if the difference was less than 10 percentage points, the estimate was based on the observed value. If this was 1999–2001, it was used unadjusted. If it was 1995–98, it was adjusted by the trend between the 1995 and 2000 predicted values (for example, if the predicted values were 30% for 1995 and 25% for 2000, i.e., trend = –1 percentage points/year, and there was a survey value of 29% in 1998, this would be adjusted to 27% for 2000). Six estimates were more than 10 percentage points different from reported survey values and were treated as described in the footnotes to the table in Annex 2.
3. For anemia, for which there were the fewest national survey data, where there were no recent surveys (for 1995 or later), or where the difference from a recent survey was less than 10 percentage points, the predicted value was used. Where this difference was more than 10 percentage points, and the recent survey was considered to be nationally representative, the predicted and survey values were averaged (since the true value was likely to lie between the two estimates, averaging was probably better than choosing one). This applied to five cases for nonpregnant women and eight cases for pregnant women, as given in the notes to the table in Annex 2. For preschool

children, the predicted values were taken as such.
4. For vitamin A deficiency, where there was a survey in 1999–2001 and less than 10 percentage points difference, the survey result was taken. When the difference was more than 10 percentage points (and the survey was national and from 1995 or later), the average was taken, as for anemia. Otherwise the predicted value was used. This applied to eight cases (see notes to the table in Annex 2). For xerophthalmia, where there was a recent survey value (not regarded as an outlier in developing the model) for 1995 or later, this was used; otherwise the predicted value is given.
5. For TGR, the year 2000 predicted value was taken. By application of these rules, the "best guess" estimates were made, as shown in the table in Annex 2.

Results

Vitamin A deficiency

Repeated national surveys

Repeated national surveys that appeared to be comparable through time are shown in **table 2** for xerophthalmia, and **table 3** for vitamin A deficiency. The Asian countries generally show a pattern of improvement in xerophthalmia; however, the results indicate a static situation in India, where the prevalences of Bitot's spots in 1988 and 2001 were both 0.7%. Trends in Laos, Mongolia, and Vietnam are unclear from these data.

Fewer repeated surveys exist for vitamin A deficiency, with seven cases for moderate and two for severe deficiency (see **table 3**). Most of these were from Central America, showing improvement. The trends in Costa Rica and Panama are related to very low levels of deficiency and do not represent important

TABLE 3. National prevalence of vitamin A deficiency in preschool children: results from repeated national surveys

A. Moderate vitamin A deficiency (serum retinol < 20 µg/dL or 0.7 µmol/L)

Country	Survey year	Prevalence (%)	Age group surveyed (mo)	Trend
Costa Rica	1979	2.3	0–59	
	1981	1.8	0–59	
	1996	8.7	12–72	Possible deterioration
Ethiopia	1980	59.6	6–59	
	1996	38.9	6–59	Improvement
Guatemala	1970	26.2	0–59	
	1995	15.8	12–59	Improvement
Honduras	1987	20.0	0–59	
	1996	13.0	12–71	Improvement
Nicaragua	1993[a]	31.1	12–59	
	2000	8.6	12–59	Improvement
Panama	1992	6.0	0–72	
	1999	9.4	12–59	Unclear
Philippines	1993	35.5	6–59	
	1998	38.0	6–59	Unclear

a. Subnational survey.

B. Severe vitamin A deficiency (serum retinol < 10 µg/dl or 0.35 µmol/L)

Country	Survey year	Age group surveyed (mo)	Prevalence (%)	Trend
Costa Rica	1979	0–59	0.0	
	1981	0–59	0.0	
	1986	12–72	0.0	No change
Ethiopia	1980	6–59	16.4	
	1996	6–59	23.7	Possible deterioration

Sources: See Annex 1, **table A1.2**.

deterioration, if any. Ages were not always comparable, and the results for vitamin A deficiency ideally might need to be adjusted for age.

The absence of a clear trend in the Philippines in vitamin A deficiency—probably a deteriorating trend—may be important, as this was in a period of high coverage of vitamin A capsule distribution; the implications of this are explored in Pedro et al. [28].

Unadjusted averages by region and time period

The xerophthalmia results averaged by country group and periods (earlier than 1990, 1990–95, and after 1995) are shown in **table 4**, here including both national and subnational data to maximize the available sample size of surveys. As noted before (in the Methods section), these averages are not directly comparable, as different countries appear in different periods, and it is only the broad pattern that may be informative. If these patterns differ from those seen from repeated national surveys, or regional averages calculated from interpolated results, this flags inconsistencies to be examined further.

Only Asia and Sub-Saharan Africa have enough xerophthalmia survey results that averages could be considered meaningful. In Africa the prevalence remains high, more than 1%, with some indications of decrease. In Asia the prevalence is lower, but improvements may have slowed after 1995. Here the varying inclusion of countries depending on available data is important: for example, the Indian results are from the periods before 1990 and after 1995, but not from the period from 1990 to 1995; thus, the average prevalence trend for Asia is not well represented as shown.

A sense of the variability of these results is provided by the scatterplot shown in **fig. 1**. Although there is a significant trend in the fitted line ($p = .001$, $n = 69$), which supports the conclusion that overall there is a decreasing prevalence, the same concern for noncomparability between different years arises.

The average values for the prevalence of moderate vitamin A deficiency are shown in **table 5**, calculated similarly to those for xerophthalmia. In this case, trends in Latin America, as well as in Asia and Sub-Saharan Africa, can be examined from the table. The scatterplot is shown in **fig. 2**; here neither the overall trend, nor those within Latin America, Asia, or Africa, is significant (by regression, not shown). The prevalences in Africa appear to be high and static (> 40%), and those in Asia are lower, with some possible improvement (**tables 5A and 7**). However, in Latin America the averages suggest possible improvements (on regression, $p = 0.2$, $n = 28$, for the years after 1980, from the same data as in **table 5A**).

Only a few results are known for severe vitamin A deficiency, indicated by serum retinol levels less than 10 μg/dl (**table 5A**). In Africa these are high, averaging 16% since 1995. Some subnational results, as in the Philippines [28, 29], report regional prevalences above 10%, and in badly affected areas (which tend to be urban), prevalences above 30% have been found.

TABLE 4. Mean prevalence (%) of xerophthalmia (night-blindness + Bitot's spots, XN + X1B) calculated by averaging survey results, according to time of survey and region[a]

Region	Time of survey		
	Before 1990	1990–95	After 1995
Middle East and North Africa	—	2.00 (3)	—
Sub-Saharan Africa	2.04 (11)	1.59 (10)	1.24 (4)
Asia	1.44 (8)	0.79 (8)	0.80 (15)
Middle America and Caribbean	1.42 (3)	0.05 (1)	—
Central Europe	—	—	—
Total	1.74 (22)	1.28 (22)	0.89 (19)

a. The number of surveys is given in parentheses. Data include national and subnational survey results for children up to 72 months of age.

Sources: National data given in Annex 1, **table A1.1**.

Results from analysis by country-year

The estimates of xerophthalmia prevalences for all countries for 1990, 1995, and 2000, calculated from the regression model described earlier (interpolating based on correlations with infant mortality rate, female literacy, and measles immunization coverage), are shown in Annex 1, **table A1.1**. These were aggregated to regional levels, as described in the Methods section. The results for all countries by country groups, based on this interpolation, for prevalences and numbers of children 0 to 72 months of age affected, are shown in **table 6**. The xerophthalmia prevalence results are also displayed in **fig. 3**.

These results can be compared with the two previous methods (repeated surveys, and averaged available data for Asia and Africa). The persistently highest prevalence in Sub-Saharan Africa is again seen here, at around 1.5%. Asia is now distinguished into India, China, other South Asia, and Southeast Asia (see **table 1** for details). These too are fairly static in the 1990s, similar to the results in **table 4**, but show improvement in China and likely increases in India. Improvements in Latin America and in the Caribbean are projected from these estimates, in line with vitamin A deficiency results (see below).

The vitamin A deficiency estimates, shown in **table 7** and displayed in **fig. 4**, imply a somewhat better trend, except in Africa, suggesting some improvement in Asia, and tending to confirm this elsewhere. For Latin America, the levels and trend rates are similar from repeated surveys (the only group that has several of these)(**table 3**) and from interpolation (**table 7**).

Overall, around 7 million children are estimated to

TABLE 5. Mean prevalence (%) of vitamin A deficiency calculated by averaging survey results, according to time of survey and region[a]

A. Moderate vitamin A deficiency (serum retinol < 20 μg/dL or 0.7 μmol/L)

Region	Time of survey		
	Before 1990	1990–95	After 1995
Middle East and North Africa	—	31.5 (3)	4.04 (1)
Sub-Saharan Africa	43.58 (5)	36.51 (10)	48.81 (16)
Asia	38.27 (7)	35.74 (5)	31.02 (12)
Middle America and Caribbean	23.57 (10)	18.30 (10)	11.87 (13)
Central Europe	—	48.90 (1)	—
Total	32.79 (22)	30.00 (29)	30.87 (42)

a. The number of surveys is given in parentheses. Data include national and subnational survey results for children up to 72 months of age.

B. Severe vitamin A deficiency (serum retinol < 10 μg/dL or 0.35 μmol/L)

Region	Time of survey		
	Before 1990	1990–95	After 1995
Middle East and North Africa	—	3.30 (3)	—
Sub-Saharan Africa	11.83 (3)	5.44 (8)	15.9 (3)
Asia	15.00 (1)	6.60 (2)	3.89 (3)
Middle America and Caribbean	3.12 (6)	1.87 (3)	0.63 (3)
Central Europe	—	—	—
Total	6.92 (10)	4.51 (16)	5.27 (12)

a. The number of surveys is given in parentheses. Data include national and subnational survey results for children up to 72 months of age.

TABLE 6. Trends in prevalence of xerophthalmia (XN + X1B) and numbers affected among preschool children (0–72 months of age) according to region, 1990–2000

Region	% of children vitamin A deficient			No. of children vitamin A deficient (millions)			Trend (pp/yr)	
	1990	1995	2000	1990	1995	2000	1990–95	1995–2000
Sub-Saharan Africa	1.7	1.5	1.5	2.0	2.0	2.0	–0.04	0.00
Middle East and North Africa	1.2	0.9	0.8	0.6	0.5	0.4	–0.06	–0.02
South Asia (without India)	1.8	1.6	1.7	1.1	1.0	1.0	–0.06	0.02
Southeast Asia	0.7	0.4	0.5	0.5	0.4	0.4	–0.06	0.02
China	0.7	0.4	0.4	1.0	0.5	0.5	–0.06	0.00
India	1.3	1.2	1.7	1.8	1.8	2.5	–0.02	0.10
Middle America and Caribbean	0.7	0.7	0.3	0.1	0.1	0.1	0.00	–0.08
South America	0.6	0.5	0.3	0.2	0.2	0.1	–0.02	–0.04
Eastern Europe and Central Asia	—	0.4	0.4	—	0.1	0.1	—	0.00
Total	1.2	1.0	1.1	7.3	6.6	7.0	–0.02	0.04

XN + XIB, Night-blindness + Bitot's spots; pp, percentage points.

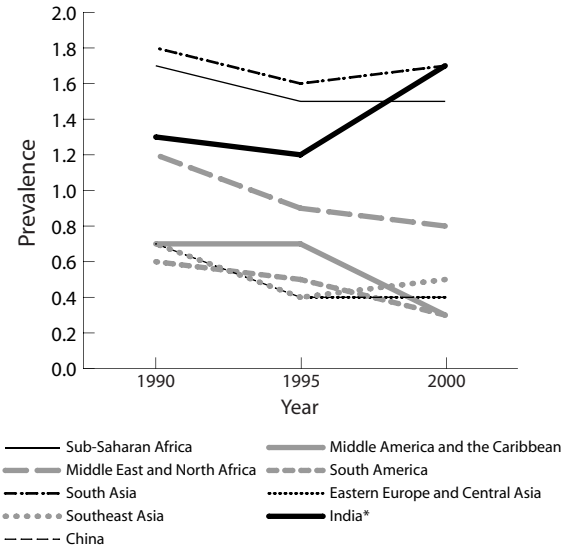


FIG. 3. Trends in the prevalence of xerophthalmia in children, 1990–2000
*India measles coverage (year/coverage): 1990/86, 1995/81, 2000/05

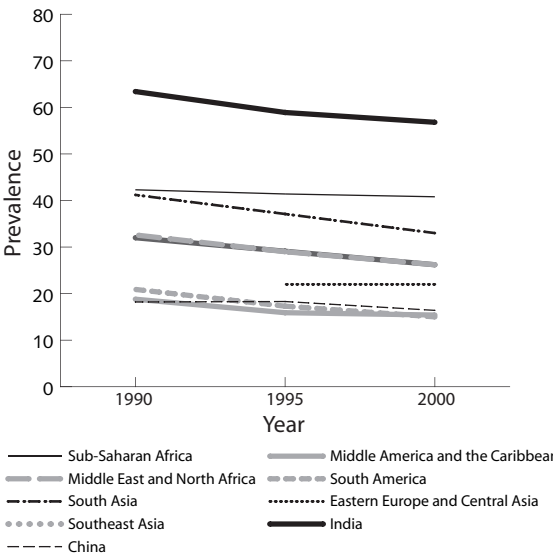


FIG. 4. Trends in the prevalence of vitamin A deficiency (VAD) in children, 1990–2000

TABLE 7. Trends in prevalence of vitamin A deficiency (< 0.7 μmol/L) and numbers affected among preschool children (0–72 months of age) according to region, 1990–2000

	% of children vitamin A deficient			No. of children vitamin A deficient (millions)			Trend (pp/yr)	
Region	1990	1995	2000	1990	1995	2000	1990–95	1995–2000
Sub-Saharan Africa	42.3	41.4	40.8	50.6	53.5	54.2	–0.18	–0.12
Middle East and North Africa	32.6	29.0	28.0	14.7	14.3	13.0	–0.72	–0.56
South Asia (without India)	41.2	37.1	33.0	24.7	22.6	19.8	–0.82	–0.82
Southeast Asia	32.0	29.1	26.2	22.3	20.8	18.0	–0.58	–0.58
China	18.2	18.0	16.4	26.0	22.3	19.0	0.02	–0.38
India	63.4	58.9	56.8	87.0	84.5	82.4	–0.90	–0.42
Middle America and Caribbean	18.8	15.9	15.3	4.4	3.8	3.6	–0.58	–0.10
South America	20.9	17.3	15.0	8.5	6.7	5.5	–0.72	–0.46
Eastern Europe and Central Asia	—	22.0	22.0	—	4.3	3.6	—	0.00
Total	37.3	35.2	34.0	239.0	232.8	219.1	–0.42	–0.24

have xerophthalmia and around 220 million to have moderate or severe vitamin A deficiency. Over half of those affected are in Africa or India.

