Estimates of Global Prevalence of Childhood Underweight in 1990 and 2015

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AT THE MILLENNIUM SUMMIT IN 2000, representatives from 189 countries committed themselves toward a world in which sustaining development and eliminating poverty would have the highest priority.[1]

The increased recognition of the relevance of nutrition as a basic pillar for social and economic development placed childhood undernutrition among the targets of the first Millennium Development goal to "eradicate extreme poverty and hunger."[2] The specific target goal is to reduce by 50% the prevalence of being underweight among children younger than 5 years between 1990 and 2015. Childhood underweight is internationally recognized as an important public health problem and its devastating effects on human performance, health, and survival are well established.[3-8] A recent study estimated that about 53% of all deaths in young children are attributable to underweight, varying from 45% for deaths due to measles to 61% for deaths due to diarrhea.[8]

Monitoring progress toward the goal requires reliable data sources based on agreed on international standards and best practices, and standardized data collection systems that enable comparison over time. The World Health Organization (WHO) Global Database on Child Growth and Malnutrition was established in the late 1980s with the ob-

Context One key target of the United Nations Millennium Development goals is to reduce the prevalence of underweight among children younger than 5 years by half between 1990 and 2015.

Objective To estimate trends in childhood underweight by geographic regions of the world.

Design, Setting, and Participants Time series study of prevalence of underweight, defined as weight 2 SDs below the mean weight for age of the National Center for Health Statistics and World Health Organization (WHO) reference population. National prevalence rates derived from the WHO Global Database on Child Growth and Malnutrition, which includes data on approximately 31 million children younger than 5 years who participated in 419 national nutritional surveys in 139 countries from 1965 through 2002.

Main Outcome Measures Linear mixed-effects modeling was used to estimate prevalence rates and numbers of underweight children by region in 1990 and 2015 and to calculate the changes (ie, increase or decrease) to these values between 1990 and 2015.

Results Worldwide, underweight prevalence was projected to decline from 26.5% in 1990 to 17.6% in 2015, a change of –34% (95% confidence interval [CI], –43% to –23%). In developed countries, the prevalence was estimated to decrease from 1.6% to 0.9%, a change of –41% (95% CI, –92% to 343%). In developing regions, the prevalence was forecasted to decline from 30.2% to 19.3%, a change of –36% (95% CI, –45% to –26%). In Africa, the prevalence of underweight was forecasted to increase from 24.0% to 26.8%, a change of 12% (95% CI, 8%-16%). In Asia, the prevalence was estimated to decrease from 35.1% to 18.5%, a change of –47% (95% CI, –58% to –34%). Worldwide, the number of underweight children was projected to decline from 163.8 million in 1990 to 113.4 million in 2015, a change of –31% (95% CI, –40% to –20%). Numbers are projected to decrease in all subregions except the subregions of sub-Saharan, Eastern, Middle, and Western Africa, which are expected to experience substantial increases in the number of underweight children.

Conclusions An overall improvement in the global situation is anticipated; however, neither the world as a whole, nor the developing regions, are expected to achieve the Millennium Development goals. This is largely due to the deteriorating situation in Africa where all subregions, except Northern Africa, are expected to fail to meet the goal.

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jective to collect, standardize, and disseminate anthropometric data on children using a standard format.[9] With 419 national population-based surveys, the database covers more than 90% of children younger than 5 years worldwide. An earlier analysis of trends from 1980 to 2005 based on 241 national surveys indicated that childhood malnutrition (as measured by stunting or low height for age) re-

mains a public health problem worldwide, with stunting rates declining in the majority of countries at about 1%

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per year or less. Moreover, in some countries, rates of stunting were rising while in many others they remained high.[10] The aims of the current analysis are to (1) quantify the magnitude of the problem and describe where malnourished children live and (2) to identify geographical regions that based on projected estimates are unlikely to achieve the goal of a 50% decrease in the 1990 prevalence of underweight by 2015.

METHODS
Data

To estimate trends in childhood underweight, national prevalence of low weight for age, which was defined as weight 2 SDs below the mean weight for age of the National Center for Health Statistics and WHO reference population, were derived from the WHO Global Database on Child Growth and Malnutrition.[9] A total of 419 nationally representative surveys, which included about 31 million children, were available from 139 countries. Of the 419 surveys, 398 were conducted in developing countries and 21 in developed countries. For 42 countries, national survey data were available from only 1 survey, 36 countries had 2 surveys, and 61 countries had 3 or more surveys. More than half of the surveys (227) were conducted between 1991 and 1999, 33% (137) dated back to 1990 and earlier, and 13% (55) were performed in 2000 or later (Table 1). The earliest survey dates back to 1965 (from Colombia), while the most recent surveys were conducted in 2002 (Eritrea, Jordan, and Romania). All surveys included boys and girls, and the age groups ranged from birth to 5 years. The complete set of surveys included in the analysis is available from the authors on request.

