# Prevalence of anemia in children 1 to 12 years of age. Results from a nationwide probabilistic survey in Mexico

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Abstract
**Objective**. To describe the epidemiology and analyze factors associated with iron deficiency anemia in a probabilistic sample of the Encuesta Nacional de Nutrición 1999 (ENN-99) [National Nutritional Survey 1999 (NNS-99)]. **Material and Methods**. The sample included 8 111 children aged 1 to 12 years, and was nationaly representative by rural and urban strata and by four geographical regions. Capillary hemoglobin was measured using a portable photometer (HemoCue). The analysis of the determining factors of anemia was performed by odds ratios derived from a logistic regression model and multiple regression models. **Results**. The prevalence of anemia was 50% in infants <2 years of age, with no significant differences between urban and rural strata or among regions. It varied between 14 and 22% in 6-11 year-old children and was higher in the South region and among the indigenous children. Dietary intake of iron was 50% of the recommended daily allowance in children <2 years of age, but not in older children. Phytate (≈500-800 mg/d) and tannin (≈19 mg/d) intakes were very high in children over 7 years of age. Hemoglobin was positively associated with nutritional status of children ($p$=0.01), socioeconomic status ($p$ range 0.05-0.001), duration of lactation in children under 2 years of age ($p$=0.1), and iron and calcium intake ($p$=0.02), but not with folic acid or vitamin B12 intake. Hemoglobin was negatively associated with maternal education ($p$=0.01) in older children, but not in those under 2 years of age. **Conclusions**. We present evidence of an alarming national epidemic of anemia, particularly marked

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Resumen
**Objetivo**. Describir la epidemiología y analizar los determinantes de la anemia en una muestra probabilística de la Encuesta Nacional de Nutrición 1999 (ENN-99). **Material y métodos**. La muestra del estudio, hecho en 1999, incluyó 8 111 menores de entre 1 a 12 años de edad, representativa a escala nacional, de estratos rural y urbano y de cuatro regiones geográficas de México. La hemoglobina capilar fue medida mediante un fotómetro portátil (HemoCue). El análisis de los determinantes de anemia se hizo mediante razón de momios obtenidas con un modelo de regresión logística y modelos de regresión múltiple. **Resultados**. La prevalencia de anemia fue más alta (50%) en menores de dos años de edad, sin diferencias entre urbanos y rurales en las cuatro regiones geográficas. La prevalencia general de anemia varió entre 14 y 22% en niños y niñas de 6 a 12 años de edad, y fue más alta en la región sur y en los niños indígenas. La ingestión de hierro fue muy baja en menores de dos años de edad (50% de la ingesta diaria recomendada), pero no en los mayores; la ingestión de fitatos (≈500-800 mg/d) y taninos (≈19 mg/d) fue muy alta en niños >7 años de edad. El nivel de hemoglobina se asoció positivamente con el estado nutricio de los niños ($p$=0.01) y el nivel socioeconómico (intervalo $p$ 0.05-0.001); en menores de dos años de edad, se asoció con la duración del amamantamiento ($p$=0.1), la ingestión de hierro y de calcio ($p$=0.02), pero no con la ingestión de ácido fólico ni de vitamina B12. El nivel de hemoglobina se asoció negativamente con la educación materna ($p$=0.01) en niños mayores, pero no en menores de

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in children 12 to 24 months of age. The control of anemia should be considered as an urgent national concern given its grave consequences on the physical and mental development of these children and on their long-term health. The English version of this paper is available too at: http://www.insp.mx/salud/index.html

Key words: National Nutrition Survey; anemia, iron deficiency; infant; child, preschool; child; Mexico

dos años de edad. **Conclusiones**. Se presenta evidencia de una alarmante epidemia nacional de anemia en niños, especialmente preocupante en los menores de 24 meses de edad. La anemia debe considerarse como una emergencia nacional, debido a las graves consecuencias que tiene sobre el desarrollo físico y mental de niños y niñas y sobre su salud durante la vida adulta. El texto completo en inglés de este artículo también está disponible en: http://www.insp.mx/salud/index.html

Palabras clave: Encuesta Nacional de Nutrición; anemia ferropriva; lactante; infante; niño; México

Anemia is one of the most extensive pandemics, affecting mostly developing countries. About 3.5 billion persons are affected by anemia in developing countries.[1] In most cases anemia is caused by iron deficiency, although a smaller proportion is due to deficiencies of other micronutrients such as folate, and vitamins A and B12.[2] Some diseases accompanied by blood loss, parasitic infections such as filariasis, and chronic diarrhea, may also result in anemia.[3]

The presence of anemia in children under five years of age is of particular relevance because it negatively impacts mental development and future social performance. Children suffering from iron deficiency anemia during their first two years of life have slower cognitive development and poorer school performance and work capacity in later years.[4] Iron deficiency anemia has also been associated with a diminished ability to fight infections by impairing cell-mediated immunity, resulting in greater rates of morbidity due to acute infections.[5] Linear growth and physical work capacity, especially endurance exercise, are also negatively affected by iron deficiency anemia.[6]

