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Prevalence and Disparities in Folate and Vitamin B12 Deficiency Among Preschool Children in Guatemala

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Abstract

Background and Objective—Folate and vitamin B12 deficiencies can impair proper growth and brain development in children. Data on the folate and vitamin B12 status of children aged 6–59 months in Guatemala are scarce. Identification of factors associated with higher prevalence of these micronutrient deficiencies within the population is needed for national and regional policymakers.

Objective—To describe national and regional post-fortification folate and vitamin B12 status of children aged 6–59 months in Guatemala.

Methods—A multistage, cluster probability study was carried out with national and regional representation of children aged 6–59 months. Demographic and health information was collected for 1246 preschool children, but blood samples for red blood cell (RBC) folate and vitamin B12 were collected and analyzed for 1,245 and 1143 preschool children, respectively. We used the following deficiency criteria as cutoff points for the analyses: < 305 nmol/L for RBC folate, < 148 pmol/L for vitamin B12 deficiency, and 148–221 pmol/L for marginal vitamin B12 deficiency. Prevalence of RBC folate deficiency and vitamin B12 deficiency and marginal deficiency were estimated. Prevalence risk ratios of RBC folate and vitamin B12 deficiency were estimated comparing subpopulations of interest.

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Author Contributions RJ, MCR, BL and KG were involved in the design, analysis, and manuscript writing. WE and RC were involved in analysis and manuscript writing.

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Consent to Participate The Guatemalan Ministry of Health requested that the study protocol be reviewed by the CDC Institutional Review Board (IRB) in Atlanta, Georgia, in the United States. CDC accepted this request, and the protocol was approved by the CDC IRB. Each participant was requested to sign a participation consent form.

Consent to Publish All authors have approved the manuscript for publication.

Results—The national prevalence estimates of RBC folate deficiency among children was 33.5% [95% CI 29.1, 38.3]. The prevalence of RBC folate deficiency showed wide variation by age (20.3–46.6%) and was significantly higher among children 6–11 months and 12–23 months (46.6 and 37.0%, respectively), compared to older children aged 48–59 months (20.3%). RBC folate deficiency also varied widely by household wealth index (22.6–42.0%) and geographic region (27.2–46.7%) though the differences were not statistically significant. The national geometric mean for RBC folate concentrations was 354.2 nmol/L. The national prevalences of vitamin B12 deficiency and marginal deficiency among children were 22.5% [95% CI 18.2, 27.5] and 27.5% [95% CI 23.7, 31.7], respectively. The prevalence of vitamin B12 deficiency was significantly higher among indigenous children than among non-indigenous children (34.5% vs. 13.1%, aPRR 2.1 95% CI 1.4, 3.0). The prevalence of vitamin B12 deficiency also significantly varied between the highest and lowest household wealth index (34.3 and 6.0%, respectively). The national geometric mean for vitamin B12 concentrations was 235.1 pmol/L. The geometric means of folate and B12 concentrations were significantly lower among children who were younger, had a lower household wealth index, and were indigenous (for vitamin B12 only). Folate and vitamin B12 concentrations showed wide variation by region (not statistically significant), and the Petén and Norte regions showed the lowest RBC folate and vitamin B12 concentrations, respectively.

Conclusions—In this study, a third of all children had RBC folate deficiency and half were vitamin B12 deficient. Folate deficiency was more common in younger children and vitamin B12 deficiency was more common in indigenous children and those from the poorest families. These findings suggest gaps in the coverage of fortification and the need for additional implementation strategies to address these gaps in coverage to help safeguard the health of Guatemalan children.

Keywords

Micronutrient deficiencies; Red blood cell folate deficiency; Vitamin B12 deficiency; Preschool children; Guatemala

Introduction

Micronutrient deficiencies can lead to health issues, including severe or chronic malnutrition, anemia, neuropathy, and birth defects in children (Bailey et al., 2015a; Black et al., 2008). Folate and vitamin B12 deficiencies can have detrimental effects in pregnant women and children (Molloy, 2010; Molloy et al., 2009; Tamura & Picciano, 2006). These micronutrients share metabolic pathways, such as one carbon metabolism, and are important for DNA and protein synthesis, which plays an important role in cell growth and differentiation (Finkelstein et al., 2015; Koury & Ponka, 2004). Reduced cell division and differentiation can have clinical consequences in growth and development (Nyaradi et al., 2013). Folate and vitamin B12 deficiencies have been associated with impaired brain development and growth leading to developmental delays, stunting, and poor neurocognitive function (Graham et al., 1992; Molloy et al., 2009; Schorah et al., 1980; Venkatramanan et al., 2016).

