

Worldwide prevalence of anemia in pre-school aged children, pregnant women and non-pregnant women of reproductive age*



Erin McLean¹



Ines Egli³



Bruno de Benoist¹



Daniel Wojdyla⁴

and Mary Cogswell²

¹Department of Nutrition for Health and Development, World Health Organization, Geneva, Switzerland

²Division of Nutrition and Physical Activity, Centers for Disease Control and Prevention, Atlanta, USA

³Human Nutrition Laboratory, Swiss Federal Institute of Technology, Zurich, Switzerland

⁴Escuela de Estadística, Universidad Nacional de Rosario, Rosario, Argentina

Contact: debenoistb@who.int

* Two of the authors are staff member of the World health Organization. They alone are responsible for the views expressed in this publication and they do not necessarily represent the decisions, policy or views of the World Health Organization. Moreover the findings and conclusions in this report are those of the authors and do not necessarily represent the views of CDC.

ERIN MCLEAN

Erin obtained her PhD in Nutrition from the University of California, Davis, USA. She is currently working as a Technical Officer for the Micronutrient Program in the Department of Nutrition for Health and Development at the World Health Organization in Geneva, Switzerland. Erin's primary work is with the Micronutrient Deficiency Information System, developing regional and global prevalence estimates for anemia.

MARY COGSWELL

Mary obtained her PhD. in nutritional epidemiology from Johns Hopkins University, School of Hygiene and Public Health, Baltimore, USA. She is currently an epidemiologist with the Division of Nutrition and Physical Activity, Centers for Disease Control and Prevention. Mary collaborates with and provides consultation to state health departments, universities, international organizations, and other constituents on nutrition assessment, surveillance, and evaluation of programs. She has over 50 publications in peer-reviewed journals and has won awards for her research on perinatal nutrition and on the assessment and prevention of iron deficiency.

INES EGLI

Ines has a PhD in Nutrition from the Swiss Federal Institute of Technology (ETH), Zurich, Switzerland.

She is currently a senior scientist and lecturer at the Human Nutrition Laboratory at ETH where she supervises research projects on mineral bioavailability and infant nutrition, and leads a postgraduate course in Nutrition and Health. She has also worked in the Nutrition Department of the World Health Organization in the area of micronutrient deficiencies with a special focus on iron, iodine, and vitamin A.

DANIEL WOJDYLA

Daniel has an MSc in Biostatistics from the University of North Carolina, Chapel Hill, USA. He is currently Adjunct Professor in the School of Statistics of the National University of Rosario, Rosario, Argentina and is also a statistician at the Rosario Center for Perinatal Studies (CREP), where he is in charge of statistical analyses for clinical trials and epidemiologic studies on reproductive health.

BRUNO DE BENOIST

Bruno is a paediatrician. He obtained his MD from the University of Paris, France, and an MSc in Nutrition from the London School of Hygiene and Tropical Medicine, UK. He is currently Coordinator of the Micronutrient Unit at the World Health Organization, Geneva, Switzerland. His special interest is micronutrient disorders and their relation to public health and food fortification.

INTRODUCTION

Anemia is a widespread public health problem associated with an increased risk of morbidity and mortality, especially in pregnant women and young children (1). Among the numerous factors, both nutritional (such as vitamin and mineral deficiencies) and non-nutritional (such as infection and hemoglobinopathies), that contribute to the onset of anemia, iron deficiency and malaria play an important role. Given the role of iron in oxygen transport and the low levels of available iron in the diets of a large proportion of the global population, it is assumed that iron deficiency is one of the biggest contributing factors to the global burden of anemia. Iron deficiency is considered one of the ten leading global risk factors in terms of its attributable disease burden.