The extent of the infant iron stores at birth is inversely proportional to the degree of maternal iron deficiency during pregnancy. Thus, maternal iron stores are associated with earlier development of anemia during infancy, frequently around 4 months of age.[7,8]

Published local surveys assessing the prevalence of anemia in children less than 12 years of age in Mexico were recently reviewed.[9] In this review the highest prevalence of anemia was found in children under 3 years of age, living in Mexico City (42.7 % for anemia, and 57% for iron deficiency),[10] and in children of low socioeconomic status aged 18 to 36 months, living in rural areas of the center plateau of Mexico (70% for anemia and 48% for iron deficiency).[11] Only one study from Durango State reported the prevalence of anemia in school children (16%).[12] Some other studies included in the above mentioned review, reported data that are not easily interpretable. Some drew their samples from populations seeking medical care in clinics, and in others, hemoglobin concentration was not corrected for altitude above sea level to set cutoff points for anemia.

This research describes the prevalence and distribution of anemia in a probabilistic sample of children aged 1 to 12 years, from the Second Mexican National Nutrition Survey (NNS-99), carried out from October 1998 to March 1999. The sample was calculated with a power to be representative nationwide, in four geographic regions, namely: North, Center, Metropolitan Mexico City, and South regions. Stratification by urban and rural areas was performed both at a national and regional level. Also, some potential determinants of anemia were explored using multiple regression models.

Because of their representativeness and timely reporting, study findings will be very useful for designing public nutrition programs, in addition to serving as a valuable instrument for decision-makers to implement effective nutritional interventions to fight against anemia and iron deficiency in Mexico.

## Material and Methods

Data were extracted from the database of the NNS-99. The methodology of this probabilistic survey was published in detail elsewhere.[13] Briefly, the sampling procedure included a randomized selection of households based on the household sampling frame provided by the Instituto Nacional de Estadistica, Geografía e Informática (INEGI), [National Institute of Statistics, Geography, and Informatics]. Two separate sub-samples made up of children under 5 years of age and children 6 to 11 years were selected from one out of every three of the 21 000 households sampled.

For the present analysis data from children under 12 years of age were analyzed for: hemoglobin concentration, birth date, gender, maternal education, socioeconomic status, ethnic origin, breast-feeding practices, consumption of dietary supplements, and food assistance program beneficiary status. Maternal education was stratified into five categories based on the education cycles completed: 1. No schooling, 2. Primary school (6 years). 3. Secondary school (9 years). 4. High school or higher (>12 years). Socioeconomic level was categorized using a scale constructed based on a principal components analysis of household belongings and characteristics. Ethnic origin was categorized as Indigenous for children of families in which at least one women 12-49 years spoke a native language.[13] Dietary supplements included vitamin and/or mineral preparations, or enriched food provided within a formal public nutrition intervention program. Food assistance was considered present when the family or the study subject were beneficiaries of any program providing food in kind or at subsidized prices.

Chronological age of children was divided into one-year intervals. Subjects were categorized as rural if they lived in a community with less than 2 500 inhabitants. Otherwise they were categorized as urban. The country was divided arbitrarily into four geographic regions. The North included the states of Baja California, Baja California Sur, Coahuila, Chihuahua, Durango, Nuevo León, Sonora and Tamaulipas. The Center included the states of Aguascalientes, Colima, Guanajuato, Jalisco, México, Michoacán, Morelos, Nayarit, Querétaro, San Luis Potosí, Sinaloa and Zacatecas. The region of Mexico City included the Federal District and the neighboring urban areas. The South included the states of Campeche, Chiapas, Guerrero, Hidalgo, Oaxaca, Puebla, Quintana Roo, Tabasco, Tlaxcala, Veracruz and Yucatán.

Hemoglobin concentrations were determined in a sample of capillary blood obtained by finger prick and measured by HemoCue. The HemoCue system is based on the principle that a dry reagent composed of sodium deoxicolate, sodium nitrite, and sodium azide coating the inside surface of a reactive plastic cuvette, transforms blood hemoglobin into azidemetahemoglobin and its absorbance is read in a portable photometer (HemoCue, Angelholm, Sweden) at two different wavelengths (570 and 880 nm) to compensate for sample turbidity.[14,15]

Each of the 21 field teams had a photometer. Variability of photometers was assessed during fieldwork twice a week using a three-level liquid quality control check (4C-ESControl, Beckman-Coulter, Miami, Fla., USA), and recording the readings of the control cuvette at the beginning and end of each working day. If the variation was greater than 0.3 g/dl, the photometer was serviced. The intra-observer variability was assessed by duplicate measurements of a blood sample, every twenty subjects screened. There were 582 duplicate human blood measurements and 273 measurements of the reference cuvette available for variability analysis per team. The average difference between duplicates was 0.03 +/- 0.99 g/dl, $p$=0.36 for human blood and -0.024 +/- 0.36 g/dl, $p$=-0.27 for the duplicates of the reference cuvette. Hemoglobin values below 4.5 g/dl and above 18.5 g/dl were considered as spurious and were excluded from the analysis.