Micronutrient food fortification is a public health approach to address vitamin deficiencies in a population and is a useful strategy to ameliorate the devastating effects of micronutrient deficiencies in children. Fortifying food products has been successful in reducing folate,

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vitamin B12 and iron deficiencies in developed and developing countries (Cordero et al., 2008). Nevertheless, not all food fortification programs impact the population equally.

Guatemala's fortification program has been fortifying centrally milled wheat flour and 2-pound packages of maize flour with 1.8 mg/Kg of folic acid since 2002; however, a 2007 study indicated that fortified foods were more available in urban settings and to those able to overcome financial barriers (Imhoff-Kunsch et al., 2007). Fortified wheat flour provided 71–78% of the estimated average requirements (EARs) for folate in women identifying as living in urban areas or being nonpoor, but only 5–15% of EARs to women identifying as living in rural areas, being extremely poor, or indigenous. A 2009–2010 study examining a nationally representative sample of women of reproductive age (WRA) in Guatemala revealed that folate deficiency was more prevalent among indigenous, rural, and urban poor populations (Rosenthal et al., 2015). The same study demonstrated that vitamin B12 deficiency was also widespread.

While micronutrient deficiencies, especially vitamin B12, are known to be common throughout Central America, little information on folate and vitamin B12 status in children under 5 years of age is available (Lopez de Romana et al., 2015). Small studies have identified vitamin B12 deficiency among Guatemalan children, but nationally representative and population-based studies of blood folate and vitamin B12 status of Guatemalan children are lacking. Such data are critical to better target, strengthen, and monitor the impact of malnutrition prevention and food fortification efforts. This is the first study to report folate and vitamin B12 status of Guatemalan children using a nationally and population-based strategy. Our findings contribute to the identification of population subgroups among Guatemalan children aged 6–59 months who are least likely to benefit from current approaches to fortification and to provide data that can be used to monitor the impact of change to current fortification initiatives.

Methods

Study Population

Our study, the Encuesta Nacional de Micronutrientes (ENMICRON), used a subsample of the Encuesta Nacional de Salud Materno Infantil (ENSMI). Conducted in 2008–2009, the ENSMI used a complex, stratified and multistage probability design to select 734 sectors, from which 26,000 men, women, and children were selected from the civilian, noninstitutionalized Guatemalan population. The ENSMI identified all sampled households with WRA and children 6–59 months of age. Selected individuals provided verbal consent to enroll into the ENSMI and no participation incentives were given. To reduce the cost of the Biochemical Analysis, the ENMICRON selected 246 sectors from the ENSMI 734 sectors using stratified simple random sampling, from which 6 WRA and her children 6–59 months of age were selected. Within them, we assessed the micronutrient status of a sample of non-pregnant WRA and children aged 6–59 months from various regions. The selected households were screened to ensure that previously identified children were still in residence and eligible (Guatemala Ministerio & de Salud Publica y Asistencia Socia, 2012). This analysis only includes data for 1,246 children aged 6–59 months.

Measures

The ENMICRON used the following ENSMI sociodemographic variables: area (rural or urban), ethnicity (indigenous or non-indigenous), educational attainment level (no education, elementary, secondary, or high school or above), wealth index (lowest, middle, or highest tercile), and region (Metropolitana, Norte, Nor-Oriente, Sur-Oriente, Central, Nor-Occidente, Sur-Occidente, or Petén). Respondents (parents or caretakers 18 years of age or older living in the same household) provided survey information for the selected child (date of birth, ethnicity). The area was defined by the location of the household. Areas with a population greater than 2500 were classified as urban. Areas with a population less than 2500 were classified as rural. Respondents who identified themselves as Mayan were categorized as indigenous, and those who identified themselves as mestizos or white were categorized as nonindigenous. The household wealth index was established using information on household characteristics (e.g., building materials, number of rooms, water source, and type of toilet) (Rutstein & Johnson, 2004). Educational attainment was self-reported.