Summary of trends in vitamin A deficiency

Xerophthalmia, as indicated by night-blindness and Bitot's spots, seems to be declining overall, judging from the few repeated surveys available; however, estimates by region show this to be so for Latin America and the Caribbean and for the Middle East and North Africa, but indicate a static picture elsewhere in the 1990s. The prevalences of xerophthalmia always have been low—a few percent or less—and are thought to reflect a broader problem not always seen clinically. This low prevalence itself makes estimating levels and changes harder. When the various assessments are put together, the trend appears headed for near-elimination in the Americas, in some countries in South Asia (e.g., Bangladesh and Nepal), and in Southeast Asia.

The story in India is less clear, but recent surveys

(e.g., Government of India and UNICEF [30]) continue to report night-blindness prevalences of around 1%, with little change from previous surveys; this is in line with the model estimates. Other results from our data show that measles immunization, which increased greatly in coverage over this same period in most countries (but not India), is associated with a reduction in xerophthalmia and may well contribute (with vitamin A capsules) to the generally improving trend. This relation with measles immunization coverage (which may be a proxy for general health services access, but could be more specific) is used here in the model for estimating xerophthalmia prevalences, so that, for example, the apparent increase in xerophthalmia in India is in line with the reported decrease in immunization coverage. (This does not apply to vitamin A deficiency.)

Trends in vitamin A deficiency (measured by serum retinol), potentially affecting many more people than xerophthalmia, have to be assessed differently, since there are far fewer repeated surveys, mostly in Central America. Trend estimates are thus almost entirely indirect. A slow improvement in most regions is estimated, but the larger story may be the very high overall prevalences of vitamin A deficiency. The estimates can be seen as around 30% or more in most countries, as shown in Annex 1, **table A1.2**, and more than 50% in India. Nonetheless, an important finding is that vitamin A deficiency and xerophthalmia prevalences seem clearly to be declining in Latin America and the Caribbean, on which the different methods agree. It also appears that vitamin A deficiency has probably been decreasing somewhat in Asia.

Finally, the uncertainties illustrate the need for better assessment methods. Xerophthalmia has by far the lowest prevalence of all the micronutrient deficiencies estimated, calling for particularly large samples to obtain accurate estimates. However, the most widely used alternative of measuring serum retinol has drawbacks, although the prevalences are in a higher range, thus economizing on survey sample sizes. First, most methods applied in routine surveys require drawing and careful handling of blood samples for biochemical assay, which is expensive and often unsuitable for routine household surveys. Second, the implications of low serum retinol are less clear, both because liver stores buffer the serum levels, and because the functional significance of low serum retinol levels in relation to health and survival is less established. Nonetheless, we can also see that the prevalence of severely low levels of serum retinol (< 10 μg/dl or 0.35 μmol/L) can be well above 10%, and such deficient levels are very likely to be associated with increased risk.

Anemia

Repeated national surveys

The survey results considered likely to be comparable through time are shown in **table 8** for nonpregnant women, **table 9** for pregnant women, and **table 10** for preschool children. The patterns are not all that clear, probably in part because there is not a large amount of change and the errors in estimates are substantial. In general (as discussed shortly) the patterns from repeated surveys are in line with those from the interpolation models. Anemia in Asia is tending to show some decrease, more so in nonpregnant than pregnant women; and is not generally improving in Africa, including the Middle East. The Americas, including the Caribbean, show a more mixed pattern.

The Asian countries with repeated surveys show the most consistent improving trends according to the latest data. In *nonpregnant women* in Indonesia, Thailand, and the Philippines, the prevalences of anemia rose between the late 1970s and the 1980s and then fell again between the 1980s and the 1990s, showing improvements in the latest surveys. Vietnam has shown striking improvement since 1995, with the prevalence dropping from 41% to 24% in five years (an improvement of 3.4 percentage points per year). Other countries showing improvement are Bangladesh (a 36 percentage point reduction in prevalence over 20 years), India, which appears to have been improving since the mid-1980s, and Kazakhstan, which saw a drop in prevalence of about 13 percentage points over four years (about the same rate of improvement as Vietnam). Countries showing worsening trends include Gambia, Kenya, Colombia, and Venezuela. Other countries have less clear trends or stable prevalences. Most countries, though, lack national survey data or repeated surveys.

Pregnant women are more often monitored than other groups in the population for hemoglobin status, and therefore more data and repeated surveys are available for this group. Again, some countries show recent improving trends. Guyana has consistently shown improvement since the late 1970s, but the prevalence of anemia is still very high (more than 50% in 1997 survey). Vietnam has shown dramatic improvement, with a drop in prevalence of anemia of 20 percentage points over five years. Stable prevalence levels are seen in pregnant women in Costa Rica, Jamaica, Indonesia, Myanmar, and elsewhere. The prevalence of anemia among pregnant women in Gambia increased from 60% in 1987 to 73% in 2001.

Data for *children under five years of age* are becoming more available in recent years. Repeated national surveys over time are fewer in number than for the other biological groups, although this group has prevalences of anemia as high as (or higher than) that of pregnant women in some countries. Several countries with

TABLE 8. Prevalence of anemia in nonpregnant women 15–49 years of age: results from repeated national surveys

Region	Country	Survey year	Prevalence (%)	Trend
Middle East and North Africa	Egypt	1983	25.9	
		2000	28.0	Unclear
	Jordan	1987	23.0	
		1996	28.0	Deterioration
Middle America and Caribbean	Costa Rica	1989	22.0	
		1990	13.5	Improvement
	Guatemala	1978	8.0	
		1995	35.0	Unclear
	Honduras	1984	15.0	
		1994	26.0	Deterioration
		1995	25.8	
		2001	14.7[a]	Improvement[a]
	Mexico	1977	14.0	
		1988	15.4	
		1990	14.0	Unclear
	Nicaragua	1993	36.3	
		2000	24.0[a]	Improvement[a]
Southeast Asia and Pacific	Indonesia	1975	33.0	
		1982	55.0	
		1995	39.5	Improvement
	Philippines	1978	50.5	
		1982	27.3	Improvement
		1993	43.6	Deterioration
		1998	32.5	Improvement
	Thailand	1978	35.0	
		1979	48.0	
		1989	28.0	Improvement
		1995	18.0	Improvement
	Vietnam	1987	40.0	
		1995	41.2	
		2000	24.3	Improvement
South America	Colombia	1977	16.8	
		1995	22.5	Deterioration
	Peru	1996	35.7	
		2000	31.6	Improvement
	Venezuela	1982	16.0	
		1992	43.0	Deterioration
Sub-Saharan Africa	Gambia	1987	41.0	
		2001	56.0	Deterioration
	Kenya	1981	33.0	
		1986	34.5	
		1999	49.2	Deterioration
South Asia	Bangladesh	1975	70.0	
		1980	70.0	
		1981	74.0	Deterioration
		1997	38.9	Improvement
		2001	34.0	Improvement
	Sri Lanka	1988	59.8	
		1994	45.1	Improvement

continued

TABLE 8. Prevalence of anemia in nonpregnant women 15–49 years of age: results from repeated national surveys *(continued)*

Region	Country	Survey year	Prevalence (%)	Trend
Eastern Europe and Central Asia	Kazakhstan	1995	48.5	
		1999	35.6	Improvement
China	China	1981	50.0	
		1988	34.0	
		1992	21.5	Improvement
India	India	1978	55.3	
		1982	56.7	
		1984	69.3	
		1988	62.5	
		1998	51.9	Improvement

a. The cutoffs for Honduras 2001 and Nicaragua 2000 are unknown.

TABLE 9. Prevalence of anemia in pregnant women: results from repeated national surveys (includes only countries with at least one data point after 1990)

Region	Country	Survey year	Prevalence (%)	Trend
Middle East and North Africa	Egypt	1977	30.5	
		1980	79.0	
		2000	46.1	Unclear
	Iran	1980	14.8	
		1990	10.0	Improvement
	Jordan	1987	46.0	
		1990	46.0	
		1991	23.4	Improvement
		1996	35.0	Deterioration
Middle America and Caribbean	Belize	1984	49.3	
		1996	51.7	No change
	Costa Rica	1989	28.0	
		1990	24.9	
		1993	27.4	
		1996	27.9	No change
	Cuba	1985	14.0	
		1992	57.0	Deterioration
	Honduras	1994	26.0	
		1995	32.4	Deterioration
	Jamaica	1978	52.6	
		1987	52.0	
		1997	51.3	No change
	Mexico	1980	54.8	
		1983	41.0	Improvement
		1989	35.0	
		1993	37.0	Unclear
	Panama	1992	38.9	
		1999	36.3	Improvement
Southeast Asia and Pacific	Indonesia	1975	37.0	
		1980	70.0	
		1982	68.0	
		1986	74.0	Deterioration
		1991	50.1	Improvement
		1995	50.9	No change

continued

TABLE 9. Prevalence of anemia in pregnant women: results from repeated national surveys (includes only countries with at least one data point after 1990)

Region	Country	Survey year	Prevalence (%)	Trend
	Myanmar	1978	72.7	
		1979	58.0	Improvement
		1993	58.1	
		1995	58.0	No change
	Philippines	1978	53.0	
		1980	53.7	Deterioration
		1982	33.8	Improvement
		1986	48.0	Deterioration
		1993	43.6	Improvement
		1998	50.7	Deterioration
	Thailand	1978	59.1	
		1980	46.0	Improvement
		1982	48.0	
		1986	20.5	Improvement
		1991	25.0	
		1993	36.9	Deterioration
		1995	22.3	
		1996	19.1	Improvement
	Vietnam	1987	46.5	
		1995	52.3	Deterioration
		2000	32.2	Improvement
South America	Bolivia	1982	16.2	
		1985	25.0	Deterioration
		1994	51.0	
		1998	27.9	Unclear
	Ecuador	1985	17.0	
		1997	40.0	Deterioration
	Guyana	1979	73.7	
		1984	71.0	Improvement
		1985	65.0	Improvement
		1986	63.0	
		1997	52.0	Improvement
	Peru	1996	35.1	
		2000	38.6	Unclear
Sub-Saharan Africa	Ethiopia	1988	(6.0)	
		1991	41.9	Unclear
	Gambia	1987	60.0	
		2001	73.0	Deterioration
	Guinea	1990	(10.7)	
		2000	63.2	Unclear
	Liberia	1982	78.0	
		1987	79.8	
		1999	62.1	Improvement
South Asia	Bangladesh	1981	53.0	
		1997	49.2	Improvement
		2001	51.0	No change
Eastern Europe and Central Asia	Kazakhstan	1995	56.6	
		1999	32.9	Improvement
China	China	1979	(13.0)	

continued

TABLE 9. Prevalence of anemia in pregnant women: results from repeated national surveys (includes only countries with at least one data point after 1990) *(continued)*

Region	Country	Survey year	Prevalence (%)	Trend
		1982	43.5	Unclear
		1984	35.0	Improvement
		1985	20.0	
		1987	35.0	
		1992	35.0	No change
India	India	1978	69.5	
		1979	71.1	
		1980	66.5	
		1982	73.7	
		1984	76.8	
		1985	88.0	Unclear
		1986	65.5	
		1988	90.0	
		1998	49.7	Improvement

TABLE 10. Prevalence of anemia in children 0–59 months of age: results from repeated national surveys (includes only countries with at least one data point after 1990)

Region	Country	Survey year	Prevalence (%)	Trend
Middle America and Caribbean	Honduras	1995	30.0	
		2001[a]	29.9[a]	No change
	Jamaica	1987	78	
		1997	48.2	Improvement
	Panama	1992	18.0	
		1999	36.0	Deterioration
Southeast Asia	Philippines	1993	49.0 (6–11 mo)	
		1998	56.6 (6–11 mo)	Deterioration
	Thailand	1986	40.6	
		1995	25.7	
		1996	25.2	Improvement
	Vietnam	1995	45.3	
		2000	34.5	Improvement
South America	Peru	1996	56.8	
		2000	49.6	Improvement
South Asia	Bangladesh	1997	52.7	
		2001	48.0	Improvement
Eastern Europe and Central Asia	Kazakhstan	1995	69.9	
		1999	36.3	Improvement

a. The hemoglobin cutoff point for Honduras in 2001 is unknown.

repeated surveys show improving trends in anemia in children. Jamaica, Thailand, Vietnam, Peru, Bangladesh, and Kazakhstan all show improvement, though prevalences are still high. Panama and the Philippines show worsening trends. No repeated national anemia surveys could be found for children under five in Sub-Saharan Africa or the Middle East and North Africa.