One of the mandates of the World Health Organization (WHO) is to inform its Member States about the global health situation. Previous estimates of anemia prevalence were made for all population groups in 1985 (2) and 2001 (3), while estimates of anemia prevalence in women were made in 1982 (4) and 1992 (5). For these estimates, the data were collected prior to 1990, with the exception of the 2001 estimates, which included data up to 1995, but did not include detailed description of the methodology on how the estimates were derived (3). Thus, it is time to update the global anemia estimates and provide a current picture of the global situation, especially in the most affected groups – women and young children. The objective of this paper is to present estimates of anemia prevalence in preschool aged children, pregnant women and nonpregnant women at global and regional levels, using data collected by WHO for the Vitamin and Mineral Nutrition Information System (VMNIS) (<http://www.who.int/vmnis>). These estimates are based on the 192 Member States of WHO, which represent 99.8% of the global population.

METHODOLOGY

Data collection

We used data from the VMNIS, which are collected from scientific literature and from partners, including WHO Regional and Country offices, United Nations organizations, Ministries of Health, research and academic institutions, and non-governmental organizations. We searched MEDLINE and WHO Regional databases systematically, and manually searched for articles published in non-indexed medical and professional journals. We included surveys in the VMNIS only if hemoglobin was measured from capillary, venous, or cord blood using quantitative photometric methods or automated cell counters and if anemia prevalence or mean hemoglobin concentrations were reported, while we excluded surveys that measured only clinical signs of anemia or hematocrit. For the VMNIS, we included data representative of any administrative level within a country, including nationally representative data, surveys representative of a Region, the first administrative level boundary, second administrative level boundary, or local surveys.

Data selection for the estimates

We selected survey data from the VMNIS on hemoglobin concentration and/or anemia prevalence for each country using four criteria: the time frame in which the survey took place, the administrative level for which the survey was representative (national or sub-national), the survey sample size, and the population groups surveyed.

The time frame for the current estimates is 1993–2005. If no survey date was provided, we used the date of publication. Nationally representative surveys were used preferentially for country estimates. If two or more national surveys were available, we used the most recent. When a

national survey was unavailable for a country, if two or more surveys representative of the first administrative boundary within a country (e.g., state, province, etc.) were available we pooled them, weighted by the population size of the area they represented and used them as representative of the entire country. A sample size of 100 or more was generally required although we made some exceptions. If the sample size was between 50 and 100 and the results were being extrapolated to fewer than 50,000 people or to pregnant women, for whom the number of women included is usually small, we used the data. When a country did not have data that met these criteria, we estimated the prevalence using prediction models.

Population

We defined the population groups as follows: preschool aged children (0–4.99 years), pregnant women (no age range defined), nonpregnant women (15.00–49.99 years). Wherever possible, children below 0.5 years of age were excluded from the estimate for preschool aged children since the cut-off for anemia is not defined in this age group. However, the estimate was applied to the entire population of children less than 5 years of age. Occasionally, in the nonpregnant women group, pregnant women could not be excluded because all women were included in the figure provided by the country report, but pregnant women usually made up a small proportion of the group and thus their exclusion would not be expected to change the figure significantly. If a survey reported results by physiological status, lactating women were combined with other nonpregnant nonlactating women to provide the estimate for nonpregnant women.

Hemoglobin threshold

The hemoglobin concentration cut-offs to define anemia are the WHO-recommended cut-offs for each population group (3): 110 g/L for preschool

aged children and pregnant women and 120 g/L for nonpregnant women. If anemia prevalence was adjusted for altitude or smoking in a survey, the adjusted figure was used since there is statistical and physiological evidence to support that hemoglobin distributions vary under these conditions (6, 7). However, we did not adjust data not already adjusted and we did not accept any other corrections.

Anemia prevalence from survey data

When the anemia prevalence was reported using the appropriate hemoglobin threshold, we used the data provided in the survey. However, if surveys provided mean hemoglobin concentration or only anemia prevalence for an alternative cut-off, we derived the prevalence by assuming a normal distribution of hemoglobin and utilizing other information provided about the population's hemoglobin concentration. We utilized, in order of preference: the mean and standard deviation provided in the survey, the mean hemoglobin concentration alongside the prevalence for an alternative cut-off to derive a standard deviation, or the prevalence for an alternative cut-off and an average standard deviation derived for the population group from data in the VMNIS. Since hemoglobin concentrations are likely to be skewed towards lower values in a population with a high prevalence of deficiency, we may have slightly overestimated anemia prevalence in some populations.