A data file was constructed and consisted of region, subregion, country, survey year, sample size, prevalence of underweight, and population of children younger than 5 years during the survey year. To obtain comparable prevalences of underweight children across countries, surveys were analyzed following a standard format using the National Center for Health Statistics and WHO international reference population, the same cut-off point (ie, 2 SDs below the mean weight for age), and the same reporting system (ie, z score). The steps followed to analyze the surveys in a standard way have been described elsewhere.[9]

Statistical Analysis

For this analysis, all available childhood underweight prevalence estimates from national surveys were used. Countries providing data were regarded as a representative sample of all countries within their subregions (ie, covering at least 80% of the population younger than 5 years), which were nested within regions. For example, the region of Asia comprised Eastern, South Central, Southeastern, and Western Asia. Trends were also derived for larger units. The group of developing regions included Africa, Asia, Latin America (including the Caribbean), and Oceania. The developed countries were grouped in 1 unit. We obtained global estimates by combining the developing regions and developed countries. Country groupings followed the United Nations (UN) country classification.[11]

The method of linear mixed-effect models, as described by Laird and Ware,[12] was applied to model the data set at subregional levels with the country's effect being defined as random. By using this model, the fact that not all countries had available underweight prevalence data was incorporated assuming countries without data were missing at random. This also allowed all data points for each country to be included in the estimates for subregions.

Using the surveys' underweight prevalence estimates, a linear mixed-effect model was considered for each group of subregions belonging to the same region. The dependent variable was the logit of the prevalence (ln [prevalence/{1−prevalence}]). The basic model contained subregion, year of survey, and the interaction between year and the subregion as fixed effects and country as a random effect. This model is part of a more general class of models—the multilevel models. In multilevel modelling literature, notably in Goldstein,[13] the same model is called a 2-level model, counting the levels of variation (ie, level 1 being the survey and level 2 being the country). Consequently, we obtained from each model an estimate of the change in prevalence for every subregion between the years 1990 and 2015. Subregion prevalence estimates and their respective confidence intervals (CIs) were derived by back-transformation.

To account for the population differences among countries and to ensure that the influence on the regional trend analysis of a country's survey estimate was proportional to the country's population, we performed weighted analysis. The population weights were derived from the UN Population Prospects.[11] For each data point, we obtained the respective population estimate of children younger than 5 years for the specific survey year. If a survey was performed over an extended period, for example 1995-1997, the mean year (ie, 1996) was used as the year from which to choose the respective population estimate. For countries with multiple data points, the weights were calculated by dividing the mean of the country's population of children younger than 5 years (over the observed years) by the sum of the population means for countries in the entire region. Weights of countries with single data points were derived by dividing the population of children younger than 5 years at the time of the survey by the sum of the countries' population means in the whole region.

We considered 3 different structures for modeling the covariance: compound symmetric, unstructured, and autoregressive.[14(pp231-273)] The compound symmetric model for a region allowed the country to have its own intercept (influencing prevalence estimate) and forced all countries to have a common slope in prevalence over time. The unstructured model for a region allowed

each country to have its own intercept and slope. The autoregressive model allowed for correlations between observations within the same country to weaken as the time between them increased. Year was centered at 1995, around which there was a high concentration of available survey data points. Models were fitted using restricted maximum likelihood.[14(pp43-47)] We used the sandwich variance estimator[14(pp61-62)] to obtain SEs of estimates. The decision on how to choose the best model among different covariance structures was based on the Akaike information criterion,[14(pp74-76)] which penalizes the log likelihood values for the number of parameters in the model. In parallel, we examined the graphed display of the fitted trend line against the survey data points and discarded models that did not present a reasonable fit with respect to the empirical data.

The prevalence estimates for 1990 and 2015 for each subregion were derived using the final regression model chosen according to the criteria described above. For the subregions of Africa and Latin America, the unstructured covariance model with random intercept and slope at country level was used. The compound symmetric covariance structure was chosen to model the subregions of Asia, imposing a common slope for all countries in that region. The estimates on the logit scale were back-transformed to provide the prevalence estimates.