Unadjusted averages by region and time period

Considerably more national survey results were available for anemia than for the other deficiencies. These are spread over a longer time period (from 1980 and earlier), but the rate of change is probably not rapid. Thus, there are larger numbers of survey results that can be averaged by country group and period, but still different countries appear in different averages, potentially confounding the conclusions. The results for the three biological groups are shown in **table 11**.

For Sub-Saharan Africa, the trend appears from these results to be static, generally in line with the repeated

TABLE 11. Mean prevalence of anemia (hemoglobin < 12 g/dL) calculated by averaging national survey results, according to biological group and survey period[a]

	Nonpregnant women		Pregnant women		Children < 5 yr old	
Region	Before 1990	1990 and after	Before 1990	1990 and after	Before 1990	1990 and after
Sub-Saharan Africa	40.9 (15)	40.8 (913)	44.2 (27)	43.3 (14)	— (0)	62.1 (12)
Middle East and North Africa	35.5 (5)	28.9 (3)	40.5 (6)	36.0 (7)	29.9 (1)	42.0 (3)
South Asia	64.9 (2)	55.1 (2)	44.1 (7)	46.4 (3)	61.5 (2)	58.5 (3)
India	64.1 (9)	51.9 (1)	75.1 (8)	49.7 (1)	— (0)	74.3 (1)
Southeast Asia	35.9 (12)	35.1 (9)	50.8 (17)	41.1 (13)	40.6 (1)	38.0 (12)
China	31.7 (3)	21.5 (1)	29.3 (5)	35.0 (1)	— (0)	16.7 (1)
Middle America and Caribbean	24.1 (14)	33.2 (9)	41.4 (15)	37.6 (15)	17.3 (2)	36.1 (9)
South America	22.2 (10)	32.1 (4)	36.9 (13)	40.8 (6)	— (0)	52.7 (6)
Eastern Europe and Central Asia	— (0)	40.3 (6)	— (0)	38.7 (6)	— (0)	43.2 (5)

a. The number of surveys averaged is in parentheses.

TABLE 12. Trends in prevalence of anemia (hemoglobin < 12 g/dL) and numbers affected among nonpregnant women 15–49 years of age, according to region, 1990–2000

	% of women anemic			No. of women anemic (millions)			Trend (pp/yr)	
Region	1990	1995	2000	1990	1995	2000	1990–95	1995–2000
Sub-Saharan Africa	43.6	45.6	46.5	49.1	59.3	69.3	0.40	0.18
Middle East and North Africa	28.8	31.2	31.5	16.0	20.0	23.8	0.48	0.06
South Asia (without India)	65.6	65.3	60.6	40.1	45.9	49.5	–0.06	–0.94
Southeast Asia	36.0	34.0	36.1	40.1	42.8	50.6	–0.40	0.42
China	27.8	24.2	20.6	86.9	80.4	72.2	–0.72	–0.72
India	70.6	72.5	70.6	142.4	162.5	176.5	0.38	–0.38
Middle America and Caribbean	28.1	25.3	25.5	13.1	10.0	11.3	–0.56	0.04
South America	24.8	22.2	23.3	16.9	17.0	19.7	–0.52	0.22
Eastern Europe and Central Asia	—	26.5	31.0	—	9.3	12.1	—	0.90
Total	41.7	40.7	39.9	404.6	447.8	484.2	–0.20	–0.16

pp, Percentage points.

surveys. The other cells with reasonable sample sizes, for pregnant women in Southeast Asia and for Middle America and the Caribbean, indicate improvement.

The uncertainty of the averaging process and the still-limited number of surveys mean that the predicted regional prevalences by reference year have a useful role in sorting out the probable trends, both to confirm the emerging pattern and to fill gaps where numbers of results are limited, as discussed next.

Results from analysis by country-year and summary of trends

The estimates by country for 1990, 1995, and 2000 based on the correlations shown in the Methods section are laid out in Annex 1, **tables A1.3–5**. The population-weighted aggregations of these are given in **tables 12–14** and shown in **figs. 5–7**.

Sub-Saharan Africa may be showing an increase in the prevalence of anemia in women. This emerges in the estimates for both nonpregnant and pregnant women, which increase by 2 to 3 percentage points during the 1990s (**tables 12–14**), and is in line with the impression from the limited number of repeated surveys (**tables 8 and 9**). In contrast, anemia in South Asia (without India) appears to be decreasing among women, but little change is apparent for India. Trends in Southeast Asia for the early 1990s show possible improvement (in line with repeated surveys), but not in the latter 1990s (for which there are fewer survey results). (National data on anemia for China are rare,

TABLE 13. Trends in prevalence of anemia (hemoglobin < 11 g/dL) and numbers affected among pregnant women, according to region, 1990–2000

	% of women anemic			No. of women anemic (millions)			Trend (pp/yr)	
Region	1990	1995	2000	1990	1995	2000	1990–95	1995–2000
Sub-Saharan Africa	47.9	48.2	48.2	6.2	6.9	7.6	0.06	0.0
Middle East and North Africa	35.6	39.6	35.1	2.0	2.6	2.6	0.80	–0.72
South Asia (without India)	50.5	49.2	48.7	3.6	3.8	4.0	–0.26	–0.10
Southeast Asia	44.4	41.5	43.2	4.8	4.9	5.4	–0.58	0.34
China	31.3	27.8	27.3	8.7	8.1	8.4	–0.70	–0.10
India	73.3	73.5	71.7	15.1	16.5	17.4	0.04	–0.36
Middle America and Caribbean	35.6	35.0	36.4	1.2	1.3	1.5	–0.12	0.28
South America	37.1	41.2	43.6	2.2	2.8	3.2	0.82	0.48
Eastern Europe and Central Asia	—	32.2	30.5	—	1.1	1.1	—	–0.34
Total	43.7	45.3	45.1	41.8	48	51.2	0.32	–0.04

pp, Percentage points.

TABLE 14. Trends in prevalence of anemia (hemoglobin < 11 g/dL) and numbers affected among children under five years of age, according to region, 1990–2000

	% of children anemic			No. of children anemic (millions)			Trend (pp/yr)	
Region	1990	1995	2000	1990	1995	2000	1990–95	1995–2000
Sub-Saharan Africa	72.1	72.5	70.5	71.8	78.1	78.1	.08	–.40
Middle East and North Africa	40.3	41.2	37.2	15.1	16.9	14.3	.18	–.80
South Asia (without India)	62.9	60.3	57.4	31.5	30.6	28.8	–.52	–.58
Southeast Asia	41.4	35.7	36.0	24.1	21.3	20.6	–1.14	.06
China	20.8	12.5	8.4	24.8	12.9	8.1	–1.66	–.82
India	79.7	78.8	74.6	92.0	94.1	90.2	–.18	–.84
Middle America and Caribbean	28.9	27.0	22.6	5.7	5.5	4.4	–.38	–.88
South America	51.7	47.2	48.4	17.6	15.3	14.8	–.90	.24
Eastern Europe and Central Asia	—	27.8	28.2	—	4.6	3.9	—	.08
Total	53.0	50.7	48.9	282.6	279.3	263.2	–0.46	–0.36

pp, Percentage points.

but generally improvement is considered likely.)

Latin America and the Caribbean have a higher prevalence of anemia than of other deficiencies, with no clear trend of improvement. The conclusions are similar for Eastern Europe and Central Asia.

The story about anemia in preschool children is more recent, with fewer datapoints available. The high levels are striking, 60% or more in South Asia and India (**tables 11 and 14**), and they are probably not decreasing much.

The global averages, while obscuring regional differences, do highlight the impression that there is little if any overall improvement in anemia. The global rates for 1995–2000 of –0.16 percentage points/year for nonpregnant women and –0.04 percentage points/year for pregnant women translate to roughly 0.5 to 1.5 percentage points change per 10 years, which if continued to 2010 would bring the average for 2000 of 40% (nonpregnant women) to only 38.5%. At this rate, the prevalence by 2100 would still be 25%. For pregnant women, these calculations are for a prevalence of 45% in 2000 decreasing to 44.5% in 2010 and to 40% in 2100. Clearly, new and more effective interventions to address anemia, especially in pregnant women, are needed; waiting for change from underlying factors is scarcely an option.

Preschool children are estimated to have the highest prevalences of anemia, nearly 50% across developing

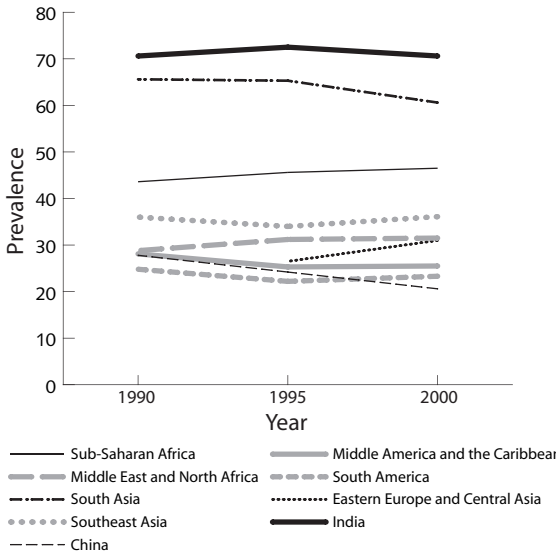


FIG. 5. Trends in the prevalence of anemia in nonpregnant women of reproductive age, 1990–2000

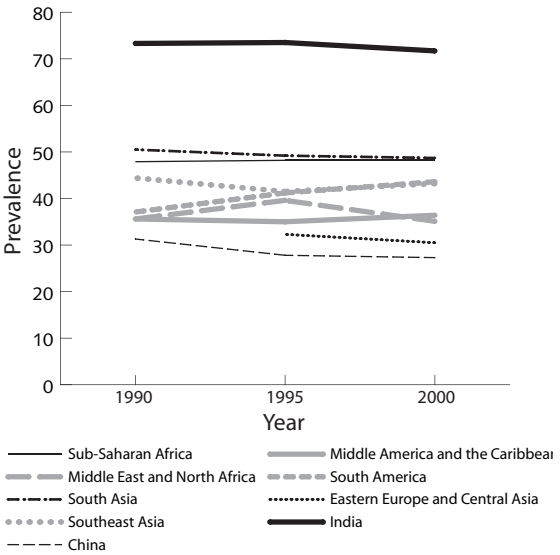


FIG. 6. Trends in the prevalence of anemia among pregnant women, 1990–2000

countries, as much as or more than pregnant women (to whom the prevalences are presumably linked as babies are born with low iron stores). This is a less-recognized problem, both as an aspect of malnutrition in children (other deficiencies get more attention) and as a condition affecting a group highly vulnerable to iron deficiency and (by implication) anemia. The latter has additional consequences beyond anemia on cognitive development and behavior in young children. Anemia in children needs urgent attention.

Iodine-deficiency disorders

Repeated national surveys

Forty-four countries have repeated survey results, all but one of which (for Cambodia) were conducted over periods in which salt iodization coverage increased to more than 25%. The results are given in **table 15.** In 37 of the 44 cases, iodine-deficiency disorders were clearly decreasing, in many instances dramatically. Examples are plotted in **fig. 8a–c**, from Nicaragua, Tanzania, and Vietnam; these all illustrate well the crossover effect of increasing salt iodization coverage with decreasing iodine-deficiency disorders, as measured by TGR.