In cases where disaggregated data were provided or where subnational data were used, we pooled the data. For data disaggregated by age, physiological status or any other classification, we derived anemia prevalence by weighting each prevalence estimate by its sample size. For subnational data, we weighted the data by the general population estimate for that area using the most recently available census data for the country between 1993 and 2005.

We considered each estimate representative of the entire country whether from national or subnational data. For each estimate, we calculated the variance in the logit scale using the sample size and generated a 95% confidence interval as a measure of uncertainty, which was back-transformed to the original scale (8, 9). We used a design effect of two to calculate the confidence interval, since the majority of the surveys employed cluster sampling, but did not provide an estimate of their design effect.

Models to estimate anemia prevalence for countries with no eligible data

The level of development and the health of a population are closely related. For this reason, we developed regression models to predict anemia prevalence in countries with no eligible data, using health and development indicators. We started with the 2002 Human Development Index (HDI) score, a numerical reflection of development produced by the United Nations Development Programme (UNDP) and comprising indicators of life expectancy, education and wealth (10). For the 17 WHO Member States with no HDI score produced by UNDP, an estimate of the HDI score was generated using a regression model and the same indicators for life expectancy and wealth, but a proxy indicator for education (11–13). HDI explained 22.4–48.9% of the variation in anemia prevalence in countries with survey data for the three population groups. To further improve the model, we included other health indicators available from WHO statistics (available for ≥ 190 of 192 WHO Member States) as potential explanatory variables. Some of these additional indicators significantly improved the anemia prediction model and we kept them in the model. For preschool aged children ($n=82$), the additional variables were expenditure on health and adult female mortality, which together with HDI explained 55% of the variation in anemia prevalence. In pregnant women ($n=60$), immunization for DTP3 before 1 year of age,

expenditure on health and adult male mortality were utilized alongside HDI to predict anemia, explaining 32.3% of the variation in prevalence. To predict anemia prevalence for nonpregnant women, population growth rate and expenditure on health with HDI explained 45.3% of the variation. For these estimates, we calculated the variance based on the regression equations and produced 95% confidence intervals as a measure of uncertainty.

Classification of anemia as a public health problem

The prevalence of anemia as a public health problem is categorized as follows: $<5\%$, no public health problem; 5–19.9%, mild public health problem; 20–39.9%, moderate public health problem; $\geq 40\%$, severe public health problem (3).

Population coverage, population proportion and number of individuals with anemia

We based these estimates on the 192 WHO Member States, which represent 99.8% of the global population. We calculated the population figures using the 2006 population projection from the 2004 revision of the United Nations Population Division (14). We calculated the population figures for pregnant women based on the total number of births (time period 2005–2010) by assuming one child per woman per year, not taking into account spontaneous and induced abortions (14). For 15 countries with a small population (0.01% of all women), birth data were unavailable and we estimated the population figure by applying the WHO regional birth average per reproductive age woman (15.00–49.99 years) to the number of reproductive age women in that country.

We estimated the population coverage by summing the population in countries with estimates based on survey data and dividing this figure by the total population of that population group.

Table 1.1: Percentage of the population covered by actual survey data globally and by UN Region.¹

Population group ²	Global	Africa	Asia	Europe	LAC	NA	Oceania
PreSAC	76.1	76.7	82.1	19.2	70.5	92.4	5.1
PW	69.0	65.3	80.9	0.9	38.4	92.8	4.7
NPW	73.5	63.6	88.8	23.9	37.5	89.9	16.5

¹ WHO Member States are stratified by United Nations Regions: Africa, Asia, Europe, Latin America and the Caribbean (LAC), Northern America (NA), and Oceania.