Using the resulting prevalence estimates, the total number of affected children was calculated by multiplying the prevalence estimates and respective CIs by the subregional population of children younger than 5 years.[11] The UN population estimates and projections are derived incorporating all new and relevant information regarding the past demographic dynamics of the population of each country or area of the world; and formulating detailed assumptions about the future paths of fertility, mortality, and migration.[11]

For the regional level, the prevalence was derived by using the sum of the numbers of affected estimates in the subregions divided by the total population of children younger than 5 years in that region. To construct a CI for the overall regional prevalence estimate, we obtained approximate SEs associated with the subregions' prevalence estimates using the delta method[15(pp56-58)] and summarized them to compute SEs corresponding to the overall weighted prevalence estimates.

For the developed countries, 21 observations were available. Considering the relative homogeneity of the group, we fitted a linear mixed-effects model with year being a fixed effect and country being a random effect.

The relative change in prevalence was calculated as the 2015 prevalence minus the 1990 prevalence divided by the 1990 prevalence. The CIs for the change in prevalence were constructed using the ratio between the 2015 and the 1990 prevalences on the log scale.

Table 1. Description of 419 Surveys Included in the Analysis

Region	No. of Surveys	Total Sample Size	Countries With Surveys/ Total No. of Countries	No. of Surveys by Survey Period		
				≤1990	1991-1999	≥2000
Africa						
Entire region	145	1 583 202	52/53	41	76	28
Northern	19	84 844	5/5	7	10	2
Sub-Saharan*	126	1 498 358	47/48	34	66	26
Eastern	49	1 190 759	17/17	12	29	8
Middle	16	67 020	8/9	3	7	6
Southern	11	35 598	5/5	2	6	3
Western	48	182 353	16/16	17	23	8
Asia						
Entire region	122	3 103 847	39/47	31	78	13
Eastern	8	128 277	3/4	1	4	3
South Central	42	251 222	13/14	13	27	2
Southeastern	45	2 637 338	9/11	14	26	5
Western	27	87 010	14/18	3	21	3
Latin America						
Entire region	125	24 886 979	27/33	53	62	10
Caribbean	25	43 931	7/13	9	12	4
Central	30	1 187 241	8/8	11	17	2
South	70	23 655 807	12/12	33	33	4
Oceania†	6	36 985	5/15	5	1	0
Developing regions	398	29 611 013	123/148	130	217	51
Developed countries‡	21	1 297 422	16/45	7	10	4
Entire world	419	30 908 435	139/193	137	227	55

*Comprises the regions of Eastern, Middle, Southern, and Western Africa and Sudan.
†Includes Fiji, Papua New Guinea, Solomon Islands, Vanuatu, Kiribati, and Samoa.
‡Europe, Japan, Australia, Canada, and United States.

RESULTS
Trends and Percentage Change in Prevalence of Underweight Children, 1990-2015

TABLE 1 presents the surveys included in the analysis and TABLE 2 presents estimates of underweight children for 1990 and projections for 2015 with 95% CIs of the prevalence and the relative percentage change. Worldwide, prevalence of childhood underweight was projected to decline from 26.5% in 1990 to 17.6% in 2015, a change of −34% (95% CI, −43% to −23%). In developed countries, the prevalence was estimated to decrease from 1.6% to 0.9%, a change of −41% (95% CI, −92% to 343%). In developing regions, the prevalence was forecasted to decline from 30.2% to 19.3%, a change of −36% (95% CI, −45% to −26%).

In Africa, the prevalence of underweight was forecasted to increase from 24.0% in 1990 to 26.8% in 2015, a change of 12% (95% CI, 8%-16%). The prevalence of childhood underweight was estimated to increase in sub-Saharan Africa by 9% (from 26.8% to 29.2%) and in Eastern Africa by 25% (from 26.7% to 33.3%). The prevalence of childhood underweight was projected to be reduced by 15% for Middle Africa; 5%, Southern Africa; and 6%, Western Africa. Only Northern Africa, with a forecasted reduction in the prevalence of childhood underweight from 9.5% to 4.2%, was estimated to reach the Millennium Development goal. FIGURE 1 presents the 2015 projections of the prevalence of underweight children for the African subregions compared with the Millennium Development goal for those subregions.

In Asia, between 1990 and 2015 the prevalence was estimated to decrease from 35.1% to 18.5%, a change of −47% (95% CI, −58% to −34%). The largest decline was estimated in Eastern Asia, where the prevalence of underweight children was forecasted to decrease by 84% in the same period. Southeastern and South Central Asia were also forecasted to experience substantial improvements, with reductions in the prevalence of underweight of 49% and

42%, respectively. However, both subregions are projected to still have high levels of childhood underweight in 2015. Western Asia was estimated to be the Asian subregion with the lowest reduction in the prevalence of childhood underweight (29%).