Biochemical Analyses

The Guatemala Ministry of Health conducted primary data collection in 2009–2010. Whole blood was collected from non-fasting participants. In selected households, one eligible woman and one eligible child were randomly chosen for blood collection. Due to insufficient blood volume obtained in some children, fewer blood samples were available for RBC folate and vitamin B12 determinations (1245 and 1143, respectively). Red blood cell (RBC) folate concentrations were determined by microbiologic assay (MBA; *Lactobacillus rhamnosus* 27,773; ATCC) using the microtiter plate adaptation of O'Brion and Kelleher (O'Brion & Kelleher, 1992). Plasma vitamin B12 analysis was performed using the Roche electrochemiluminescence assay on the E-170 instrument platform (Roche vitamin B12 assay package insert, 2007–2008, V4). Serum vitamin B12 concentration was used as an indicator of vitamin B12 status. We used the following deficiency criteria as cutoff points for the analyses: <305 nmol/L for RBC folate, <148 pmol/L for vitamin B12 deficiency, and 148–221 pmol/L for marginal vitamin B12 deficiency (Rogers et al., 2018). Additional information about the biochemical analyses have been previously described (Rosenthal et al., 2015).

Analytical and Statistical Methods

All statistical analyses were conducted using SUDAAN (version 11.1) statistical software. Descriptive weighted statistics for children's characteristics and blood concentrations were calculated using data from the ENMICRON. All estimated prevalence data, prevalence risk ratios (PRRs), and associated 95% confidence intervals (CIs) used procedures that accounted for the complex survey design and sample weights (Bieler et al., 2010). A logarithmic transformation was used for all analyses of RBC folate and vitamin B12 concentrations. We stratified all analyses by area, ethnicity, child's sex (male, female), child's age in months (6–11, 12–23, 24–35, 36–47, 48–59), parent's/caretaker's age in years (15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49), respondent's educational status, household wealth index, and geographic region.

We estimated the predictive margins, means for the unadjusted and adjusted weighted prevalence, and 95% CIs for RBC folate deficiency, vitamin B12 deficiency, and marginal vitamin B12 deficiency. We utilized PRRs for the prevalence status variables to compare amongst sociodemographic variables. In addition, we calculated adjusted PRRs from the overall logistic regression models.

We calculated unadjusted and adjusted geometric means and 95% CIs for RBC folate and vitamin B12 concentrations. Differences in the sociodemographic variables were tested using geometric mean ratios.

The Guatemalan Ministry of Health requested that the study protocol be reviewed by the CDC Institutional Review Board (IRB) in Atlanta, Georgia, in the United States. CDC accepted this request, and the protocol was approved by the CDC IRB. Informed consent was obtained from parents or respondents to draw blood from the children. No incentives were provided.

Results

Characteristics of the Study Population

Among the 1446 households, our study sample consisted of 1246 children aged 6–59 months. Table 1 illustrates the characteristics of the study children. The majority of sampled children were younger (< 3 years of age; 72.8%), non-indigenous (55.1%), and lived in rural areas (60.4%). Approximately half of the children were female (51.2%), and about 46% were in the lowest wealth tertile. Our sample population resembled the general population of children under 5 years of age in Guatemala (Guatemala Ministerio de Salud Publica y Asistencia Social, 2015). Among respondents (parents/caretakers), 52.0% were women, and most respondents had an elementary education or less (82.6%).

Prevalence of RBC Folate Deficiency among Guatemalan Children

RBC folate analysis was conducted in the blood samples of 1245 children. The prevalence of RBC folate deficiency and unadjusted and adjusted PRRs are presented in Table 2. The national prevalence estimates of folate deficiency based on RBC folate concentrations was 33.5% (95% CI 29.1, 38.3). The prevalence of RBC folate deficiency was greater in rural areas compared to urban areas (38.1% vs. 26.7%), but the difference was not significant after adjusting for other covariates. RBC folate deficiency among children aged 6–11 and 12–23 months were significantly higher compared to children 48–59 months [aPRRs (2.0 95% CI 1.3, 3.1) and (1.6 95% CI 1.1, 2.3), respectively]. Similarly, the prevalence of RBC folate deficiency was higher among children living in households with younger parents/caretakers <15–19 years [PRR = 3.8 (95% CI 1.1, 13.3)]; 20–24 years [4.2 (95% CI 1.2, 14.2)] and 30–34 years [3.5 (95% CI 1.01, 12.3)] than among children living in households with respondent’s 45–49 years of age.