² Population groups: PreSAC, preschool aged children (0.00–4.99y); PW, pregnant women (no age range defined); NPW, non-pregnant women (15.00–49.99y).

Table 1.2: Anemia in preschool aged children, pregnant women and non-pregnant women globally and by Region.

Area	PreSAC ¹		PW		NPW	
	Prevalence (%) ³	# affected (millions)	Prevalence (%) ³	# affected (millions)	Prevalence (%) ³	# affected (millions)
Global	47.4 (45.7–49.1)	293.1 (282.8–303.5)	41.8 (39.9–43.8)	56.4 (53.8–59.1)	30.2 (28.7–31.6)	468.4 (446.2–490.6)
<i>UN Region²</i>						
Africa	64.6 (61.7–67.5)	93.2 (89.1–97.4)	55.8 (51.9–59.6)	19.3 (18.0–20.7)	44.4 (40.9–47.8)	82.9 (76.5–89.4)
Asia	47.7 (45.2–50.3)	170.0 (161.0–178.9)	41.6 (39.0–44.2)	31.7 (29.7–33.6)	33.0 (31.3–34.7)	318.3 (302.0–334.6)
Europe	16.7 (10.5–23.0)	6.1 (3.8–8.4)	18.7 (12.3–25.1)	1.4 (0.9–1.8)	15.2 (10.5–19.9)	26.6 (18.4–34.9)
LAC	39.5 (36.0–43.0)	22.3 (20.3–24.3)	31.1 (21.8–40.4)	3.6 (2.5–4.7)	23.5 (15.9–31.0)	33.0 (22.4–43.6)
NA	3.4 (2.0–4.9)	0.8 (0.4–1.1)	6.1 (3.4–8.8)	0.3 (0.2–0.4)	7.6 (5.9–9.4)	6.0 (4.6–7.3)
Oceania	28.0 (15.8–40.2)	0.7 (0.4–1.0)	30.4 (17.0–43.9)	0.2 (0.1–0.2)	20.2 (9.5–30.9)	1.5 (0.7–2.4)

¹ Population groups: PreSAC, preschool aged children (0.00–4.99y); PW, pregnant women (no age range defined); NPW, non-pregnant women (15.00–49.99y).

² WHO Member States are stratified by United Nations Regions: Africa, Asia, Europe, Latin America and the Caribbean (LAC), Northern America (NA), and Oceania.

³ 95% CI

We estimated the number of individuals with anemia for each country and grouping of countries for all population groups based on the estimated proportion of the population with anemia for every country and presented the 95% confidence intervals as a measure of uncertainty.

Combining national estimates

We combined country estimates to provide estimates at the global level as well as by United Nations Region by pooling the data and weighting it by the population that each estimate represented. We constructed a 95% confidence interval by using the estimated variance of the weighted average. For one country without data, no proxy indicators were available and so no country estimate was generated, but the UN subregional estimate had to be applied to that country to make regional and global estimates.

RESULTS

All three population groups were covered by a significant amount of actual data, which covered between 69.0–76.1% of the population in all groups (**Table 1.1**). Coverage varied by UN Region and was highest in Northern America, Asia, and Africa, while it was lower in Europe and Oceania. Only preschool children had eligible subnational data, which covered a small proportion of the population (3.7%) and the coverage of this group by national data remained high at 72.3%.

The global prevalence of anemia in preschool aged children, pregnant women and nonpregnant women is 47.4%, 41.8%, and 30.2% respectively. These estimates, the number of individuals affected, and the information from UN Regions are presented in **Table 1.2**. Globally, 818 million (95% CI; 751–885) women (both pregnant and nonpregnant) and young children suffer from anemia and over half of these, approximately 520

million (95% CI: 493–547), live in Asia. The highest prevalence of anemia is in Africa for all three population groups, but the greatest number of people affected are in Asia, where 58.0%, 56.1%, and 68.0% of the global anemia burden exists in preschool aged children, pregnant women and nonpregnant women respectively.