In Latin America, the prevalence of underweight children was forecasted to decrease from 8.7% in 1990 to 3.4% in 2015, a change of −61% (95% CI, −77% to −35%). All subregions in Latin America were estimated to experience decreasing trends with changes of −72%

Table 2. Estimates of Prevalence of Underweight Children in 1990 and 2015

Region	Prevalence (95% CI), %		Relative Change (95% CI), %
	1990	2015	
Africa			
Entire region	24.0 (23.5 to 24.5)	26.8 (26.1 to 27.5)	11.6 (7.9 to 15.5)
Northern	9.5 (7.9 to 11.3)	4.2 (2.0 to 8.5)	−55.6 (−78.3 to −8.9)
Sub-Saharan*	26.8 (23.9 to 29.6)	29.2 (26.0 to 32.5)	9.2 (−6.5 to 27.5)
Eastern	26.7 (22.0 to 32.0)	33.3 (27.6 to 39.6)	25.0 (−3.1 to 61.2)
Middle	27.8 (19.8 to 37.5)	23.6 (17.7 to 30.8)	−14.9 (−43.8 to 28.7)
Southern	14.0 (9.9 to 19.5)	13.3 (9.3 to 18.6)	−5.2 (−41.0 to 52.4)
Western	27.8 (23.6 to 32.4)	26.2 (21.2 to 31.9)	−5.8 (−26.8 to 21.2)
Asia			
Entire region	35.1 (31.7 to 38.5)	18.5 (14.6 to 22.4)	−47.2 (−58.1 to −33.5)
Eastern	18.5 (17.6 to 19.4)	3.0 (2.8 to 3.3)	−83.6 (−84.9 to −82.2)
South Central	49.6 (42.4 to 56.8)	28.7 (22.0 to 36.5)	−42.2 (−56.8 to −22.8)
Southeastern	35.2 (30.8 to 40.0)	17.9 (13.8 to 22.9)	−49.1 (−61.6 to −32.5)
Western	12.9 (9.9 to 16.7)	9.2 (1.4 to 41.4)	−28.5 (−87.7 to 315.3)
Latin America			
Entire region	8.7 (6.1 to 11.3)	3.4 (2.0 to 4.8)	−60.8 (−76.5 to −34.7)
Caribbean	10.0 (5.9 to 16.4)	2.8 (1.3 to 5.8)	−72.2 (−88.5 to −32.6)
Central	12.4 (7.5 to 19.9)	5.8 (2.9 to 11.3)	−53.5 (−79.7 to 6.7)
South	7.0 (4.5 to 10.8)	2.4 (1.4 to 4.2)	−65.0 (−82.5 to −30.0)
Developing regions	30.2 (27.8 to 32.5)	19.3 (16.9 to 21.8)	−35.9 (−44.7 to −25.6)
Developed countries†	1.6 (0.8 to 3.0)	0.9 (0.2 to 4.3)	−41.0 (−92.1 to 342.8)
Entire world	26.5 (24.5 to 28.6)	17.6 (15.4 to 19.8)	−33.7 (−42.8 to −23.1)

Abbreviation: CI, confidence interval.
*Comprises the regions of Eastern, Middle, Southern, and Western Africa and Sudan.
†Europe, Japan, Australia, Canada, and United States.

Figure 1. Projections of Underweight Prevalence in African Subregions in 2015 Compared With the Millennium Development Goal
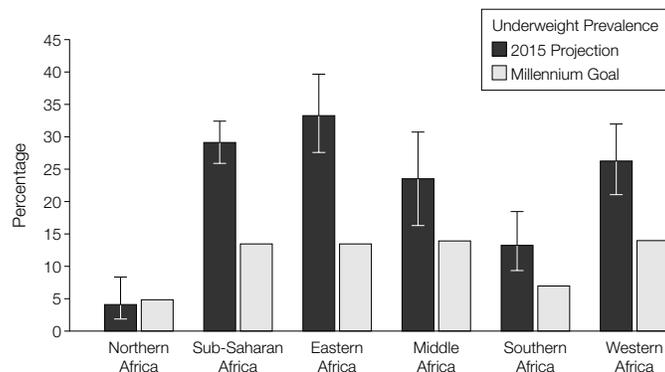
Percentage with weight 2 SDs below the mean weight for age of the reference population from the National Center for Health Statistics and World Health Organization. Sub-Saharan Africa comprises the subregions of Eastern, Middle, Southern, and Western Africa and Sudan.