These results show clearly the overall pattern of substantial decrease in iodine-deficiency disorders with salt iodization. The response seems fairly immediate, with not much lag: goiter falls in line with iodization. This is seen by inspection of **table 15**. At the same time, the results support the expectation that iodized salt coverage of nearly 100% is needed. Those countries reaching coverage of 90% or so generally have goiter prevalences of less than 10%; those with only 50% or 60% coverage have considerably higher prevalences and have some way yet to go. In the few cases where TGR is not falling

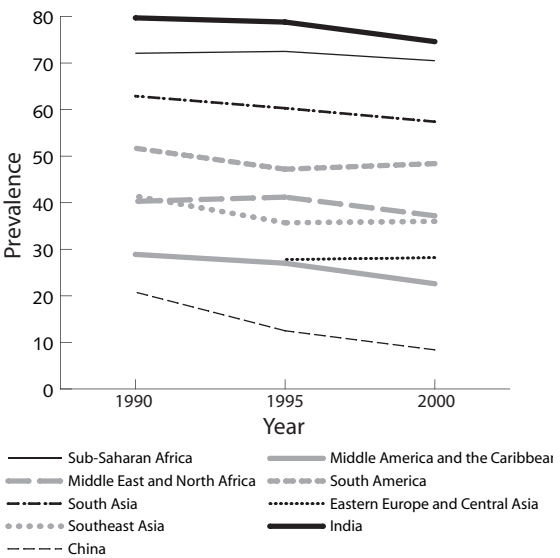


FIG. 7. Trends in the prevalence of anemia in children under five years of age, 1990–2000

as expected (Sri Lanka is an example, where salt quality control has been an issue, and Nepal is probably similar) the reasons may need further investigation.

Unadjusted averages by region and time period

Averaging the goiter prevalences by region for the two periods before and after 1990 is unsatisfactory but is included anyway as a point of departure in assessing recent trends. The results from 158 surveys are shown in **table 16**. The levels are higher than previously shown (e.g., Mason et al. [1], p. 34; [18, 19]), largely because these results are not population weighted (and larger

TABLE 15. National prevalences (%) of iodine-deficiency disorders as goiter (TGR) with % of households with adequately iodized salt (>15ppm; column heading HHIOD): results from repeated surveys

Region	Country	Year	TGR	HHIOD	Change in IDD prevalence
Southeast Asia and Pacific	Bhutan	1982	65.4	0	
		1992	25.0	96	Improving, with iodized salt
	Cambodia	1994	62.0	1	
		1997	17.0	1	Improving
	China	1995	20.4	50	
		1997	10.8	83	
		1999	8.0	91	Improving, with iodized salt
	Indonesia	1980	32.0	1	
		1988	27.7	40	
		1996	9.8	65	Improving, with iodized salt
	Laos	1988	25.0	1	
		2000	9.0	76	Improving, with iodized salt
	Mongolia	1993	28.0	1	
		1999	21.4	68	Improving, with iodized salt
	Myanmar	1992	25.1	1	
		1997	25.1	50	
		1999	12.2	80	Improving, with iodized salt
	Nepal	1960	55.0	1	
		1979	57.6	37	
		1986	44.2	41	
		1998	40.0	55	Improving somewhat, with iodized salt
	Philippines	1987	14.7	1	
		1993	6.7	40	Improving, with iodized salt
	Sri Lanka	1988	16.6	1	
		2000	21.0	87	Not improving
	Thailand	1986	17.0	1	
		1991	16.3	25	
		1993	11.0	45	
		1996	5.9	75	
		1999	2.7	75	Improving, with iodized salt
	Vietnam	1993	34.9	1	
		1995	27.1	42	
		1998	14.9	89	
		2000	10.1	78	Improving, with iodized salt
South America	Argentina	1967	49.8	1	
		1989	8.3	25	Improving, with iodized salt
	Bolivia	1979	77.0	1	
		1981	60.8	29	
		1989	20.9	38	
		1994	4.5	92	Improving, with iodized salt
	Brazil	1966	27.2	1	
		1975	14.7	25	
		2000	1.4	87	Improving, with iodized salt
	Chile	1972	24.8	1	
		1982	9.0	52	
		1991	11.4	90	Improving, with iodized salt
	Colombia	1945	52.6	1	
		1950	33.9	25	
		1994	6.5	90	Improving, with iodized salt
	Paraguay	1983	33.4	1	

continued

TABLE 15. National prevalences (%) of iodine-deficiency disorders as goiter (TGR) with % of households with adequately iodized salt (>15ppm; column heading HHIOD): results from repeated surveys *(continued)*

Region	Country	Year	TGR	HHIOD	Change in IDD prevalence
		1994	40.0	64	Not improving
	Peru	1977	28.9	1	
		1996	10.8	93	
		1998	1.0	93	Improving, with iodized salt
	Venezuela	1981	17.2	1	
		1990	10.7	50	
		1996	14.0	65	
		2000	2.2	90	Improving, with iodized salt
Middle America and Caribbean	Costa Rica	1966	18.0	1	
		1979	5.3	39	
		1990	3.0	90	Improving, with iodized salt
	El Salvador	1966	48.0	1	
		1990	24.6	65	Improving, with iodized salt
	Guatemala	1983	15.5	15	
		1995	20.4	38	Not improving
	Honduras	1969	17.0	1	
		1987	8.8	50	
		1996	4.9	86	
		1999	3.5	80	Improving, with iodized salt
	Mexico	1945	28.8	1	
		1996	3.0	99	Improving, with iodized salt
	Nicaragua	1971	32.5	1	
		1981	20.0	35	
		1990	4.3	66	
		2000	2.5	86	Improving, with iodized salt
	Panama	1967	16.5	1	
		1975	6.0	40	
		1991	13.2	92	
		1999	10.2	95	Improving, with iodized salt
Middle East and North Africa	Algeria	1987	8.5	90	
		1993	8.0	90	Low anyway
	Jordan	1993	37.7	1	
		2000	32.1	86	Unclear
	Yemen	1991	32.0	1	
		1998	16.8	25	Improving, with iodized salt
Sub-Saharan Africa	Benin	1983	23.7	1	
		1994	19.1	35	
		2000	1.1	98	Improving, with iodized salt
	Cameroon	1984	70.0	1	
		1991	26.3	86	Improving, with iodized salt
	Eritrea	1994	22.0	80	
		1998	36.6	97	Not improving
	Gabon	1989	34.4	1	
		2001	17.1	36	Improving, with iodized salt
	Kenya	1984	20.0	50	
		1994	16.3	89	Improving, with iodized salt
	Madagascar	1990	24.1	1	
		2001	3.5	76	Improving, with iodized salt
	Malawi	1989	12.7	1	
		1996	27.0	58	Not improving

continued

TABLE 15. National prevalences (%) of iodine-deficiency disorders as goiter (TGR) with % of households with adequately iodized salt (>15ppm; column heading HHIOD): results from repeated surveys *(continued)*

Region	Country	Year	TGR	HHIOD	Change in IDD prevalence
	Mozambique	1992	76.0	1	
		1998	19.2	62	Improving, with iodized salt
	Niger	1994	35.8	1	
		1998	20.4	64	Improving, with iodized salt
	Rwanda	1990	49.6	1	
		1997	25.9	95	Improving, with iodized salt
	Tanzania	1983	42.5	1	
		1999	23.0	74	
		2001	17.0	83	Improving, with iodized salt
	Togo	1986	22.1	1	
		2001	7.2	98	Improving, with iodized salt
	Zambia	1971	50.5	1	
		1993	32.0	94	Improving, with iodized salt
	Zimbabwe	1989	42.3	1	
		1999	14.8	93	Improving, with iodized salt

IDD, Iodine-deficiency disorder; TGR, total goiter rate; HHIOD, households using iodized salt.

TABLE 16. Mean prevalences (%) of goiter (total goiter rate, TGR) according to region and survey year, calculated by averaging national survey results[a]

	Survey year	
Region	1990 or before	After 1990
Middle East and North Africa	21.5 (3)	26.8 (12)
Sub-Saharan Africa	29.0 (20)	26.1 (34)
Asia	32.6 (12)	20.4 (25)
Middle America and Caribbean	23.9 (32)	9.0 (19)
Central Europe	15.0 (1)	—
Total	26.7 (68)	21.0 (90)

a. Average survey years are 1981 and 1996. The number of surveys is given in parentheses.

countries, notably China and India, happen to report lower prevalences), and also because of new data. The trend here is potentially more important than the levels, which are suggested to be improving overall and in all regions (except for the Middle East and North Africa, which, however, have few cases). This implication is in line with the repeated national data. The implied overall rate, from 26.7% in the first period (the average year being 1981) to 21.0% for the average year 1996, is a reduction of 5.7 percentage points, or 0.4 percentage points/year. As will be seen later, this is similar to the predicted rate of change (from all-country-region estimates) of 0.5 percentage points/year from 1994 to 2000.

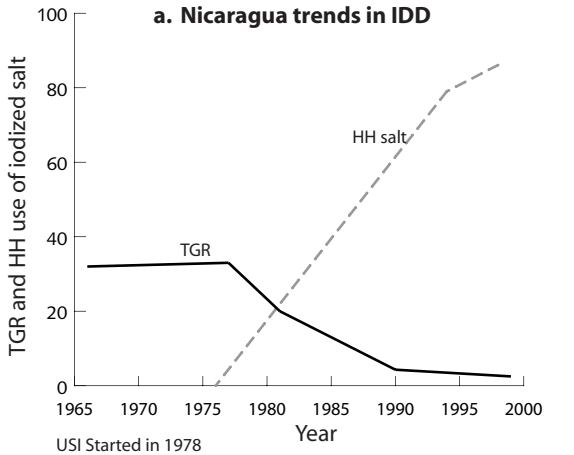
Estimates by region and time period in relation to pre-iodization (endemic) goiter prevalence and coverage of iodized salt

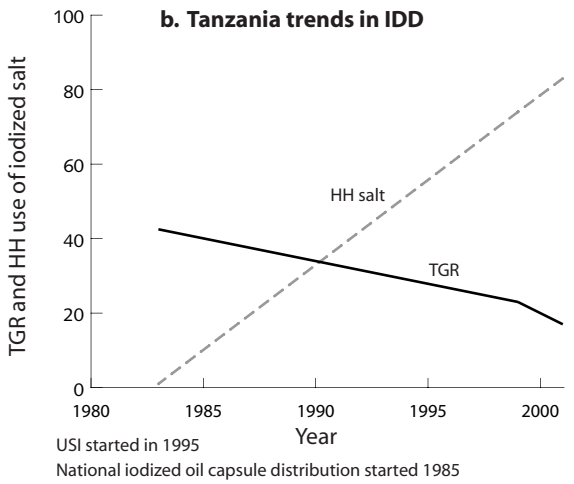
Inspection of repeated survey results (**table 15** and **fig. 8a–c**) supported the expectation that more rapid changes in TGR with iodization were to be seen in those countries starting with higher TGRs. Therefore, countries were put into three categories of pre-iodization (or endemic) goiter rates, as described in the Methods section. The average TGR was then calculated from the extent of salt iodization coverage. The results for all years are shown in the first five results columns of **table 17** and plotted in **fig. 9**, and these are discussed first.

The relation with iodized salt coverage is clear: for countries with high endemic goiter prevalences, TGR is halved when iodized salt coverage reaches 50%, but there is probably not much effect at coverages of 25% to 50%. The relation appears more linear, but with a smaller slope, for the intermediate endemic goiter group (prevalences of 20%–40% pre-iodization). As noted in **fig. 10**, the relations between TGR and iodized salt coverage are highly significant for the three endemic goiter groups separately and are different from each other, with a greater effect of iodized salt in the groups with higher endemic goiter rates. The coefficients imply the size of the effect of increasing iodized salt coverage; for example, the coefficient of –0.393 for the group with the highest endemic goiter rate implies that a 10% increase in iodized salt coverage is linked to a decrease of nearly 4% in goiter (although, being somewhat nonlinear, this effect is greater on average nearer to 50% coverage).

The relation of iodized salt coverage to TGR can be seen also as the scatterplot, distinguishing pre-iodization TGR (PTGR) groups, as shown in **fig. 10**.