Anemia as a public health problem

Anemia is a worldwide public health problem. More than half the world's population of preschool aged children and pregnant women reside in countries where anemia is a severe public health problem (56.3% and 57.5% respectively) (**Table 1.3**). The proportion is lower for nonpregnant women of childbearing age, but still significant (29.6%). The degree of severity of the public health problem by country for preschool aged children, pregnant women, and nonpregnant women is presented in **Figures 1.1–1.3**. Countries with anemia as a severe public health problem were grouped in Africa, Asia, and Latin America and the Caribbean.

DISCUSSION

Globally, almost half of preschool aged children and pregnant women and close to one third of nonpregnant women suffer from anemia. Since a large segment of the population is covered by actual survey data (69.0–76.1%), these estimates are likely to reflect the actual global prevalence of anemia for these population groups. However, UN regional estimates may be more accurate for some populations and in some areas since the coverage varies significantly among regions. For all three groups, the coverage is the greatest in three UN regions: North America, Asia, and Africa. North America is the best covered, but the number of countries in this region is much lower (two countries) than in the African (53 countries) and Asian (47 countries) UN regions. The coverage in the European and Oceania

Table 1.3: Anemia as a public health problem¹ in WHO Member States.

Level of public health problem	PreSAC ²		PW		NPW	
	# of countries	Total population 1000's (%) ³	# of countries	Total population 1000's (%)	# of countries	Total population 1000's (%)
None	2	20570 (3.3)	0	0 (0.0)	1	4171 (0.3)
Mild	40	40921 (6.6)	33	11156 (8.3)	59	647857 (41.7)
Moderate	81	208472 (33.7)	91	46162 (34.2)	78	441285 (28.4)
Severe	69	348322 (56.3)	68	77466 (57.5)	54	459518 (29.6)
	192	618285	192	134783	192	1552831

¹ The prevalence of anemia as a public health problem is categorized as follows: <5%, no public health problem; 5–19.9%, mild public health problem; 20–39.9%, moderate public health problem; ≥40%, severe public health problem.

² Population groups: PreSAC, preschool aged children (0.00–4.99y); PW, pregnant women (no age range defined); NPW, nonpregnant women (15.00–49.99y).

³ This is the percentage of preschool aged children who live in countries where anemia presents this level of a public health problem.

regions is low, where data are available for less than one quarter of the population in all groups. In Latin America and the Caribbean, coverage for preschool aged children is similar to coverage in Asia or Africa, but for pregnant and nonpregnant women it is about half the coverage found in Asia and Africa.

The pattern of anemia prevalence by region is similar for the three groups, Africa and Asia being the most affected. These regions are the poorest and this may therefore reflect the link between anemia and development. Compared to North America, anemia is three times more prevalent in Europe. One reason may be that the European region includes countries with a range of social and economic profiles, especially in the Eastern subregion. However, the difference remains when North America is compared to Western or Northern Europe, where the countries have more similar economic profiles to those in North America (data not shown). It may also be the result of the low coverage of anemia survey data in Europe compared to North America. Finally, it could be that in North America foods are widely fortified

with iron and a high proportion of iron intake comes from fortified foods (15).

The current estimates are the first to utilize nationally representative data for China, which accounts for 20% of the global population. Furthermore, the majority of the surveys used are nationally representative, which was not the case for previous estimates. Surveys are also based on larger sample sizes than many of the previous estimates. For example, the median sample size in our estimates was 2,580 preschool aged children, 611 pregnant women, and 4,265 nonpregnant women; while in the DeMaeyer estimates, the median number of subjects was 500 for all population groups (2). Finally, in these estimates, we used regression-based equations to generate estimates for countries with no eligible data, considering the country's health and development situation. In previous estimates, neighbouring country information or regional estimates were applied to countries without data.