Table 3. Estimates of Underweight Children in 1990 and 2015

Region	Estimates (95% CI), in millions		Percentage of Relative Change (95% CI)
	1990	2015	
Africa			
Entire region	25.8 (25.2 to 26.3)	43.3 (42.2 to 44.4)	68.3 (62.7 to 74.1)
Northern	1.6 (1.4 to 2.0)	0.7 (0.3 to 1.3)	−59.3 (−80.2 to −16.5)
Sub-Saharan*	24.1 (21.5 to 26.7)	42.7 (37.9 to 47.5)	76.9 (51.5 to 106.6)
Eastern	9.5 (7.8 to 11.4)	19.1 (15.8 to 22.7)	101.6 (56.2 to 160.0)
Middle	3.7 (2.6 to 5.0)	6.3 (4.7 to 8.2)	71.5 (13.4 to 159.4)
Southern	0.8 (0.6 to 1.1)	0.7 (0.5 to 1.0)	−13.9 (−46.5 to 38.4)
Western	8.8 (7.4 to 10.2)	13.5 (10.9 to 16.4)	53.6 (19.4 to 97.6)
Asia			
Entire region	131.9 (119.2 to 144.7)	67.6 (53.4 to 81.7)	−48.8 (−59.3 to −35.5)
Eastern	23.1 (22.0 to 24.2)	3.0 (2.8 to 3.2)	−86.9 (−88.0 to −85.8)
South Central	86.0 (73.5 to 98.5)	52.1 (39.9 to 66.3)	−39.4 (−54.7 to −19.0)
Southeastern	20.2 (17.6 to 22.9)	9.7 (7.5 to 12.4)	−51.8 (−63.6 to −36.0)
Western	2.7 (2.1 to 3.5)	2.7 (0.4 to 12.1)	0.4 (−82.7 to 483.3)
Latin America			
Entire region	4.8 (3.4 to 6.2)	1.9 (1.1 to 2.7)	−60.2 (−76.1 to −33.8)
Caribbean	0.4 (0.2 to 0.7)	0.1 (0.05 to 0.20)	−74.2 (−89.3 to −37.4)
Central	1.9 (1.2 to 3.1)	0.9 (0.5 to 1.8)	−51.9 (−79.0 to 10.3)
South	2.5 (1.6 to 3.8)	0.9 (0.5 to 1.5)	−64.4 (−82.2 to −28.8)
Developing regions	162.6 (149.8 to 175.5)	112.8 (98.6 to 127.1)	−30.6 (−40.2 to −19.5)
Developed countries†	1.2 (0.6 to 2.4)	0.6 (0.1 to 2.6)	−54.1 (−93.9 to 244.4)
Entire world	163.8 (151.0 to 176.7)	113.4 (99.2 to 127.6)	−30.8 (−40.3 to −19.7)

Abbreviation: CI, confidence interval.
*Comprises the regions of Eastern, Middle, Southern, and Western Africa and Sudan.
†Europe, Japan, Australia, Canada, and United States.

Trends and Percentage Change in Numbers of Underweight Children, 1990-2015

TABLE 3 presents estimates for 1990 and projections for 2015 of the number of underweight children, and the relative percentage change with corresponding 95% CIs by geographical region. Worldwide, the number of underweight children was projected to decline from 163.8 million in 1990 to 113.4 million in 2015, a change of −31% (95% CI, −40% to −20%). In developed countries, the number was estimated to decline from 1.2 to 0.6 million, a change of −54% (95% CI, −94% to 244). In developing regions, the number was forecasted to decline from 162.6 to 112.8 million, a change of −31% (95% CI, −40% to −20%).

In Africa, the number of underweight children was forecasted to increase from 25.8 million in 1990 to 43.3 million in 2015, a change of 68% (95% CI, 63%-74%). The subregions of sub-Saharan, Eastern, Middle, and Western Africa were all forecasted to experience substantial increases in the number of underweight children (77%, 102%, 72%, and 54%, respectively). Only Southern and Northern Africa were estimated to reduce the number of underweight children by 14% and 59%, respectively.

In Asia, where the largest number of underweight children live, the number was estimated to decrease from 131.9 to 67.6 million between 1990 and 2015, a change of −49% (95% CI, −59% to −36%). The largest decline was projected for Eastern Asia (−87%), followed by Southeastern Asia (−52%) and South Central Asia (−39%). Western Asia was estimated to remain stagnant.