Hemoglobin determinations of children living in communities located more than 1 000 m above sea level were corrected for by the following equation published by Ruiz-Argüelles *et al:*[16]

$$\text{Hb g/l}=(93.3197) * (10^{2.51 \times 10\text{-}5 \, * \text{altitude}})$$

Cutoff values to diagnose anemia in children were: 6-11.9 months old <95 g/l, 12-71 months old <110 g/l and 6-11 years of age <120 g/l, as recommended by INACG in 1989,[17] and by WHO in 1992.[18]

Children's micronutrient intake was assessed by 24-h recall by the mother. Nutrient values were calculated by multiplying the portion size in grams of a given food by its nutrient content per gram. Food composition data were obtained from a database in which micronutrient information was pooled at the Instituto Nacional de Salud Pública (National Institute of Public Health), Mexico, from 7 published food composition tables[19-24] and from the unpublished composition table: Información Nutricional de Marinela (Marinela [a food industry company] Nutritional Information).

Results from descriptive analysis are presented as prevalence of anemia and means and standard deviations of hemoglobin concentrations. The association of anemia with potential explanatory variables such as those indicative of nutritional status, dietary, and socioeconomic characteristics, maternal education, employment status, and literacy, was assessed by the odds ratio derived from a logistic regression model adjusted for complex sampling to minimize the effects of clustering. In a second series of regressions, hemoglobin concentration was introduced to the model as a dependent variable; the dietary intake of iron, folic acid, vitamin B12, and calcium were entered as independent variables. After prevalences were calculated, they were expanded to represent the original population using the formula:

$$FSV_w = \frac{Q}{PD\,(Vx)\,X}$$

Where:

PD($V_w$) = Probability of selecting one household for the dietary survey.
S = Number of households selected for blood sampling.
Q = Number of households selected for the dietary survey.

Expansion factors were calculated based on the characteristics of the national population in 1995.

Data were entered using the Clipper software program using data entry formats that included range and contingency validation checks (version 5.01 Nantucket™ Corporation 1991 S.F. California). Descriptive analysis was run in SPSS for Windows (version 10; SPSS Inc, Chicago, 1999). Regression models were adjusted using the Stata statistical software (V. 7.0, College Station, TX, Stata Corp., 2001).

# Results

The highest prevalence of anemia was found in infants 12 to 24 months old (48.9%). Rural infants of this age tended to have a higher prevalence (52.9%) than their urban counterparts (46.8%) however, the difference was not statistically significant. The prevalence of anemia declined progressively with age, reaching 16% at 5 years of age, and remained essentially stable until 11 years of age. Within the 5-11 year interval, the prevalence varied from 14.6 to 22%. Anemia was more prevalent in rural than in urban children 5-6 years of age ($p<0.05$), but not at other age intervals (Table I).

Of all regions, the South of the country had the highest prevalence of anemia in children aged 12 to 24 months of age. No interregional differences were noted among children of other age intervals (Table II). The prevalence of anemia was 57.9% in indigenous infants 12 to 24 months old, and was approximately 10