These estimates are not quantitatively comparable to previous estimates since the methodolo-

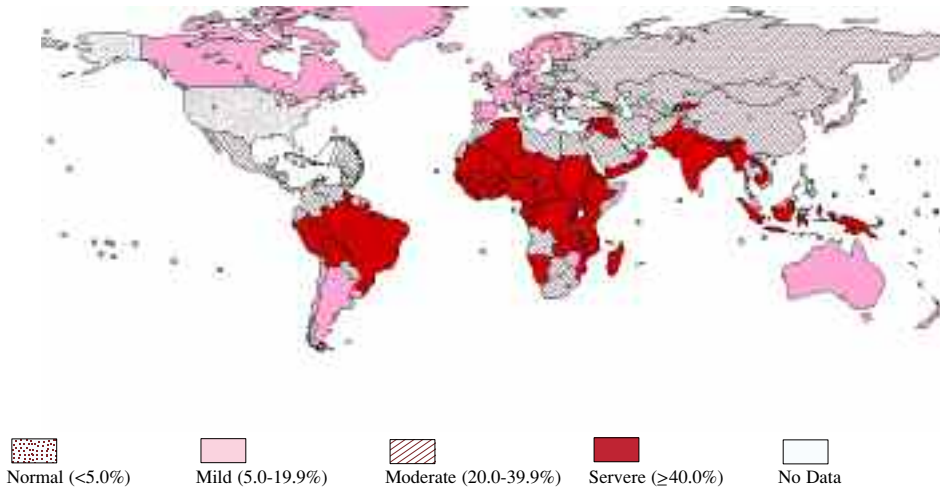


Figure 1.1: Anemia as a public health problem in preschool aged children.

The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement. © WHO 2005. All rights reserved

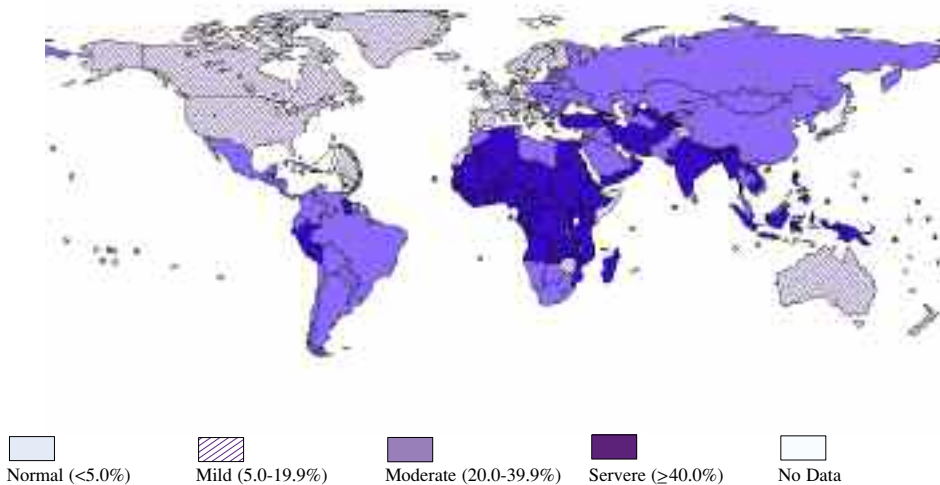


Figure 1.2: Anemia as a public health problem in pregnant women.

The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement. © WHO 2005. All rights reserved