In Latin America, the number of underweight children was forecasted to decline from 4.8 million in 1990 to 1.9 million in 2015, a change of −60% (95% CI, −76% to −34%). All subregions in Latin America were forecasted to experience decreas-

ing trends in childhood underweight (Caribbean, −74%; Central America, −52%; and South America, −64%).

Geographical Patterns of Underweight Children

FIGURE 2 shows the geographical distribution of the prevalence of underweight children based on the latest survey data. Prevalences were categorized as less than 10%, 10% to 19%, 20% to 29%, and 30% or more.[16] Very high levels of childhood underweight were found in 12 African countries (Angola, Burkina Faso, Burundi, Democratic Republic of the Congo, Eritrea, Ethiopia, Madagascar, Mali, Mauritania, Niger, Nigeria, and Sudan) and 13 Asian countries (Afghanistan, Bangladesh, Cambodia, India, Lao People's Democratic Republic, Maldives, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Vietnam, and Yemen). Prevalences of childhood underweight for each country were based on available information from the WHO Global Database on Child Growth and Malnutrition.[17] Prevalence data by urban and rural residence, age groups, sex, and subnational level administrative regions can be found at the database's Web site (http://www.who.int/nutgrowthdb).

COMMENT

Based on national surveys of past prevalences of underweight children, we have estimated prevalence rates and numbers of underweight children by geographic region for the years 1990 and 2015 to assess the likelihood of meeting the Millennium Development Goal of reducing 1990-level prevalence by 50% in the year 2015. According to our analysis, despite an overall improvement on the global situation, neither the world as a whole nor the developing regions are expected to achieve the goal. This is largely due to the deteriorating situation in Africa where all subregions, with the exception of Northern Africa, are expected to fail to meet the goal. Moreover, sub-Saharan and Eastern Africa are forecasted to experience an increase in the prevalence of underweight children during the 25-year period. In Asia, Eastern Asia (mainly

for the Caribbean, −54% for Central America, and −65% for South America. There were no sufficient data to derive estimates for the region of Oceania.

driven by China), and Southeastern Asia are forecasted to reach the goal, while South Central and Western Asia are not. Moreover, our estimates project that in 2015, most subregions in Africa and South Central Asia will continue to have very high prevalences of underweight children. According to our projections, all subregions in Latin America will achieve the Millennium goal.

The vast majority of underweight children live in developing regions, mainly in Asia and Africa. The projected trends in the prevalence of underweight children combined with the different population growth these regions are experiencing (increasing in Africa, decreasing in Asia)[11] will narrow the gap between their respective contributions to the total number of underweight children. While in 1990, of 100 underweight children, 80 were estimated to live in Asia and 16 in Africa;

in 2015, these numbers are expected to change to 60 and 38, respectively, if recent trends continue.

Our study has a number of limitations. First, the availability of trend data is limited for a number of countries and some have not yet conducted national surveys. Second, surveys were not done randomly. Depending on where and when surveys were conducted, this may have biased our estimates of past and future prevalences. Third, although the surveys included in the WHO database undergo data quality control that results in the exclusion of surveys with obvious flawed data,[9] there are variations in data quality between the different surveys included in the analysis. Fourth, when estimating prevalence trends we did not account for uncertainty in each survey's prevalence estimate, that is, the estimate of the variance of each prevalence was not included in the regression analysis. As a result, our CIs are likely to be

too narrow. Similarly, for constructing the CIs for the number of underweight children, the uncertainty around the population estimates was not considered. Lastly, the precision of the estimates of the prevalence and numbers of underweight children, as expressed by the 95% CIs, varies depending on the availability of data for each region. The developed countries and the subregion of Western Asia present large CIs for the 2015 projections, which result in wide CIs for the relative percentage change between 1990 and 2015. Despite these limitations and the inherent speculative nature of extrapolations to 2015, the present estimates provide a useful base for monitoring progress toward the achievement of the goal.