Table I
**PREVALENCE OF ANEMIA* IN CHILDREN UNDER 11 YEARS OF AGE. MEXICO, 1999**

| | *Children under 5 years of age* | | | | | *Children 5-11 years of age* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Stratum* | *Age (Months)* | *Sample N* | *Expansion N (Thousands)* | *Prevalence of anemia %* | *Confidence interval $_{95\%}$* | *Age (Years)* | *Sample n* | *Expansion N (Thousands)* | *Prevalence of anemia %* | *Confidence interval $_{95\%}$* |
| Urban | 6-11 | 171 | 225.6 | 11.3 | (7.94, 14.75) | | | | | |
| | 12-23 | 572 | 775.7 | 46.8 | (43.13, 50.48) | 5-6 | 1 612 | 2 206.4 | 18.4 | (16.57, 19.98) |
| | 24-35 | 731 | 1 049.0 | 30.8 | (27.71, 33.94) | 7-8 | 1 631 | 2 259.7 | 21.9 | (20.08, 23.77) |
| | 36-47 | 797 | 1 106.3 | 20.9 | (18.31, 23.41) | 9-10 | 1 646 | 2 257.4 | 16.8 | (15.07, 18.45) |
| | 48-59 | 828 | 1 182.7 | 16.2 | (13.87, 18.52) | 11 | 707 | 937.5 | 13.3 | (11.04, 15.64) |
| | Total | 3 099 | 4 339.2 | 26.1 | (24.52, 27.75) | Total | 5 596 | 7 661.0 | 18.3 | (17.32, 19.28) |
| Rural | 6-11 | 154 | 123.9 | 16.2 | (11.83, 20.63) | | | | | |
| | 12-23 | 462 | 391.4 | 52.9 | (47.96, 57.85) | 5-6 | 1 357 | 1 150.7 | 23.0 | (20.69, 25.29) |
| | 24-35 | 550 | 479.1 | 34.9 | (31.47, 38.35) | 7-8 | 1 371 | 1 140.9 | 24.6 | (21.94, 27.26) |
| | 36-47 | 630 | 521.8 | 23.1 | (20.31, 25.95) | 9-10 | 1 315 | 1 116.1 | 20.1 | (18.09, 22.04) |
| | 48-59 | 631 | 537.0 | 17.0 | (14.26, 19.75) | 11 | 579 | 478.2 | 17.0 | (14.23, 19.69) |
| | Total | 2 427 | 2 053.3 | 29.5 | (27.75, 31.33) | Total | 4 622 | 3 885.9 | 21.9 | (20.44, 23.32) |
| National | 6-11 | 325 | 349.5 | 13.1 | (10.38, 15.77) | | | | | |
| | 12-23 | 1 034 | 1 167.1 | 48.9 | (45.91, 51.80) | 5-6 | 2 969 | 3 357.15 | 19.9 | (18.51, 21.27) |
| | 24-35 | 1 281 | 1 528.1 | 32.1 | (29.70, 34.51) | 7-8 | 3 002 | 3 400.6 | 22.8 | (21.3, 24.35) |
| | 36-47 | 1 427 | 1 628.1 | 21.6 | (19.62, 23.55) | 9-10 | 2 961 | 3 373.4 | 17.9 | (16.54, 19.17) |
| | 48-59 | 1 459 | 1 719.7 | 16.4 | (14.63, 18.26) | 11 | 1 286 | 1 415.7 | 14.6 | (12.77, 16.35) |
| | Total | 5 526 | 6 392.5 | 27.2 | (26.00, 28.46) | Total | 10 218 | 11 546.9 | 19.5 | (18.68, 20.32) |

* Hemoglobin adjusted by altitude using the equation proposed by Ruiz Argüelles (16). Cutoff values for anemia at sea level: children 6 to 11.9 months of age <9.5 g/dl; children 12 months to 5 years of age <11 g/dl; children 6 to 11 years of age<12 g/dl

percentage points higher in indigenous children younger than 5 years of age than their non-indigenous counterparts. Nevertheless, at later ages the differences between indigenous and non-indigenous children were smaller than 7 percentage points (Table III).

The median of dietary iron intake of children under 5 years of age corresponded to 50% of the RDA (recommended daily allowance) and increased progressively reaching 80.8% of the RDA at 9-10 years of age. Folic acid intakes ranged between 75 and 107% of the RDA from 3- 11 years of age, and Vitamin B12 intake was close to 100% at all ages. The phytic acid and tannin intakes were relatively high; phytic acid intake was more than 500 mg/d after 4 years reaching 852 mg/d at 11 years of age. Tannin intake was greater than 19 mg/d after 7 years of age (Table IV).

In infants 12 to 24 months of age hemoglobin concentration was significantly and positively associated with height for age ($p< 0.01$) and weight for age ($p=0.01$). Although weight for height ($p=0.07$), tended to have a positive association with hemoglobin concentration, it did not reach statistical significance. Because of the high co-linearity among the latter indices, they were introduced alternately to the model. Hemoglobin concentration was also positively associated with socioeconomic level ($p< 0.05$), and altitude above sea level ($p=0.001$). There was also a trend towards a relationship with duration of lactation ($p=0.1$). All of