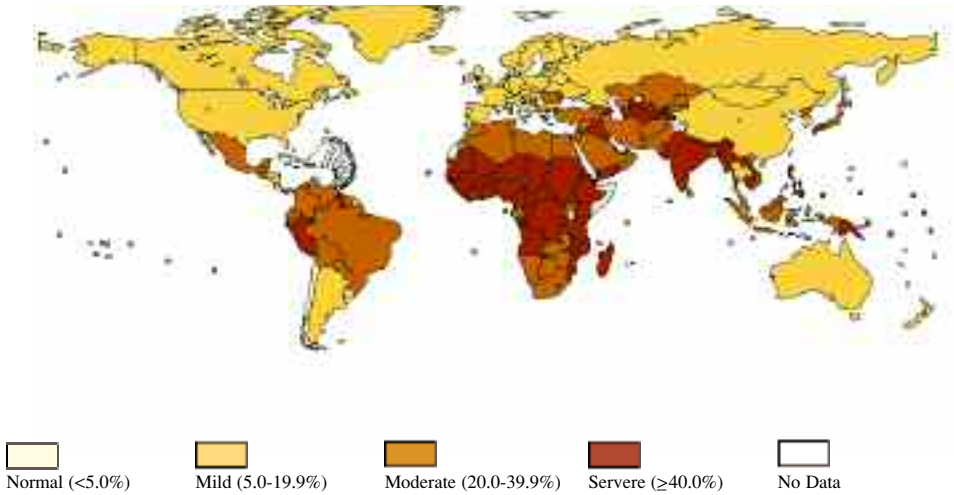


Figure 1.3: Anemia prevalence in non-pregnant women.

The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement. © WHO 2005. All rights reserved

gies used are so different. However, it is interesting to note that DeMaeyer's anemia estimates (which excluded China) were 43% for preschool aged children, 51% in pregnant women, and 35% in all reproductive aged women. When we exclude China from our estimates, the prevalence of anemia is respectively 52%, 44%, and 34%. The variation in methods and a larger number of nationally representative surveys in the current estimates compared with previous estimates may be responsible for these differences.

In 1992, WHO published the anemia prevalence estimates of 37%, 51%, and 35% for all women, pregnant and nonpregnant respectively. These estimates included subnational data for China. Current estimates of 31%, 42%, and 30% are lower, but this change may be accounted for by the considerable difference in methods and coverage of national surveys.

The current estimates do have some limitations. Firstly, we treated all surveys as equal

despite the fact that quality varies greatly and adjustments are made in some surveys for population representativeness, smoking or altitude, but not in others. Secondly, some surveys covered only a segment of the population group (e.g., 3.00–4.99 years for preschool aged children), but we used these data to make an estimate for the entire population group. Similarly, the estimates for pregnant women do not take into account the trimester assessed by the surveys since it is rarely reported. However, this could affect the estimate of anemia prevalence, since prevalence is likely to be lower early in pregnancy. Also, subnational data were treated equally to national data even though they may actually under- or over-estimate the prevalence of anemia depending on the reasons for which the survey was conducted. Finally, we had to adjust hemoglobin concentrations for country estimates which did not present the prevalence of anemia for the appropriate threshold and we based this adjustment on normal hemoglobin distribution. In fact, the distribution may be negatively skewed in populations with a

high prevalence of anemia and we may have slightly over-estimated the anemia prevalence in these populations.

These data on anemia prevalence are based on the best available information and they are a good starting point to track progress in eliminating anemia. However, additional information would allow interventions to be more targeted and specific.

Anemia in children less than two years of age is of greatest concern since their rapid growth requires a high intake of iron which is frequently not covered by their diet. It was not possible to estimate the anemia prevalence in this group separately because of insufficient data. However, given that almost half the global population of preschool aged children suffer from anemia, with a prevalence as high as 64.6% in Africa and 47.7% in Asia, and that we know anemia prevalence is higher in the group of children less than two years old, we would expect that anemia in this age group is a major global public health problem, especially in low income countries.

Based on these estimates of anemia prevalence, the magnitude of nutritional anemia or even of iron deficiency anemia is difficult to assess since most anemia surveys in the WHO VMNIS do not address the causes of anemia and are restricted solely to measuring hemoglobin. More specifically, few surveys provide information on iron deficiency, on the relative proportions of anemia with concomitant iron deficiency, or on iron deficiency with concomitant anemia. The surveys that do provide information on iron deficiency often use different indicators and thresh-

olds. The assumption in designing anemia surveys is that iron deficiency is the main cause of anemia and therefore anemia prevalence can be used as a proxy for iron deficiency prevalence. Previously, the US NHANES 1976–80 data were utilized to estimate iron deficiency from the prevalence of anemia (3, 16) and it has been suggested that when anemia prevalence is 20%, iron deficiency exists in 50% of the population, and when anemia prevalence is greater than 40%, the entire population suffers from some degree of iron deficiency. This assumption may apply to countries with a high prevalence of anemia and iron deficiency where the primary cause of anemia is iron deficiency, but does not necessarily hold in situations where the prevalence of anemia and iron deficiency are low or where factors other than iron deficiency (other nutritional deficiencies, malaria, infections) cause anemia (17).