The deteriorating situation in Africa is likely to be partly due to the effect of the human immunodeficiency virus and AIDS epidemic, together with the political and social instability ex-

Figure 2. Geographical Pattern of Underweight in Children Younger Than 5 Years
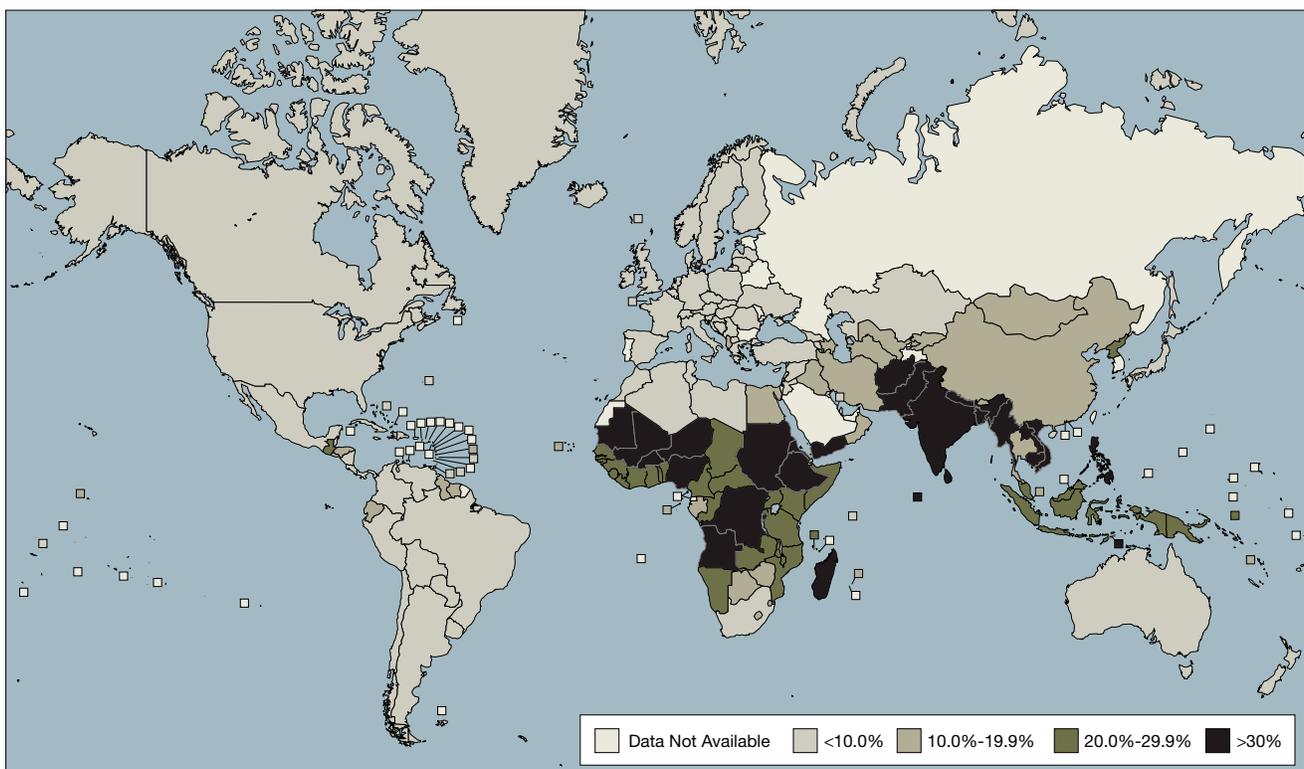
Percentage with weight 2 SDs below the mean weight for age of the reference population from the National Center for Health Statistics and World Health Organization. Geographical distribution of the prevalence of underweight children based on latest survey data.

perienced in many African countries. The disease has both a direct and indirect effect: infected children are more likely to be underweight, but also AIDS orphans or children of parents affected by AIDS are at increased risk of becoming malnourished. In sub-Saharan Africa, an estimated 333 000 children younger than 5 years died in 1999 with human immunodeficiency virus infection[18] and 11 million are estimated to be orphaned because of AIDS.[19] The predictions of childhood underweight made for 2015 might be underestimates if the human immunodeficiency virus and AIDS epidemic worsens in Africa.

Economic progress is a major determinant for improving childhood nutrition. Higher purchasing power enables improved dietary intake in terms of both quality and quantity. Countries in Asia, such as China and Vietnam, have experienced rapidly growing economies and changes in lifestyles.[20,21] Consequently, child-

hood nutritional status has been improving in these countries. The improvement in some areas has even moved beyond what is desirable and has lead to an increase in childhood overweight.[20,22] An analysis of childhood overweight in developing countries reported that 16 of the 38 countries with more than 1 national survey showed a rising trend in overweight.[23]