This approach can also help to clarify trends through time, although the results discussed above do imply a time dimension in that salt iodization tends to increase with time. Results according to time period are given





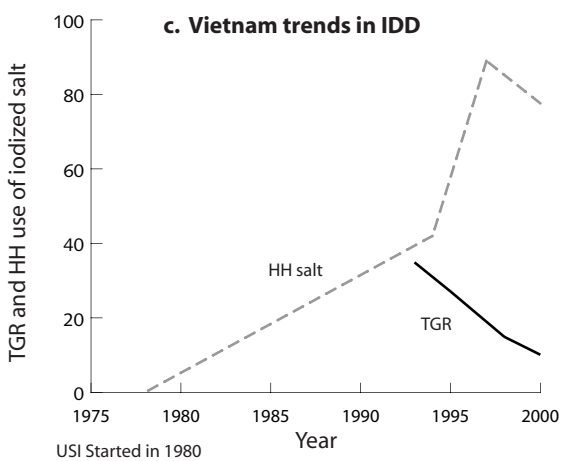


FIG. 8a–c. Examples of improvement in iodine-deficiency disorders (IDD) with increasing coverage of iodized salt. TGR, total goiter rate; HH, household; USI, universal salt iodization

TABLE 17. Prevalence of goiter (total goiter rate, TGR) according to endemic TGR category, salt iodization coverage, and period

Endemic (pre-iodization) TGR	Coverage of iodized salt (% of households)									
	Before and after 1990				1990 or before		After 1990			
	Before iodization, or < 25%	25%–50%	> 50% (earlier[a])	> 50% (later[a])	All cases	Before iodization, or < 25%	All cases	Before iodization, or < 25%	25%–50%	> 50% (earlier[a])	> 50% (later[a])	All cases
< 20%	14.1 (24)	8.0 (10)	10.2 (12)	5.4 (5)	11.1 (52)	14.6 (17)	12.0 (25)	12.9 (7)	9.9 (4)	11.1 (10)	5.4 (5)	10.3 (27)
20%–40%	28.9 (28)	20.8 (11)	12.7 (20)	11.6 (6)	20.9 (65)	28.1 (19)	25.2 (25)	30.5 (9)	20.9 (7)	13.4 (18)	11.6 (6)	18.3 (40)
> 40%	53.6 (21)	53.8 (4)	23.5 (12)	(17.0) (1)	42.6 (40)	53.8 (12)	49.3 (18)	53.4 (9)	(63.0) (1)	23.4 (11)	(17.0) (1)	37.2 (22)
All	31.1 (73)	20.9 (25)	15.0 (44)	9.5 (12)	23.2 (157)	29.7 (48)	26.7 (68)	33.8 (25)	20.7 (12)	15.6 (39)	9.5 (12)	20.6 (89)

a. Note: earlier refers to first measure of iodized salt coverage above 50% (usually within 5–10 years of iodization starting); later refers to the second or more of at least two measures of iodized salt coverage above 50%, usually 5–10 years after the first measurement

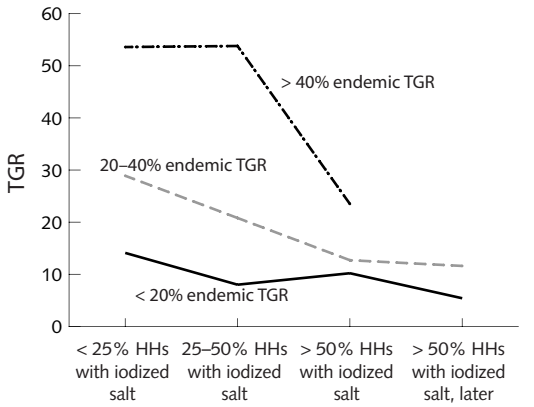


FIG. 9. Goiter prevalences by level of salt iodization coverage, stratified by endemic (preiodization) goiter prevalence. TGR, total goiter rate; HH, household

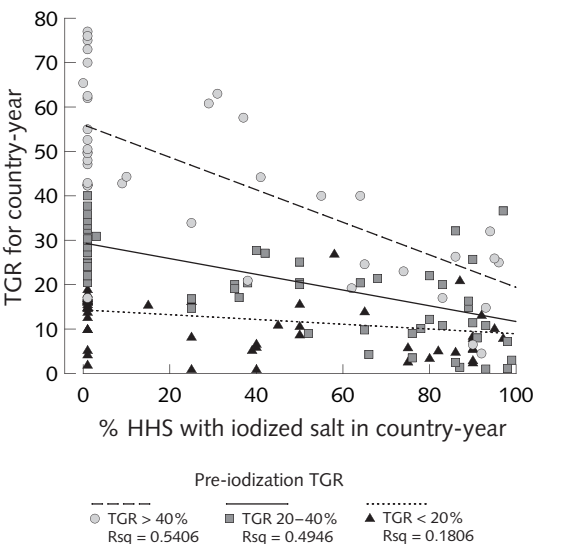


FIG. 10. Scatterplot of TGR against iodized salt coverage, by pre-iodization TGR group. TGR, total goiter rate

Note: Slopes are significantly different from each other. For regression with TGR as dependent variable, preiodization TGR group (PTGR) as categorical variable (value = 1, 2, or 3), with iodized salt coverage as continuous variable (*hhiod*, %), and interaction (PTGR group * salt coverage %), interaction has $t = -6.303$, $p = .000$.

All three slopes are also significantly less than 0, as follows: for preiodization TGR group, < 20%; *hhiod* has coefficient –0.069, $n = 52$, $t = -3.319$, $p = .002$; for 20%–40%, *hhiod* has coefficient –0.189, $n = 65$, $t = -7.852$, $p = .000$; for > 40%, *hhiod* has coefficient –0.393, $n = 40$, $t = -6.774$, $p = .000$

in the results columns 6 to 12 in **table 17**. The "All groups, all cases" TGRs of 26.7% ($n = 68$) for 1990 or earlier and of 20.6% ($n = 89$) for the years after 1990 are equivalent to the "Totals" row in **table 16.** (One case could not be classified for endemic TGR, hence the *n* of 89 not 90.) Before 1990 there are insufficient cases with iodized salt coverage to examine the effect within endemic goiter groups (20 across the three groups, i.e., 68–48). However, the iodized salt coverage groups "Before, or < 25%" can be compared between the periods (results columns 6 and 8); these are similar, 29.7% ($n = 48$) and 33.8% ($n = 25$), in line with the expectation of little change through time without iodized salt; the prevalences within endemic goiter groups for these columns are also similar. Comparing "Before, or < 25%" in the period after 1990, generally very similar slopes to those in **fig. 9** are seen: the effect is of iodization, not of some other secular trend.

Overall, these results provide good evidence for the extensive impact of iodized salt.

TABLE 18. Estimated total goiter rate and percentage of households using iodized salt by region and period (1992–96, 1997–2002)

Region	Predicted endemic TGR	1994 (1992–1996)		2000 (1997–2002)		Change in pp/year
		Average HH salt iodization	Average TGR (%)	Average HH salt iodization	Average TGR (%)	
Sub-Saharan Africa	34.8	43.1	21.6	59.4	17.3	–0.72
S Asia (except India)	44.8	30.2	28.9	45.3	24.7	–0.70
India	25.3	67.0	14.2	49.0	17.1	1.18
Middle East/North Africa	35.3	75.6	12.0	75.5	14.0	0.33
S E Asia (except China)	18.8	42.9	15.0	52.2	13.8	–0.20
China	35.5	51.0	20.0	91.0	10.0	–1.67
Middle America/Caribbean	23.2	75.5	10.8	72.9	10.9	0.02
South America	40.5	82.3	12.8	93.0	9.2	–0.60
Central Asia	25.7	17.1	16.2	24.0	16.6	0.07
All developing regions			17.6		14.4	–0.53

TGR, Total goiter rate; HH, household; pp, percentage points.

Results from analyses by country-year for reference years (1994 and 2000)

However, to obtain more self-consistent and reliable results by country and region, estimates were made for every country based first on predicted pre-iodization TGR for each country, and then on predicting national levels from associations with iodized salt coverage (see Methods section under Analysis (3)).

The population-weighted results by regional group standardized to 1994 and 2000 are shown in **table 18**. Differences from the crude averages in **table 16** are due to several factors, including the population weighting; the adjusted estimates are considered more reliable in terms of both prevalence levels and trends. Moreover, these can apply to smaller country groups, as sample size is no longer the issue.

Prevalences in the Americas (including Caribbean) are estimated as around 10% for 2000. Taking into account also the data in **tables 14 and 15**, this almost certainly reflects a major achievement of salt iodization in the last three decades, most of the improvement having been achieved by 1994 (which is why the trend is not improving much further, as seen in **table 18**).

Many countries in Sub-Saharan Africa have improved iodized salt coverage recently—from an average of 43% in 1994 to 59% in 2000—which accounts for the estimated improvement of 4.3 percentage points over this time. However, the Middle East and North Africa group may be more static, at around 14% TGR and 75% iodized salt coverage.

The trends for China and India must be interpreted with particular caution. The predicted TGRs for these countries are very dependent on the reported values of iodization and are not smoothed by averaging with other countries, as is the case with the other regions. Additionally, the model is based almost entirely on data showing that salt iodization increases over time; however, India has a marked *decrease* in reported salt iodization (67% to 49%). As discussed in the Methods section, the estimates here of post-iodization TGR for India of 14% in 1994 and 17% in 2000 are considered reasonable in view of the currently available data on both iodization and TGR. China is well known to have achieved high coverage of iodized salt in the 1990s, as shown in **tables 15 and 18**, and the reduction to 10% TGR or less is plausible.

Other country groups in South and Southeast Asia show a decrease in TGR in line with increasing iodized salt coverage, although the average coverage is still around 50%. Middle America and the Caribbean and Central Asia show only very small increases.

The rates of improvement are generally consistent with those seen in individual countries with salt iodization programs, as seen in **table 15**, allowing for regional averaging including faster and more slowly improving trends. The rates in individual countries (e.g., in **fig. 9**) are around 2.0 percentage points/year, with faster improvement in countries with higher endemic goiter rates once iodization starts. The global average rate of 0.5 percentage points/year (**table 18**), if sustained, would reach 5% TGR globally in 20 years (by 2020 in this estimate). This may be longer than anticipated in global goals, and while being an encouraging achievement could argue for renewed efforts.

Another way of estimating the improvement due to iodizing salt is to compare the 2000 TGR value here of 14.4% with what the prevalence would have been without any salt iodization. The prevalence of TGR in the developing world in 2000 *without iodized salt* can be estimated as equivalent to applying the weighted average pre-iodization endemic TGR to the 2000 population. The average endemic TGR is approximately

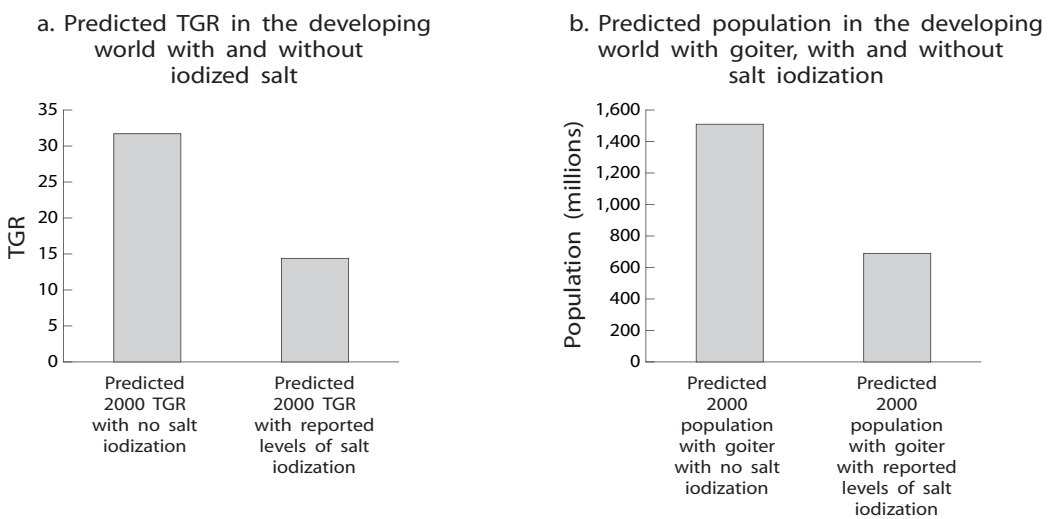


FIG. 11. Estimated impact of iodized salt: predicted goiter prevalences (**a**) and numbers affected (**b**) for 2000 if there were no iodized salt compared with actual prevalences. TGR, total goiter rate

31.7%, which gives around 1,510 million people, or 1.5 billion, predicted to have goiter without any iodized salt. With the current reported levels of iodized salt consumption, however, the TGR for 2000 is predicted to be 14.4%, equivalent to 690 million people affected. In other words, salt iodization is estimated to have halved the prevalence of goiter, or iodine-deficiency disorders, from what it otherwise would be. In population numbers, as of 2000 iodized salt has decreased the number of people in the developing world suffering from goiter from around 1.5 billion to around 700 million: iodized salt in 2000 prevented around 800 million people from developing goiter. These results are illustrated in **fig. 11**.

The estimates for each country are shown in Annex 1, **table A1.6A and B**, and Annex 2.

Underweight

Repeated national surveys

Repeated survey data considered to be comparable through time were available for 82 countries, as given in **table 19.** These results are summarized in **table 20**: overall, nearly half the countries showed improvement in the most recent survey pairs (45%). The apparently lower improvement in Southeast Asia reflects vagaries of the sample, but indicates that although there is overall improvement, some countries (Cambodia, Mongolia, and the Philippines) have shown increased prevalences of underweight. The results from Sub-Saharan Africa show that some countries do improve, despite the static or deteriorating average trend, but some of these (e.g., Malawi and Mozambique) may be because the earlier measurement was conducted in a drought period and does not represent a long-term improvement. In general, the trends from repeated survey results are in line with those from calculations discussed below.

Unadjusted averages by region and time period

The prevalence data from the 318 surveys included in the database are averaged (unweighted) by region and time period in **table 21**. Although these remain vulnerable to different countries appearing in different periods by chance, there is now a substantial amount of data, and this issue is less worrisome. Comparing these apparent trends with the repeated surveys (above) and the results from the interpolation model should (and do) give a consistent picture, as discussed next.