In spite of its limitations, anemia prevalence data remains an important indicator of public health since anemia is related to morbidity and mortality in the population groups usually considered the most vulnerable – preschool aged children and pregnant women. At a global level, anemia prevalence is a useful indicator to assess the impact of widespread or highly effective interventions and to track the progress made towards the goal of reducing anemia in pregnant women and preschool children by one third that was adopted by the UN Special Session on Children in 2002 (18). However, in order to make full use of these prevalence data, information on the cause of anemia should be collected in any anemia survey so that interventions for anemia control can be better adapted to the local situation and can therefore be more effective.

REFERENCES

1. World Health Organization. The world health report 2002: reducing risks, promoting healthy life. Geneva: WHO, 2002.
2. DeMaeyer E, Adiels-Tegman M. The prevalence of anaemia in the world. *World Health Stat Q* 1985;38:302–16.
3. UNICEF/UNU/WHO. Iron deficiency anaemia: assessment, prevention, and control. A guide for programme managers. WHO/NHD, 2001 [report no. 01.3].
4. Royston E. The prevalence of nutritional anaemia in women in developing countries: a critical review of available information. *World Health Stat Q* 1982;35:52–91.
5. World Health Organization. The prevalence of anaemia in women: a tabulation of available information. WHO/MCH/MSM, 1992 [report no. 92.2].
6. Hurtado A, Merino C, Delgado E. Influence of anoxemia on haematopoietic activities. *Arch Int Med* 1945;75:284–323.
7. Nordenberg D, Yip R, Binkin NJ. The effect of cigarette smoking on hemoglobin levels and anemia screening. *JAMA* 1990;264:1556–9.
8. Lohr SL. Sampling: design and analysis. Pacific Grove, CA: Duxbury Press, 1998.
9. Wackerly D, Mendenhall W, Scheaffer RL. Mathematical statistics with applications. Pacific Grove, CA: Duxbury Press, 2001.
10. United Nations Development Programme. Human development indicators. In: Murphy C, Ross-Larson B, eds. Human development report 2004. New York: UNDP, 2004:139–250.
11. World Health Organization. The world health report 2004 – changing history. Geneva: WHO, 2004.
12. World Health Organization. The world health report 2000 – health systems: improving performance. Geneva: WHO, 2000.
13. Mathers CD, Loncar D. Projections of global mortality and burden of disease from 2002 to 2030. *PLoS Med.* 2006;3:e442.
14. United Nations Population Division. World Population Prospects - the 2004 revision. New York: UN, 2005.
15. Hurrell RF, Jacob S. Role of the food industry in iron nutrition: iron intake from industrial food products. In: Hallberg L, Asp NG, eds. Iron nutrition in health and disease. London: John Libbey & Co., 1996:339–47.
16. Dallman PR, Yip R, Johnson C. Prevalence and causes of anemia in the United States, 1976 to 1980. *Am J Clin Nutr* 1984;39:437–45.
17. Asobayire FS, Adou P, Davidsson L, Cook JD, Hurrell RF. Prevalence of iron deficiency with and without concurrent anemia in population groups with high prevalences of malaria and other infections: a study in Cote d'Ivoire. *Am J Clin Nutr* 2001;74:776–82.
18. United Nations Children's Fund. A world fit for children: millennium development goals; special session on children documents; the convention on the rights of the child. New York: UNICEF, 2004.