The Millennium Development goals are intended to focus attention on the most critical problems and to maintain that focus by monitoring progress toward the achievement of specific goals. For childhood underweight, there are many countries for which national data are still not available. For this group, surveys would need to be conducted to have a baseline against which to assess progress. Moreover, because subnational differences in the prevalence of underweight children can be substantial, it is recommended to map underweight hot spots for better targeting of interventions aimed at pre-

venting and treating childhood undernutrition. These interventions are particularly important during the period from birth to age 3 years—the critical time in which growth failure and malnutrition occur.[24]

REFERENCES

1. UN General Assembly. UN Res A/55/2 (2000).
2. United Nations. Millennium development goals. Available at: http://www.un.org/millenniumgoals. Accessed May 1, 2002.
3. Chang SM, Walker SP, Grantham-McGregor S, Powell CA. Early childhood stunting and later behaviour and school achievement. *J Child Psychol Psychiatry*. 2002;43:775-783.
4. Martorell R, Rivera J, Kaplowitz H, Pollitt E. Long-term consequences of growth retardation during early childhood. In: Hernandez M, Argente J, eds. *Human Growth: Basic and Clinical Aspects*. Amsterdam, the Netherlands: Elsevier; 1992:143-149.
5. Walker SP, Grantham-McGregor SM, Powell CA, Chang SM. Effects of growth restriction in early childhood on growth, IQ, and cognition at age 11 to 12 years and the benefits of nutritional supplementation and psychosocial stimulation. *J Pediatr*. 2000; 137:36-41.
6. Pelletier DL, Frongillo EA. Changes in child survival are strongly associated with changes in malnutrition in developing countries. *J Nutr*. 2003;133:107-119.
7. Ezzati M, Lopez AD, Rodgers A, Vander Hoorn S, Murray CJL, and the Comparative Risk Assessment Collaborating Group. Selected major risk factors and global and regional burden of disease. *Lancet*. 2002;360: 1347-1360.
8. Caulfield LE, de Onis M, Blössner M, Black RE. Un-

dernutrition as an underlying cause of child deaths associated with diarrhea, pneumonia, malaria and measles. *Am J Clin Nutr*. In press.
9. de Onis M, Blössner M. The World Health Organization Global Database on Child Growth and Malnutrition: methodology and applications. *Int J Epidemiol*. 2003;32:518-526.
10. de Onis M, Frongillo EA, Blössner M. Is malnutrition declining? an analysis of changes in levels of child malnutrition since 1980. *Bull World Health Organ*. 2000;78:1222-1233.
11. Department of Economic and Social Affairs, UN Population Division. *World Population Prospects: the Sex and Age Distribution of the World Population, the 2000 Revision*. New York, NY: United Nations; 2001.
12. Laird NM, Ware JH. Random-effects models for longitudinal data. *Biometrics*. 1982;38:963-974.
13. Goldstein H. *Multilevel Statistical Models*. 2nd ed. London, England: Arnold; 1995.
14. Verbeke G, Molenberghs G. *Linear Mixed Models for Longitudinal Data*. New York, NY: Springer-Verlag; 2000.
15. Agresti A. *Categorical Data Analysis*. New York, NY: John Wiley and Sons; 1990.
16. WHO Expert Committee Report. *Physical Status: the Use and Interpretation of Anthropometry*. Geneva, Switzerland: World Health Organization; 1995. Technical report series 854.

17. WHO Global Database on Child Growth and Malnutrition. Available at: http://www.who.int /nutgrowthdb. Updated November 2003. Accessed April 27, 2004.
18. Walker N, Schwartländer B, Bryce J. Meeting international goals in child survival and HIV/AIDS. *Lancet*. 2002;360:284-288.
19. UNICEF. *The State of the World's Children 2004*. New York, NY: UNICEF; 2004.
20. Luo J, Hu FB. Time trends of obesity in preschool children in China from 1989 to 1997. *Int J Obes Relat Metab Disord*. 2002;26:553-558.
21. Hop le T. Programs to improve production and consumption of animal source foods and malnutrition in Vietnam. *J Nutr*. 2003;133(11 suppl 2):4006S-4009S.
22. Sakamoto N, Wansorn S, Tontisirin K, Marui E. A social epidemiologic study of obesity among preschool children in Thailand. *Int J Obes Relat Metab Disord*. 2001;25:389-394.
23. de Onis M, Blössner M. Prevalence and trends of overweight among preschool children in developing countries. *Am J Clin Nutr*. 2000;72:1032-1039.
24. Shrimpton R, Victora CG, de Onis M, Lima RC, Blössner M, Clugston G. Worldwide timing of growth faltering: implications for nutritional interventions. *Pediatrics*. 2001;107:E75.