Results from analysis by country-year and summary of trends

The estimates by region for 1990, 1995, and 2000 are shown in **table 22** and **fig. 12**. These are from national estimates, weighted by population, and provide the most reliable picture of recent trends.

Sub-Saharan Africa, as a region, was essentially static on average from 1990 to 2000, perhaps improving slightly in the earlier 1990s; this is seen in **tables 21 and 22**. The overall numbers of underweight children for both of these time periods increased. This regional trend can be compared with the trends of each country. These results from the countries that had two or more surveys, from which a trend can be calculated, are found in **table 19**. When looking at the country trends for Sub-Saharan Africa, it is fairly evident that for most countries, the trend in underweight children has shifted from an improving trend to a deteriorating or static trend. There were 18 countries that had surveys done in either 1999 or 2000. Of these, 5 had improving trends, whereas 13 had worsening or static trends. It is important to note that this deteriorating trend also coincides with increased food insecurity in southern Africa and increasing numbers of people affected by HIV/AIDS.

South Asia showed a substantial rate of improvement over the 1990s, with a –0.7 percentage points/year rate of change on average. The repeated national surveys for this region (see **table 19**) exhibit the pattern. Bangladesh, India, Pakistan, and Sri Lanka all had improving trends from their most recent pairs of surveys. The only country in this region that did not have an improving trend was Nepal.

Southeast Asia had an overall improving trend from 1990 to 2000 as well, seen in the averaged and weighted results in **table 22**. This reflects decreased prevalences in Indonesia, Thailand, and Vietnam, as examples. Not all countries improved, however: Cambodia, Mongolia, and the Philippines had deteriorating trends, with Laos and Malaysia being static.

Middle America and the Caribbean had a slight improving trend from 1990 to 2000. This is also seen from the repeated surveys. Six countries had surveys done in 1998–2000. Two of these, the Dominican Republic and Nicaragua, had static trends, while Guatemala, Haiti, Jamaica, and Mexico had improving trends. South America showed an improving trend from 1990 to 2000, slowing down after 1995. The repeat surveys for this region exhibit the slowing down of the trend. Of seven countries that had surveys done in 1998–2000, six were static, with only one having an improving trend.

Central Europe and the Newly Independent States had only two countries with repeated national surveys. Azerbaijan had a deteriorating trend, whereas Kazakhstan had an improving trend. The Middle East and North Africa had a fairly flat trend, but improved slightly. Egypt had an improving rate of 2.6 percentage points/year from 1997 to 2000. Yemen deteriorated by 3.2 percentage points/year from 1992 to 1997.

Discussion and Conclusions

The interpretation and use of data on malnutrition

TABLE 19. Prevalences of underweight (<–2 SD NCHS/WHO) among children under five years of age: results from repeated national surveys, 1975–2001

Region	Country	Year	Prevalence (%)	Trend	Rate (pp/yr)
Middle East and North Africa	Algeria	1987	8.60		
		1990	9.20	No change	0.20
		1992	9.20	No change	0.00
		1995	12.80	Deterioration	1.20
		2000	6.00	Improvement	–1.36
	Egypt	1978	16.60		
		1988	13.30	Improvement	–0.33
		1990	10.40	Improvement	–1.45
		1992	9.90	No change	–0.25
		1997	11.70	No change	0.36
		2000	4.00	Improvement	–2.57
	Iran	1994	15.70		
		1998	10.90	Improvement	–1.20
	Jordan	1975	17.40		
		1990	6.40	Improvement	–0.73
		1991	9.70	Deterioration	3.30
		1997	5.10	Improvement	–0.77
	Morocco	1987	14.80		
		1992	9.50	Improvement	–1.06
	Syria	1993	12.00		
		1995	12.90	No change	0.45
	Tunisia	1975	20.20		
		1988	10.30	Improvement	–0.76
		1994	8.70	No change	–0.27
		2000	4.00	Improvement	–0.78
	Turkey	1993	10.40		
		1998	8.30	Improvement	–0.42
	Yemen	1992	30.00		
		1997	46.10	Deterioration	3.22
Middle America and Caribbean	Costa Rica	1978	16.00		
		1982	6.00	Improvement	–2.50
		1992	2.30	Improvement	–0.37
		1996	5.10	Deterioration	0.70
	Dominican Republic	1986	12.50		
		1991	10.40	Improvement	–0.42
		1996	5.90	Improvement	–0.90
		2000	4.60	No change	–0.33
	El Salvador	1975	21.60		
		1988	15.50	Improvement	–0.47
		1993	11.20	Improvement	–0.86
	Guatemala	1980	43.60		
		1987	33.20	Improvement	–1.49
		1995	26.60	Improvement	–0.83
		1998	24.20	Improvement	–0.80
	Haiti	1978	37.40		
		1990	35.20	Improvement	–0.18
		1994	27.50	Improvement	–1.93
		2000	17.00	Improvement	–1.75

continued

TABLE 19. Prevalences of underweight (<–2 SD NCHS/WHO) among children under five years of age: results from repeated national surveys, 1975–2001 *(continued)*

Region	Country	Year	Prevalence (%)	Trend	Rate (pp/yr)
	Honduras	1987	20.60		
		1992	19.30	No change	–0.26
		1996	25.40	Deterioration	1.53
	Jamaica	1978	15.00		
		1985	14.90	No change	–0.01
		1989	7.20	Improvement	–1.93
		1993	10.20	Deterioration	0.75
		1999	3.90	Improvement	–1.05
	Mexico	1988	14.20		
		1998	7.50	Improvement	–0.67
	Nicaragua	1982	10.50		
		1993	11.90	No change	0.13
		1998	12.20	No change	0.06
	Panama	1980	16.00		
		1992	6.10	Improvement	–0.83
		1997	6.80	No change	0.14
	Trinidad and Tobago	1976	16.30		
		1987	6.70	Improvement	–0.87
Southeast Asia	Cambodia	1994	39.80		
		2000	45.00	Deterioration	0.87
	Indonesia	1978	43.60		
		1987	41.40	Improvement	–0.24
		1989	38.70	Improvement	–1.35
		1995	34.00	Improvement	–0.78
		1999	26.40	Improvement	–1.90
	Laos	1984	36.50		
		1994	40.00	Deterioration	0.35
		2000	40.00	No change	0.00
	Malaysia	1983	28.20		
		1986	23.30	Improvement	–1.63
		1993	23.30	No change	0.00
		1995	20.10	Improvement	–1.60
		1999	18.30	No change	–0.45
	Mongolia	1992	12.30		
		1994	10.20	Improvement	–1.05
		2000	12.70	Deterioration	0.42
	Myanmar	1984	44.10		
		1990	38.40	Improvement	–0.95
		1991	36.70	No change	–1.70
		1994	42.90	Deterioration	2.07
		2000	36.00	Improvement	–1.15
	Papua New Guinea	1983	29.90		
		1984	34.70	Deterioration	4.80
	Philippines	1978	33.30		
		1982	33.20	No change	–0.02
		1987	32.90	No change	–0.06
		1990	33.50	No change	0.20
		1992	33.00	No change	–0.25
		1993	29.60	Improvement	–3.40
		1996	28.20	No change	–0.47
		1998	32.00	Deterioration	1.90

continued

TABLE 19. Prevalences of underweight (<–2 SD NCHS/WHO) among children under five years of age: results from repeated national surveys, 1975–2001 *(continued)*

Region	Country	Year	Prevalence (%)	Trend	Rate (pp/yr)
	Thailand	1982	36.00		
		1987	25.40	Improvement	–2.12
		1990	13.00	Improvement	–4.13
		1993	18.60	No change	1.87
	Vietnam	1986	51.50		
		1990	41.90	Improvement	–2.40
		1994	44.90	Deterioration	0.75
		1998	39.80	Improvement	–1.28
		2000	33.10	Improvement	–3.35
South America	Bolivia	1981	14.50		
		1989	13.20	No change	–0.16
		1994	11.50	No change	–0.34
		1998	7.60	Improvement	–0.98
	Brazil	1975	18.40		
		1986	12.40	Improvement	–0.55
		1989	7.10	Improvement	–1.77
		1996	5.70	No change	–0.20
	Chile	1978	2.10		
		1982	1.10	No change	–0.25
		1986	2.50	No change	0.35
		1994	0.90	No change	–0.20
		1998	0.80	No change	–0.03
	Colombia	1980	16.70		
		1986	12.00	Improvement	–0.78
		1989	10.10	No change	–0.63
		1995	8.40	No change	–0.28
		2000	6.70	No change	–0.34
	Ecuador	1987	16.50		
		1999	14.80	No change	–0.14
	Guyana	1981	22.10		
		1991	26.60	Deterioration	0.45
		1993	18.30	Improvement	–4.15
		1997	11.80	Improvement	–1.63
	Paraguay	1990	3.70		
		1998	5.00	No change	0.16
	Peru	1975	16.10		
		1984	13.40	Improvement	–0.30
		1992	10.80	Improvement	–0.33
		1996	7.80	Improvement	–0.75
		2000	7.10	No change	–0.18
	Uruguay	1987	7.40		
		1992	4.40	Improvement	–0.60
		1994	4.50	No change	0.05
	Venezuela	1982	10.20		
		1987	5.90	Improvement	–0.86
		1997	5.10	No change	–0.08
		1999	4.70	No change	–0.20
Sub-Saharan Africa	Botswana	1984	27.00		
		2000	12.50	Improvement	–0.91

continued

TABLE 19. Prevalences of underweight (<–2 SD NCHS/WHO) among children under five years of age: results from repeated national surveys, 1975–2001 *(continued)*

Region	Country	Year	Prevalence (%)	Trend	Rate (pp/yr)
	Burkina Faso	1992	32.70		
		1993	29.50	Improvement	–3.20
		1998	34.30	Deterioration	0.96
	Burundi	1987	37.70		
		2000	45.10	Deterioration	0.57
	Cameroon	1978	17.30		
		1991	15.10	Improvement	–0.17
		1998	17.10	Deterioration	0.29
	Central African Republic	1993	21.00		
		2000	24.30	No change	0.47
	Chad	1996	38.80		
		2000	27.60	Improvement	–2.80
	Congo	1987	23.50		
		1998	13.90	Improvement	–0.87
	Congo, Democratic Republic of	1975	28.80		
		1995	34.40	Deterioration	0.28
	Côte d'Ivoire	1986	12.40		
		1994	18.30	Deterioration	0.74
		1998	21.20	Deterioration	0.73
	Djibouti	1989	22.90		
		1996	18.20	Improvement	–0.67
	Ethiopia	1983	37.30		
		1992	46.90	Deterioration	1.07
		2000	47.10	No change	0.03
	Ghana	1988	30.30		
		1993	21.00	Improvement	–1.86
		1998	24.90	Deterioration	0.78
	Guinea	1980	23.40		
		1999	23.20	No change	–0.01
	Kenya	1982	22.00		
		1987	18.00	Improvement	–0.80
		1993	22.30	Deterioration	0.72
		1994	22.50	No change	0.20
		1998	17.00	Improvement	–1.38
		2000	22.70	Deterioration	2.85
	Lesotho	1976	17.30		
		1981	13.30	Improvement	–0.80
		1992	15.80	Deterioration	0.23
		1994	21.40	Deterioration	2.80
		1996	16.00	Improvement	–2.70
	Liberia	1976	20.30		
		2000	26.40	Deterioration	0.25
	Madagascar	1984	33.00		
		1992	39.00	Deterioration	0.75
		1994	32.10	Improvement	–3.45
		1997	30.80	No change	–0.43
		2000	33.10	Deterioration	0.77

continued

TABLE 19. Prevalences of underweight (<–2 SD NCHS/WHO) among children under five years of age: results from repeated national surveys, 1975–2001 *(continued)*

Region	Country	Year	Prevalence (%)	Trend	Rate (pp/yr)
	Malawi	1981	24.00		
		1992	27.00	Deterioration	0.27
		1995	29.90	Deterioration	0.97
		2000	25.40	Improvement	–0.90
	Mali	1987	30.70		
		1995	30.80	No change	0.01
	Mauritania	1981	31.00		–0.01
		1991	47.60	Deterioration	1.66
		1996	23.00	Improvement	–4.92
	Mauritius	1985	23.90		
		1995	14.90	Improvement	–0.90
	Mozambique	1995	27.00		
		1997	20.10	Improvement	–3.45
	Niger	1992	42.60		
		1998	38.20	Improvement	0.00
		2000	39.60	No change	0.70
	Nigeria	1990	35.70		
		1993	39.10	Deterioration	1.13
		1999	21.00	Improvement	–3.02
	Rwanda	1976	27.80		
		1985	27.50	No change	–0.03
		1992	29.40	No change	0.27
		2000	29.00	No change	–0.05
	São Tome	1986	16.60		
		1996	16.00	No change	–0.06
	Senegal	1986	21.90		
		1992	20.10	No change	–0.30
		1993	22.20	Deterioration	2.10
		1996	22.30	No change	0.03
		2000	18.40	Improvement	–0.98
	Sierra Leone	1975	31.00		
		1978	23.20	Improvement	–2.60
		1990	28.70	Deterioration	0.46
		2000	27.20	No change	–0.15
	Sudan	1992	34.00		
		1995	16.70	Improvement	–5.77
	Tanzania	1987	33.00		
		1992	28.90	Improvement	–0.82
		1996	30.60	No change	0.43
		1999	29.40	No change	–0.40
	Togo	1977	20.50		
		1988	24.40	Deterioration	0.35
		1998	19.30	Improvement	–0.51
	Uganda	1989	23.30		
		1995	19.70	Improvement	–0.60
		2000	22.50	Deterioration	0.56
	Zambia	1985	20.50		
		1988	25.80	Deterioration	1.77
		1992	25.10	No change	–0.18

continued

TABLE 19. Prevalences of underweight (<–2 SD NCHS/WHO) among children under five years of age: results from repeated national surveys, 1975–2001 *(continued)*