Table II

**PREVALENCE OF ANEMIA* IN CHILDREN UNDER 11 YEARS OF AGE BY GEOGRAPHIC REGION. MEXICO, 1999**

| | *Children under 5 years of age* | | | | | *Children 5-11 years of age* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Region* | *Age (Months)* | *Sample N* | *Expansion N (Thousands)* | *Prevalence of anemia %* | *Confidence interval 95%* | *Age (Years)* | *Sample n* | *Expansion N (Thousands)* | *Prevalence of anemia %* | *Confidence interval 95%* |
| North | 6-11 | 108 | 70.6 | 8.2 | (5.34, 10.99) | | | | | |
| | 12-23 | 312 | 204.9 | 46.8 | (41.59, 51.92) | 5-6 | 899 | 621.7 | 23.7 | (20.96, 26.36) |
| | 24-35 | 366 | 278.0 | 28.9 | (25.09, 33.13) | 7-8 | 939 | 707.5 | 25.9 | (23.26, 28.56) |
| | 36-47 | 444 | 311.6 | 20.3 | (16.18, 24.48) | 9-10 | 864 | 580.1 | 23.4 | (20.41, 26.34) |
| | 48-59 | 418 | 299.7 | 19.1 | (15.35, 22.94) | 11 | 401 | 273.9 | 19.5 | (15.71, 23.36) |
| | Total | 1 648 | 1 164.8 | 26.0 | (24.07, 27.99) | Total | 3 103 | 2 183.3 | 23.8 | (22.12, 25.47) |
| Center | 6-11 | 103 | 124.0 | 15.7 | (11.75, 19.74) | | | | | |
| | 12-23 | 310 | 397.6 | 47.3 | (42.08, 52.60) | 5-6 | 875 | 1 133.5 | 18.1 | (15.71, 20.61) |
| | 24-35 | 420 | 568.4 | 33.2 | (29.53, 36.96) | 7-8 | 889 | 1 117.3 | 22.0 | (19.38, 24.6) |
| | 36-47 | 445 | 571.3 | 25.0 | (21.94, 28.00) | 9-10 | 920 | 1 185.9 | 15.7 | (15.53, 17.81) |
| | 48-59 | 461 | 630.5 | 14.3 | (11.63, 17.00) | 11 | 393 | 482.7 | 14.6 | (11.44, 17.69) |
| | Total | 1 739 | 2 291.7 | 27.5 | (25.52, 29.42) | Total | 3 077 | 3 919.4 | 18.0 | (16.65, 19.47) |
| Mexico City | 6-11 | 30 | 54.0 | 11.6 | (‡) | | | | | |
| | 12-23 | 74 | 155.4 | 47.1 | (35.45, 58.72) | 5-6 | 203 | 417.2 | 13.6 | (8.46, 18.66) |
| | 24-35 | 77 | 178.4 | 33.0 | (20.41, 45.52) | 7-8 | 209 | 420.3 | 12.7 | (7.59, 17.83) |
| | 36-47 | 95 | 215.8 | 20.8 | (11.48, 30.11) | 9-10 | 205 | 422.2 | 8.7 | (4.34, 13.15) |
| | 48-59 | 76 | 172.0 | 16.2 | (5.98, 26.35) | 11 | 82 | 155.3 | 5.9 | (1.16, 10.67) |
| | Total | 352 | 775.6 | 27.2 | (20.71, 33.68) | Total | 699 | 1 415.0 | 11.0 | (8.18, 13.88) |
| South | 6-11 | 84 | 100.9 | 14.0 | (1.05, 17.96) | | | | | |
| | 12-23 | 338 | 409.3 | 52.0 | (47.76, 56.32) | 5-6 | 992 | 1 184.7 | 21.9 | (19.73, 23.85) |
| | 24-35 | 418 | 503.3 | 32.2 | (28.77, 35.56) | 7-8 | 965 | 1 155.5 | 25.4 | (22.91, 27.92) |
| | 36-47 | 443 | 529.4 | 19.0 | (16.64, 21.35) | 9-10 | 972 | 1 185.2 | 20.6 | (18.55, 22.6) |
| | 48-59 | 504 | 617.4 | 17.4 | (14.91, 19.88) | 11 | 410 | 503.8 | 14.5 | (11.52, 17.52) |
| | Total | 1 787 | 2 160.4 | 27.6 | (26.05, 29.21) | Total | 3 339 | 4 029.2 | 21.6 | (20.36, 22.77) |

* Hemoglobin adjusted by altitude using the equation proposed by Ruiz Argüelles (16). Cutoff values for anemia at sea level: children 6 to 11.9 months of age <9.5 g/dl; children 12 months to 5 years of age <11 g/dL; children 6 to 11 years of age <12 g/dl

‡ The sample size was insufficient for calculations.

Table III
**PREVALENCE OF ANEMIA IN CHILDREN UNDER 11 YEARS OF AGE BY ETHNICITY. MEXICO,1999**

| | Children under 5 years of age | | | | | Children 5-11 years of age | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ethnicity | Age (Months) | Sample N | Expansion N (Thousands) | Prevalence of anemia % | Confidence interval $_{95\%}$ | Age (Years) | Sample n | Expansion N (Thousands) | Prevalence of anemia % | Confidence interval $_{95\%}$ |
| Indigenous | 6-11 | 27 | 38.8 | 16.2 | (9.20, 23.15) | | | | | |
| | 12-23 | 120 | 138.0 | 57.9 | (50.64, 65.19) | 5-6 | 335 | 380.8 | 26.1 | (21.42, 30.39) |
| | 24-35 | 149 | 164.1 | 42.0 | (35.47, 48.47) | 7-8 | 312 | 334.2 | 25.8 | (21.55, 30.02) |
| | 36-47 | 163 | 192.1 | 30.5 | (24.57, 36.47) | 9-10 | 294 | 328.8 | 22.6 | (19.06, 26.12) |
| | 48-59 | 155 | 180.3 | 23.0 | (15.4, 30.58) | 11 | 127 | 143.8 | 17.9 | (13.48, 22.24) |
| | Total | 614 | 713.3 | 35.8 | (32.03, 39.51) | Total | 1 068 | 1 187.7 | 24.0 | (21.29, 26.66) |
| Non-Indigenous | 6-11 | 298 | 310.7 | 12.7 | (9.86, 15.50) | | | | | |
| | 12-23 | 914 | 1 029.1 | 47.6 | (44.29, 50.99) | 5-6 | 2 634 | 2 976.3 | 19.1 | (17.68, 20.56) |
| | 24-35 | 1 132 | 1 363.9 | 30.9 | (28.22, 33.53) | 7-8 | 2 690 | 3 066.4 | 22.5 | (20.86, 24.14) |
| | 36-47 | 1 264 | 1 435.9 | 20.4 | (18.26, 22.51) | 9-10 | 2 667 | 3 044.6 | 17.3 | (15.95, 18.73) |
| | 48-59 | 1 304 | 1 539.4 | 15.7 | (13.89, 17.46) | 11 | 1 159 | 1 271.9 | 14.2 | (12.27, 16.1) |
| | Total | 4 912 | 5 679.1 | 26.1 | (24.86, 27.43) | Total | 9 150 | 10 359.2 | 19.0 | (18.14, 19.85) |