Region	Country	Year	Prevalence (%)	Trend	Rate (pp/yr)
		1996	23.50	No change	–0.40
		1999	25.00	No change	0.50
	Zimbabwe	1984	14.00		
		1988	11.40	Improvement	–0.65
		1994	11.90	No change	0.08
		1999	13.00	No change	0.22
South Asia	Bangladesh	1975	84.40		
		1981	70.10	Improvement	–2.38
		1985	71.50	No change	0.35
		1990	66.50	Improvement	–1.00
		1996	56.40	Improvement	–1.68
		1999	47.60	Improvement	–2.93
	India	1977	71.00		
		1988	63.00	Improvement	–0.73
		1993	54.50	Improvement	–1.70
		1998	50.10	Improvement	–0.88
	Nepal	1975	69.60		
		1994	48.70	Improvement	–1.10
		1996	47.80	No change	–0.45
		1998	47.10	No change	–0.35
		2001	48.40	No change	0.43
	Pakistan	1977	54.70		
		1986	48.80	Improvement	–0.66
		1990	40.40	Improvement	–2.10
		1995	38.20	Improvement	–0.44
	Sri Lanka	1976	58.30		
		1980	47.50	Improvement	–2.70
		1987	36.60	Improvement	–1.56
		1993	37.60	No change	0.17
		2000	33.00	Improvement	–0.66
Eastern Europe and Central Asia	Azerbaijan	1996	10.10		
		2000	16.80	Deterioration	1.68
	Kazakhstan	1995	6.38		
		1999	4.20	Improvement	–0.55
China	China	1987	21.70		
		1990	17.50	Improvement	–1.40
		1992	17.70	No change	0.10
		1994	15.80	No change	–0.95
		1998	9.60	Improvement	–1.55

TABLE 20. Countries showing change in prevalence of underweight according to most recent pair of surveys[a]

Region	Improvement (%)	No change (%)	Deterioration (%)	No. of countries
Sub-Saharan Africa	38	32	29	34
Middle East and North Africa	78	11	11	9
South Asia	80	20	0	5
Southeast Asia	33	33	33	9
China	100	0	0	1
Middle America and Caribbean	50	40	10	10
South America	20	80	0	10
Eastern Europe and Central Asia	50	0	50	2
Total	45	34	21	80

a. Two cases (Trinidad and Tobago, and Papua New Guinea) in which the later survey was done before the 1990s were excluded.

TABLE 21. Mean prevalence of underweight among children 0 to 59 months of age calculated by averaging survey results, according to region and time period[a]

Region	Before 1983	1983–87	1988–92	1993–97	1998–2001
Sub-Saharan Africa	23.1 (13)	24.2 (16)	28.8 (22)	24.1 (33)	25.1 (32)
Middle East and North Africa	18.1 (3)	11.7 (2)	11.8 (10)	12.4 (15)	10.4 (7)
South Asia	65.1 (7)	52.3 (3)	56.6 (3)	45.4 (8)	45.2 (5)
Southeast Asia	36.5 (4)	33.4 (11)	30.9 (8)	30.2 (12)	34.3 (10)
China	—	21.7 (1)	17.6 (2)	15.8 (1)	9.6 (1)
Middle America and Caribbean	20.3 (9)	17.6 (5)	12.9 (9)	14.5 (9)	10.7 (8)
South America	12.7 (8)	10.0 (7)	10.8 (7)	8.2 (9)	6.7 (7)
Eastern Europe and Central Asia	—	—	—	9.9 (4)	8.4 (7)
Overall	28.2 (44)	24.8 (45)	22.9 (61)	21.6 (91)	21.4 (77)

a. The number of surveys is given in parentheses.

TABLE 22. Trends in prevalence of underweight (< –2 SD by NCHS/WHO standards) among children 0 to 60 months of age and numbers affected, according to region and time period, 1990–2000

	% of children underweight			No. of children underweight (millions)			Trend (pp/yr)	
Region	1990	1995	2000	1990	1995	2000	1990–95	1995–2000
Sub-Saharan Africa	28.3	27.5	27.0	28.2	29.6	30.0	–0.16	–0.10
Middle East and North Africa	12.5	11.7	11.2	4.7	4.8	4.3	–0.16	–0.10
South Asia (without India)	60.4	57.2	53.6	30.3	29.0	26.9	–0.64	–0.72
Southeast Asia	35.9	34.4	32.9	20.9	20.5	18.8	–0.30	–0.31
China	17.5	15.2	8.4	20.8	15.7	8.1	–0.46	–1.36
India	54.7	52.9	48.6	63.1	63.3	58.8	–0.36	–0.86
Middle America and Caribbean	14.7	12.6	11.3	2.9	2.6	2.2	–0.42	–0.26
South America	9.8	7.5	5.7	3.3	2.4	1.7	–0.46	–0.35
Eastern Europe and Central Asia	—	9.4	9.2	—	1.6	.3	—	–0.06
Total	32.6	30.8	28.3	174.2	169.5	152.1	–0.36	–0.50

NCHS/WHO, National Center for Health Statistics/World Health Organization; pp, Percentage points.

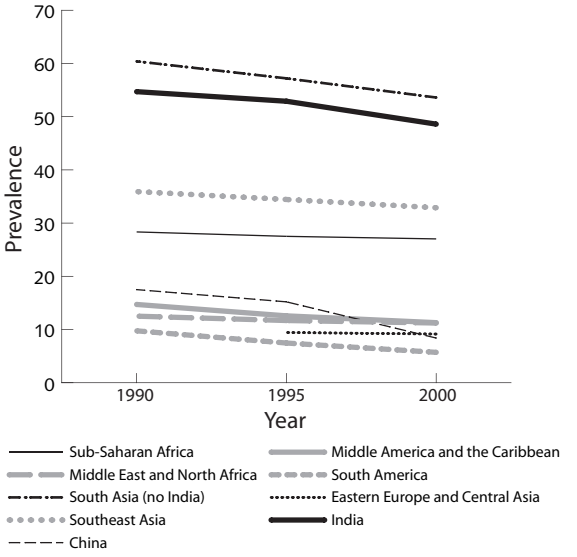


FIG. 12. Trends in the prevalence of underweight children, 1990–2000

differs between overall prevalence *levels*, *differentials* (e.g., between population groups, often defined geographically), and *trends* through time. This report concentrates on trends. After these have been summarized, some implications are put forward for policies and programs and for relative priorities. The difference in interpretation is illustrated by considering the contrast between a situation that is good but deteriorating, or serious but improving (or with the opposite combinations). Better still would be to understand the causes of this changing picture, but this requires evaluation data, which are scarce (see Mason et al. [31]). Nonetheless, the analyses and results described here provide some pointers.

Levels of malnutrition based on indicators of vitamin A deficiency, anemia, iodine-deficiency disorders, and child underweight are now reasonably well agreed, for developing countries overall and by regional groupings. Recent prevalence data were compiled by ACC/SCN [4], and earlier estimates on the same four indicator sets were published by the Micronutrient Initiative [1]. Xerophthalmia affects around 1% of children in developing regions [6, 15]. Vitamin A deficiency affects some 25% to 30% of children [6]. Anemia is considered to affect 50% or more of women in developing regions (a higher percentage in pregnant women) and is becoming recognized as a serious problem in young children as well [4]. Iodine deficiency measured as goiter is known to have affected some 15% (although this may have been a low estimate) [18], and measured as low urinary iodine excretion the prevalence is estimated as around 35% [4, 7]. Child underweight prevalences are perhaps the best known—and the only one with trends regularly assessed—with overall developing region levels of 25%, decreasing by 0.5 percentage points/year [4]. The results here are consistent with these findings—they are based on much the same input data—and the regional differentials are similar as well.

Malnutrition has been estimated to be the largest single risk factor in the global burden of disease [32–35]. The contributions of different deficiencies, and the distinctions between these as risk factors and as disabilities themselves have been calculated [36–38]. **Table 23** shows estimates of the contribution to the overall burden (developing countries, all groups, all causes) of the four types of malnutrition considered, based on the prevalence estimates used here, from recent calculations [39]. The total disease burden in developing countries would be reduced by nearly one-third if malnutrition* were eliminated; the larger part of this would be indirect, from reducing the risks of mortality and morbidity due to malnutrition.

Turning to *trends*, estimates have been calculated for regional prevalences in 1990, 1995 (1994 for iodine-deficiency disorders), and 2000, for the seven indicators: xerophthalmia and vitamin A deficiency in 0- to 72-month-old children; anemia in nonpregnant women 15 to 49 years of age, pregnant women, and children; goiter in all ages; and underweight in children (0–59 months, < –2SD weight-for-age). The results (from **tables 6, 7, 12–14, 18, and 22**) are shown in **fig. 13** as trends by region (defined in **table 1**), which are discussed next.

Sub-Saharan Africa shows a generally unchanging or worsening situation, except for iodine-deficiency disorders, which are improving with expanding iodized salt coverage. The overall prevalences of child underweight were decreasing slightly up to 2000, but this was reversed at least in Eastern and Southern Africa with drought (and the HIV/AIDS epidemic) after 2001 [40]. Of particular concern are the prevalences of anemia (although based on a limited number of surveys; see **tables 8, 9, and 11**), which appear to be increasing in women and are extremely high overall for children (> 70% is estimated). The general picture of static nutrition, or deteriorating nutrition in some countries, is in line with the discouraging health and economic situation in Africa.

In the Middle East and North Africa, both vitamin A deficiency and child underweight are showing improvement, with underweight now the least prevalent condition (except for xerophthalmia). The prevalence of vitamin A deficiency remains high, although decreasing. Iodine-deficiency disorders did not appear to improve, with a number of countries still reporting low iodized salt coverage (e.g., coverage in Iraq, Morocco, and Yemen was around 40% in 1997–

* Malnutrition as used here refers to the effects of inadequate dietary intake and ill-health, thus excluding obesity.

2002; see table 2 in WHO [7]). However, anemia is the most extensive problem, affecting around one-third of women and children, and although it has shown signs of improvement recently (in pregnant women and children, but not in nonpregnant women), it should attract priority attention.

India is considered separately from the rest of South Asia (Afghanistan, Bangladesh, Bhutan, Nepal, Pakistan, and Sri Lanka), because its large population would otherwise dominate the results. The prevalences of all forms of malnutrition are highest in South Asia and India. However, they are falling quite rapidly in some countries, notably Bangladesh (for underweight children, **table 19**, and anemia, **table 8**), and significantly in India for underweight children. Vitamin A deficiency is estimated to be falling in South Asia, including India (based on model estimates), but the prevalence of xerophthalmia remains above 1% in India (see also ACC/SCN [4], pp. 102–3); the prevalence of night-blindness in children is reported as 6%, or 18% for difficulty in seeing during the day or nighttime for 0- to 14-year-olds (Government of India and UNICEF [30], pp. 14 and 42). These estimates suggest that vitamin A deficiency persists in India, in line with a vitamin A prophylaxis coverage of only about 30% (Government of India and UNICEF [30], p. 41).

In other South Asian countries, vitamin A supplement distribution has much higher coverage (e.g., more than 85% for Bangladesh, Nepal, and Pakistan; UNICEF [9], pp. 106–9; Mason et al. [1], pp. 52 and 110), and the extent of xerophthalmia and vitamin A deficiency is lower (and not increasing for xerophthalmia). The prevalence of anemia is extremely high in India (70%–80%) and is scarcely changing, in part probably because of low consumption of animal products, as well as the extent of parasitic infestations. In other South Asian countries, the prevalence of anemia is on average falling somewhat, substantially as reported in Bangladesh (**table 8**), but anemia remains both a high-priority concern and one of the most problematic to address. Goiter prevalence in India is also thought to have increased rather than fallen; this is based largely on the reported low and falling iodized salt coverage, recently estimated as 50% overall and as low as 25% in some states [30]. Although goiter prevalences are falling in some countries in South Asia, (for example in Bhutan and Nepal, **table 14**), nonetheless South Asia still has the highest prevalence of all regions, at around 25% (**table 18**).