* Hemoglobin adjusted by altitude using the equation proposed by Ruiz Argüelles (16). Cutoff values for anemia at sea level: Children 6 to 11.9 months of age <9.5 g/dl; children 12 months to 5 years of age <11 g/dl; children 6 to 11 years of age <12 g/dl

these associations remained stable when nutritional status indices were alternately introduced to the model. No associations were found between hemoglobin concentration and age, gender, use of dietary supplements, being a beneficiary of food assistance programs, ethnic origin, or maternal education (Table V). In children 25 months to 11 years of age, hemoglobin concentration was positively associated with nutritional status indices i.e. height for age, weight for age, and weight for height ($p< 0.001$). For brevity, only the model including height for age is presented here. In all models, hemoglobin concentration was positively associated with socioeconomic status ($p< 0.001$), participation in a food assistance program ($p=0.01$), and altitude above sea level ($p=0.001$), and negatively associated with maternal education ($p=0.001$). A positive trend was also noted between intake of dietary supplements and hemoglobin concentrations ($p< 0.1$). Indigenous ethnicity was associated with hemoglobin levels only when weight for height was introduced to the model ($p< 0.02$). No associations were found between hemoglobin concentration and gender.

In infants 12 to 24 months of age, hemoglobin concentrations were positively associated with iron and calcium intakes ($p=0.02$). These associations remained significant after controlling for fiber, phytic acid, and tannin intakes. There were no associations with folate and vitamin B12 intakes. On the other hand, in children 25 months to 11 years of age no association was found between hemoglobin concentration and iron, folate, and vitamin B12 intakes. However, a positive association was found with calcium intake ($p< 0.001$) (Table V).

# Discussion

The prevalence of anemia was extremely high at all ages, with a more alarming prevalence occurring in the group of one to two years of age. Potential factors that may explain the highest prevalence in young infants are, among others: a) the high prevalence of iron deficiency observed in pregnant women (see corresponding article reviewing micronutrient status in this issue), which frequently has an effect on the development of limited fetal iron stores; b) the amount of iron secreted daily in breast milk is insufficient, (3 mg/d) to cover the daily iron requirements of the infant (9 mg/d); iron concentrations in breast milk are independent of the maternal iron status; and c) the transition from full lactation to the family diet occurs within the first two years of life, and in this period weaning foods are frequently of low energy and micronutrient density, especially for iron.[25-28]

The robustness of these data is supported by the coinciding high proportion of anemia with iron deficiency (70%, in terms of percent transferrin satura-

Table IV
**DIETARY INTAKE OF MICRONUTRIENTS AND ADEQUACY OF INTAKE.* MEXICO, 1999**

| | | Age (months) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 12–23 (N =135) | | | 24–35 (N= 224) | | | 36–47 (N= 234) | | | 48–59 (N= 255) | | |
| | | | Quartile | | | Quartile | | | Quartile | | | Quartile | |
| | | Median | 1 | 3 | Median | 1 | 3 | Median | 1 | 3 | Median | 1 | 3 |
| Daily Intake | Iron (mg) | 3.2 | 1.9 | 5.5 | 3.8 | 2.5 | 6.1 | 4.9 | 3.3 | 7.7 | 5.7 | 4.0 | 8.3 |
| | Folate (ug) | 92.2 | 54.7 | 161.0 | 116.2 | 77.0 | 184.5 | 142.1 | 81.7 | 236.0 | 167.0 | 106.1 | 264.8 |
| | Vitamin B12 (ug) | 1.5 | 0.9 | 2.7 | 1.3 | 0.6 | 2.3 | 1.5 | 0.7 | 2.3 | 1.5 | 0.6 | 2.7 |
| | Fiber (g) | 5.3 | 2.8 | 8.9 | 7.6 | 4.5 | 12.5 | 9.1 | 5.5 | 14.8 | 11.2 | 7.0 | 17.3 |
| | Calcium (mg) | 481.4 | 299.5 | 813.7 | 454.1 | 269.6 | 679.2 | 477.2 | 291.9 | 702.6 | 596.7 | 381.8 | 803.7 |
| | Phytic Acid (mg) | 230.9 | 105.0 | 531.9 | 351.9 | 124.0 | 707.1 | 414.2 | 174.4 | 807.9 | 510.6 | 219.6 | 1027.5 |
| | Tannins (mg) | 5.7 | 0.2 | 40.6 | 9.3 | 0.3 | 45.2 | 11.1 | 0.3 | 57.7 | 6.7 | 0.3 | 56.1 |
| % RDA | Iron | 32.1 | 18.8 | 55.3 | 37.8 | 24.6 | 60.9 | 49.0 | 33.3 | 77.0 | 56.5 | 40.1 | 83.1 |
| | Folate | 60.1 | 36.4 | 106.2 | 77.5 | 51.3 | 120.6 | 94.7 | 54.5 | 157.3 | 84.7 | 53.0 | 133.0 |
| | Calcium | 94.3 | 49.9 | 160.0 | 90.3 | 53.2 | 135.8 | 95.4 | 58.4 | 140.5 | 76.3 | 47.7 | 101.4 |

| | | Age (years) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5–6 (N=551) | | | 7–8 (N=616) | | | 9–10 (N=620) | | | 11 (N=270) | | |
| Daily Intake | Iron (mg) | 6.2 | 4.1 | 9.2 | 7.6 | 5.1 | 11.1 | 8.1 | 5.8 | 11.7 | 8.7 | 5.7 | 12.8 |
| | Folate (ug) | 175.4 | 109.7 | 279.5 | 215.3 | 131.9 | 334.1 | 226.1 | 142.1 | 354.7 | 232.0 | 132.3 | 353.2 |
| | Vitamin B12 (ug) | 1.4 | 0.6 | 2.4 | 1.5 | 0.7 | 2.6 | 1.4 | 0.6 | 2.5 | 1.6 | 0.5 | 3.0 |
| | Fiber (g) | 11.5 | 7.6 | 18.5 | 14.9 | 9.8 | 22.7 | 16.5 | 11.0 | 24.7 | 17.3 | 11.0 | 25.7 |
| | Calcium (mg) | 558.7 | 363.9 | 805.1 | 646.1 | 433.7 | 897.6 | 664.6 | 461.1 | 929.6 | 690.6 | 483.4 | 946.5 |
| | Phytic Acid (mg) | 524.9 | 250.5 | 1049.6 | 763.4 | 376.4 | 1316.3 | 789.9 | 400.7 | 1553.1 | 852.3 | 408.7 | 1656.0 |
| | Tannins (mg) | 17.4 | 0.7 | 71.5 | 19.5 | 0.9 | 80.8 | 21.0 | 0.7 | 70.4 | 22.2 | 0.9 | 73.2 |
| % RDA | Iron | 61.6 | 41.0 | 92.3 | 75.8 | 50.8 | 110.7 | 80.8 | 57.6 | 116.9 | 61.4 | 40.8 | 94.1 |
| | Folate | 87.7 | 54.9 | 139.7 | 107.6 | 65.9 | 167.0 | 75.4 | 47.4 | 118.2 | 77.3 | 44.1 | 117.7 |
| | Calcium | 69.8 | 45.5 | 100.6 | 80.8 | 54.2 | 112.2 | 51.1 | 35.5 | 71.5 | 53.1 | 37.2 | 72.8 |

* Adequacy expressed % of RDA (30)

tion).[29] This high prevalence of anemia in small infants is alarming because of its expected negative impact on their short- and long-term health status. In the short-term it will have a negative effect on their ability to combat acute infections, as well as on their mental development and physical growth. In the long-term will result in short stature, poor school performance, and a lower capacity for physical work.[4,5]

The daily iron intake of infants 12 to 24 months of age was well below the RDA, as expected. Hemoglobin was positively associated with iron intake in this group, the association probably resulted significant because iron is provided mostly by breast milk, and complementary food used at this age includes only small amounts of foods with a high content of substances that interfere with iron absorption. Typical complementary foods include fruits, vegetables, egg, cereals, wheat flour preparations, rice, and small amounts of meat and corn tortillas. On the other hand, older children had iron intakes very close to the RDA (75-81%). Thus, the high prevalence of iron deficiency anemia seems to be a bioavailability problem and not due to insufficient iron intake. Furthermore, hemoglobin concentrations in children 25 months to 11 years of age were not associated with iron, folate, or vitamin B12 intakes. The notion of anemia being caused by a low availability of iron in this sample is based also on the following arguments: a) most of the iron consumed by