The countries of Southeast Asia include some that are going through transitions in nutrition and living standards, such Thailand. China is viewed separately, and it too is changing rapidly. The prevalences of underweight (and stunted) children have fallen rapidly in China, Thailand, and Vietnam, by more than 2 percentage points/year. The prevalence of vitamin A deficiency has dropped as well, and that of xerophthalmia is well below 1%. In China, Thailand, and Vietnam, anemia fell in the 1990s—an unusual observation—probably linked to improved living standards and diet (also reflected in parallel decreases in child underweight prevalences); it could also be linked to improving vitamin A status, which can reduce anemia. But in Southeast Asia on average, anemia again persists at high levels. Goiter fell by half, to about 10%, in China, following vigorous efforts in salt iodization, which reached a reported national coverage of 93% in 1997–2002 (UNICEF [9], p. 106)—a major success story. Similar success was seen in some Southeast Asian countries, Indonesia up to the mid-1990s in this case, as well as Thailand and Vietnam. Thus, China and the rapidly improving Southeast Asian countries are well into a nutrition transition,* but significant populations still remain underserved, and progress for these needs to be accelerated.

Developing regions in the Americas—here grouped as Middle America (Mexico and Central America)/Caribbean and South America—have low levels of general malnutrition measured as child underweight prevalences, and these are continuing to fall. Xerophthalmia has reached very low levels—estimated as less than 0.3%—and is now seldom assessed in populations. Vitamin A deficiency estimated from serum retinol is the usual measure, showing generally falling prevalences, especially in Central America (see **table 3** for repeated survey results), in many cases with vitamin A fortification of sugar.

Anemia is the most prevalent of the deficiencies and was estimated to be increasing in the late 1990s in pregnant women in both regions, and in all groups in South America. The persistence or even increase in high prevalences of anemia, while other deficiencies fall, is not fully explained; it may relate to living conditions, although these are usually reflected in other nutritional indicators. The trends may indicate a relative lack of progress for poor women and continuation of poor diets; the transition to adequate energy intakes and obesity, which is beginning to emerge as a problem for the poor, may be linked to diets with high energy and low iron (or micronutrients), so anemia and anthropometric indicators begin to diverge from each other.

Iodine deficiency is falling in most South American countries, with high and sustained coverage of iodized salt. In the Caribbean, Haiti and the Dominican Republic have low usage of iodized salt, and the relatively low goiter levels on average are not estimated to be improving.

In sum, xerophthalmia is reaching near-elimination levels in China and the Americas—well below 1%—but

* An accelerated improvement when a number of factors come together, somewhat analogous to the demographic transition.

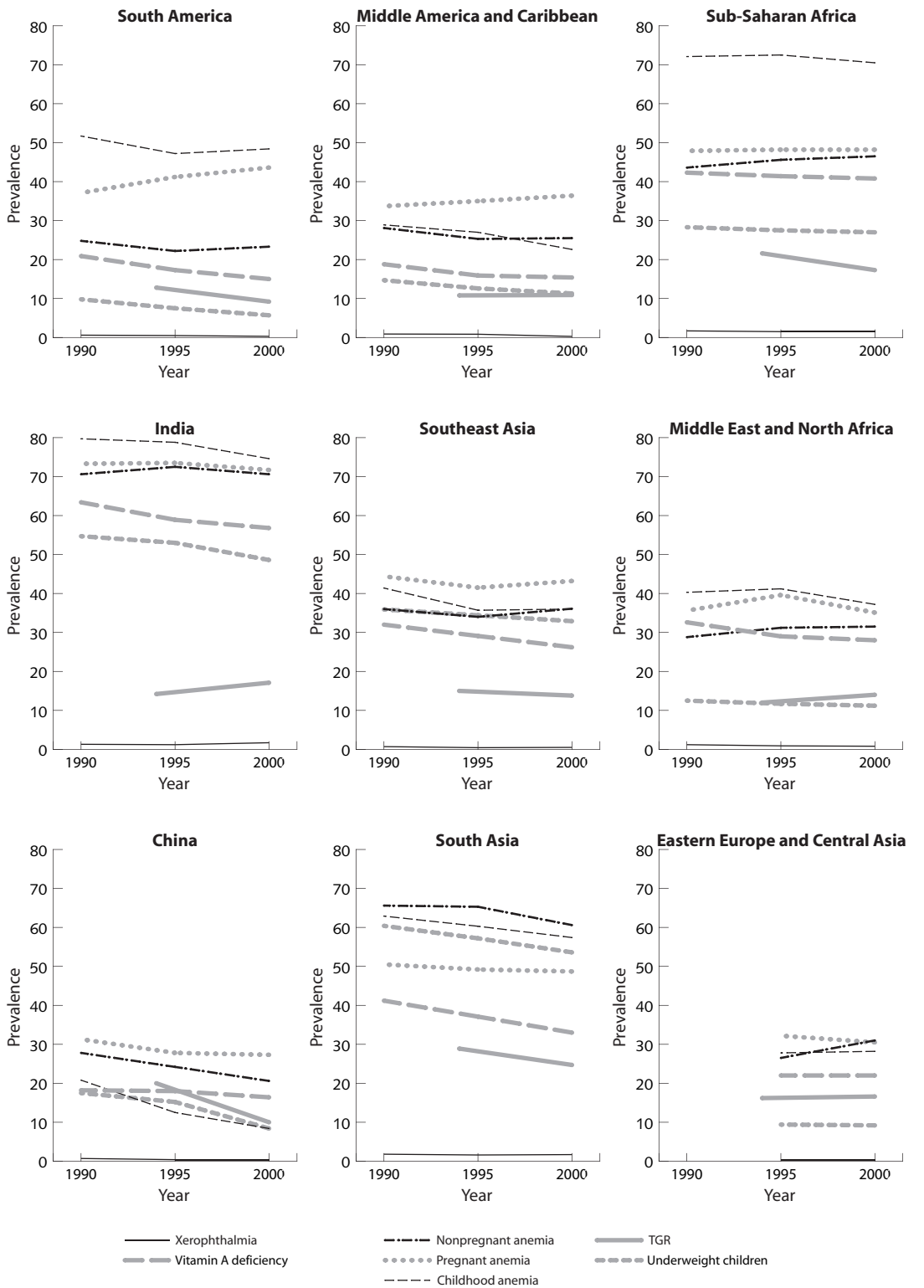


FIG. 13. Integrated plots of indicators of deficiencies and underweight by region, for 1990, 1995, and 2000.
TGR, total goiter rate; HH, household

persists stubbornly elsewhere, notably at 1% to 2% in India and Sub-Saharan Africa. The larger threat is thought to be from vitamin A deficiency, which is implicated in increased mortality risk in young children [41]. Trends in vitamin A deficiency tend to parallel those in general malnutrition (e.g., as underweight), driven substantially by changing living standards. Intervention through vitamin A supplementation is now widespread but may need to be targeted to the most deficient populations and increased in frequency [14, 15, 28]; fortification is technically proven and could now contribute to vitamin A deficiency reduction for many more at-risk populations.

It should be noted that the paralleling of trends, rather than similarity of their levels (within reason), is more informative, because the cutoffs used to derive prevalences are fairly arbitrary. This is illustrated by vitamin A deficiency and underweight. Both of these have cutoffs used to calculate prevalence (< 20 μg/dl for vitamin A deficiency and < –2 SD for underweight); although in establishing these cutoffs, the relation to risk is taken into account, they do not necessarily have the same significance either for causality or outcome. For instance, in **fig. 13**, the higher prevalence levels of vitamin A deficiency compared with underweight (in all regions except in Asia) do not imply that vitamin A deficiency is necessarily a greater priority; but it *is* interesting that these relative levels switch in South Asia and Southeast Asia, where children are relatively more underweight, for reasons not yet fully agreed on (see Ramalingaswami et al. [42]). But equally, as underweight reaches low levels—perhaps 10% or less, as in China and the Americas—then micronutrient deficiencies may assume greater priority.

The levels of anemia are strikingly high and are not improving rapidly, or are even worsening; moreover, anemia particularly affects women. A significant association with percentage of kilocalories from meat (as national averages) was seen in the analysis, and public health conditions are important causes (intestinal worm infestation, malaria). Thus, eventually improvements may occur due to environmental and socioeconomic change. But specific intervention is critically needed, and indeed, if effective, could itself contribute to economic change, given the debilitating effect of anemia, through positive feedback creating a virtuous cycle. Supplementation, although efficacious in trials, proves resistant to being effective in large-scale programs, related to logistics and adherence to daily (or possibly weekly) consumption of supplements (which often should contain multiple micronutrients). A review of iron supplementation programs in Asia concluded that where there was improvement (Bangladesh, Thailand, and Vietnam), although supplementation may have contributed (although similar improvements were seen in unsupplemented men), other countries such as Indonesia and Myanmar also had supplementation programs but no improvement (Mason et al. [1], pp. 69–71). Undoubtedly, renewed efforts to extend supplementation, especially during pregnancy, must be pursued. But there is a high-priority need for more vigorous investment in research and development of methods for fortification with iron, especially of rice (the staple in the most affected countries), followed by systematic efficacy trials, and—crucially—careful expansion to national programs, including the requisite monitoring, evaluation, and program adaptation.

TABLE 23. Estimated reductions in the disease burden (% DALYs lost) in developing countries, (all population groups, all causes), from children underweight or deficiencies of vitamin A (clinical), iodine (measured as goiter), and anemia; from the direct effect (the deficiency considered as a disease itself) and as a risk factor for other diseases (infectious diseases only included in estimating reduction).

	Direct effect (%)	As risk factor (%)	Total (%)
Child underweight	1.0%	14.0%	15.0%
Vitamin A deficiency	1.0%	4.5%	5.5%
Anemia	3.3%	0.3%	3.6%
IDDs	4.7%	3.7%	8.4%
Total	10.0%	22.5%	32.5%

Note: underweight refers to children 0–59 months, < –2 SDs weight-for-age; vitamin A deficiency is calculated from clinical deficiency in children 0–59 months; anemia refers to women 15–49 years; IDDs refers to iodine deficiency disorders, all ages, calculated from goiter prevalences. Methods are given in the source.
Source: [39]

Salt iodization overall is a great success story. We estimated here, comparing the present situation with one without any iodized salt, that iodine fortification has halved the prevalence of iodine-deficiency disorders, and that without iodized salt, there would accordingly be some 800 million more people today with iodine deficiency (see **fig. 11**). This must rank among the major public health achievements of recent times. In terms of current disease burden averted, since that due to iodine-deficiency disorders would be doubled (see **table 23**), we can estimate that iodized salt averts about 8%, and it surely must be among the most cost-effective interventions. But nonetheless, the hardest part may be yet to come: although two-thirds of the populations of developing regions get iodized salt, the other third does not, and these are the hardest to reach and likely to live in the most iodine-deficient areas. This is an implementation rather than a research issue, and the problems are well recognized: multiple small salt producers, quality control and regulation, consumer awareness, and the like. Encouraging communities to monitor their access to iodized salt with simple testing kits would help. Continued attention to this issue, with monitoring, could drive the coverage up to the goal of universal salt iodization. Here is a clear case

for sustaining the effort and resisting distractions to newer priorities.

Persistent exposure to goitrogens, for example, from cassava and water-borne substances in some environments, can reduce the impact of increased iodine intakes. Extending access to iodized salt is not the only intervention needed, and this must be considered in interpretation of progress in populations exposed to goitrogens.

Finally, evidence for trends such as these described, and for their attribution to causes including program interventions, must be sustained as the underpinning for designing and implementing successful intervention. Presently available data are limited in several ways, with availability, representativeness, and comparability between different times and places being the most important constraints.

First, continued surveys deliberately designed to elucidate trends are urgently needed. This is especially true for anemia; if there were improvements taking place they would hardly be recognized for lack of representative and comparable data. The analyses using repeated national surveys (e.g., as given in **tables 2, 3, 8–10, 15, and 19**) provide the most direct and useful evidence for change, yet these comparisons are unsystematic, and the actual comparability taken on faith more than is comfortable.

Second, some developments in method are in order, both in technical terms (e.g., more robust biochemical methods) and in terms of approach: measures of function in relation to the specific deficiency are wanted. For example, hemoglobin does directly relate to one function of iron (although not to others like cognitive development), but serum retinol has an indirect (and not straightforward) link to vitamin A deficiency—here a measure of physiological function using dark adaptation would be easier to interpret. Noninvasiveness would be another advantage of dark-adaptation assessment; this also could apply to assessing anemia by methods that do not require drawing blood.

Third, the scarcity of evaluations of the effectiveness of large-scale programs needs urgently to be addressed. This is not for lack of methodology, but for lack of priority and resources for implementation. In the two instances in which the effectiveness of vitamin A capsule distribution has been assessed [29, 43], inferences were made which, if tested and implemented, could make the extensive capsule distribution program (well over a billion capsules have been distributed) much more effective. Continuing micronutrient programs without adequate evaluation is equivalent to, for example, running immunization campaigns—which have effectively controlled measles and other infectious diseases and saved millions of children's lives—without monitoring coverage, vaccine efficacy, and the integrity of the cold chain to maintain this. Success in micronutrient deficiency control is in sight: sustained and scientifically based efforts now must be promoted to go to the next level of effectiveness. From reviewing the recent trends in the deficiencies, both the extent of the problem and what needs to be done now are reasonably clear.

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