Table V

**THE RELATION BETWEEN HEMOGLOBIN CONCENTRATIONS AND POTENTIALLY PREDICTOR VARIABLES. MEXICO, 1999**

| *Independent variables* | *Coefficient* | *p* | $R^2$ |
|---|---|---|---|
| Full model. Children younger than 2 years of age | | | 0.093 |
| Height for age | 0.108 | 0.009 | |
| Age | 0.0135 | 0.197 | |
| Sex | -0.153 | 0.110 | |
| Socioeconomic level | 0.116 | 0.050 | |
| Indigenous household | 0.254 | 0.129 | |
| Intake of dietary supplements | -0.084 | 0.493 | |
| Beneficiary of food assistance programs | 0.130 | 0.216 | |
| Maternal education | 0.0274 | 0.646 | |
| Duration of lactation | 0.013 | 0.099 | |
| Altitude above sea level | 0.00045 | 0.0001 | |
| Full model v 1. Children older than 2 years of age | | | 0.122 |
| Height for age | 0.109 | 0.0001 | |
| Sex | -0.0135 | 0.587 | |
| Socioeconomic level | 0.107 | 0.0001 | |
| Indigenous household | 0.0103 | 0.814 | |
| Intake of dietary supplements | 0.058 | 0.095 | |
| Beneficiary of food assistance programs | 0.0708 | 0.007 | |
| Maternal education | -0.066 | 0.0001 | |
| Altitude above sea level | 0.0054 | 0.0001 | |
| Reduced model 2. Children older than 2 years of age | | | 0.118 |
| Weight for height | 0.092 | 0.0001 | |
| Altitude | 0.0005 | 0.0001 | |
| Socioeconomic level | 0.124 | 0.0001 | |
| Maternal education | -0.052 | 0.001 | |
| Beneficiary of food assistance programs | -0.067 | 0.015 | |
| Indigenous household | 0.101 | 0.022 | |

**RELATIONSHIP BETWEEN HEMOGLOBIN CONCENTRATIONS AND MICRONUTRIENT INTAKE. MÉXICO, 1999**

| | | | |
|---|---|---|---|
| Model 1. Children younger than 2 years of age | | | 0.065 |
| Calcium | 0.001 | 0.021 | |
| Iron | 0.087 | 0.023 | |
| Folate | -0.001 | 0.499 | |
| Vitamin B12 | -0.183 | 0.123 | |
| Model 2. Children older than 2 years of age | | | 0.024 |
| Calcium | 0.0006 | 0.0001 | |
| Iron | 0.001 | 0.824 | |
| Folate | -0.0001 | 0.441 | |
| Vitamin B12 | -0.004 | 0.286 | |

this group was non-heme iron (data not presented); b) their diet contained a high amount of iron absorption antagonists, such as phytic acid, tannin and calcium; and c) the very low intake of substances facilitating non-heme iron absorption, as indicated by the high prevalence of vitamin C deficiency in this population (see related article in this issue). Other authors have demonstrated that the prevalence of anemia is not necessarily correlated with the degree of iron deficiency.[2] In a separate analysis based on the sample of children herein presented, it was found that 35% of the cases of anemia were not associated to iron deficiency but to the deficiency of one or more vitamins.[30] A puzzling finding was the positive correlation between calcium intake and hemoglobin concentrations of children 25 months to 11 years of age, especially because calcium antagonizes iron absorption. It can be speculated that such a relationship is not causal, and that calcium intake might be a proxy for the intake of animal foods.

The persistent positive association between height for age and the concentration of hemoglobin, and the high prevalence of stunting in this sample strongly support the existing knowledge of the contribution of iron deficiency anemia to growth retardation. However, hemoglobin concentrations were also positively associated, although weakly, with weight for height, an index for wasting, suggesting a relationship between acute malnutrition and iron deficiency anemia. The results of this survey are unable to establish whether iron deficiency anemia is a cause or effect of wasting.

Being a family beneficiary of food assistance programs was positively associated with the concentrations of hemoglobin in children older than two years of age but not in younger children. Such a differential effect might be due to the fact that most food assistance programs do not provide baby foods adequate for small children; thus, the impact of those programs is reflected only in older children. The Federal Program for Education Health and Feeding (Progresa, as abreviated in Spanish) is the only program that provides a supplement adequate for children of less than two years of age. Food assistance programs must consider baby foods with adequate energy and micronutrient densities.

Maternal education is a known determinant of the health of children, however, in this study it was not related with the concentrations of hemoglobin of children under two years of age, probably because the introduction of iron rich foods as weaning foods depends more on cultural-related beliefs than on the level of maternal education. On the contrary, maternal education was significantly associated with the concentration of hemoglobin of children older than 2 years, confirming that common knowledge.

In sum, we present herein evidence of an alarmingly high prevalence of anemia in children at a national level, regardless of urban or rural residence. The prevalence in children between 12 to 24 months of age is of special concern. Combating and preventing this ailment is a national emergency, considering the grave consequences of anemia and iron deficiency on the physical and mental growth and development of these children and on their long-term health. We do not fail to recognize that some actions have been taken in that regard, for instance, the enrichment of corn and wheat flours, the fortified food supplement distributed to children younger than two years of age and pregnant and lactating women living in extreme poverty by Progresa, and the pharmacological supplement containing iron and several vitamins included in two public health programs (Atención a Población Indígena and Arranque Parejo, Indigenous Population Care and "Even Start"). The short-term results of those interventions are in the process of being evaluated.

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