Prevalence of Vitamin B12 Deficiency and Marginal Deficiency Among Guatemalan Children

Vitamin B12 analysis was conducted in the blood samples of 1143 children. The national prevalence estimates of vitamin B12 deficiency and marginal deficiency based on serum vitamin B12 concentrations among children were 22.5% (95% CI 18.2, 27.5) and 27.5% (95% CI 23.7, 31.7), respectively (Table 3). The prevalence of vitamin B12 deficiency was greater in rural areas than in urban areas (27.3% vs 15.4%), but the difference was not significant after adjusting for covariates. The prevalence of vitamin B12 deficiency was significantly higher among indigenous children than among nonindigenous children (34.5% vs. 13.1%, aPRR 2.1 95% CI 1.4, 3.0). Children living in households with the lowest and middle wealth indices showed significantly higher prevalence of vitamin B12 deficiency compared to those living in households with the highest wealth index (34.3, 16.9 vs. 6.0%, respectively, aPRR 4.4 95% CI 2.3, 8.3 and 2.4 95% CI 1.3, 4.4, respectively). Similarly, for marginal vitamin B12 deficiency, significant differences in adjusted PRRs were detected for children aged 12–23 months compared to children aged 48–59 months [2.0 (95% CI 1.3, 3.1)] and among children from households with the lowest or middle tertile of the wealth index compared to children from households with the highest tertile wealth index [1.6 (95% CI 1.03, 2.4)] and [1.6, 95% CI 1.1, 2.4)].

Geometric Means of RBC Folate and Vitamin B12 concentrations in Guatemalan Children

National geometric means for RBC folate and vitamin B12 concentrations were 354.2 nmol/L and 235.1 pmol/L, respectively (Tables 4 and 5). The geometric means for folate concentrations were significantly lower for children who were younger and from households with respondents who were under 40 years of age, with no education, and with a lower household wealth index. The geometric means for vitamin B12 concentrations were significantly lower for children who were indigenous, younger, and from households with respondents who had no education and with the lowest and middle household wealth index.

Discussion

Our study is the first to provide nationally and regionally representative information on the prevalence of folate, vitamin B12, and marginal vitamin B12 deficiencies among children aged 6–59 months in Guatemala. Nationally, a third of the children in our study were RBC folate deficient, and half of the children had either a marginal or overt vitamin B12 deficiency. These prevalences indicate micronutrient deficiencies are of public health concern for this population (McLean et al., 2008). We found that RBC folate deficiencies are more likely among younger children (aged 6–23 months).

Our study provides a baseline against which future studies might be compared to assess Guatamala’s progress in nutrition after implementation of folic acid fortification. Most studies to date have only reported serum folate concentrations instead of RBC folate concentrations, which is recognized as more reflective of true folate body stores (Bailey et al., 2015b). It is of interest to notice that the higher prevalence of RBC folate deficiency in the Norte and Petén regions, home to vulnerable populations such as the Mayans or the poor, may be due to inadequate access to fortified wheat flower, limited purchasing power, and the low consumption of wheat flour. Our study also reported lower vitamin B12 deficiency and higher marginal deficiency than a prior study in Guatemala. A study in San Jose La Comunidad in Guatemala among children 12 months of age reported a 30.8% prevalence of vitamin B12 deficiency and 18.5% marginal vitamin B12 deficiency (Jones et al., 2007). Perhaps differences between both studies are based on the study objectives and study populations. Our study was a national and regional representative study of preschool children. In contrast, the San Jose La Comunidad study was the baseline evaluation of an intervention study in a community that was poor and peri-urban.

Our study findings suggest a limited reach of the Guatemala's fortification programs for selected populations. RBC folate deficiency (33.5% prevalence) was much higher than the prevalence data reported for children living in countries where fortification programs have a high population coverage, such as among US children under five years (< 1%) (U.S. Centers for Disease Control & Prevention, 2012) and Ecuadorian children 5–59 months of age (0.8%) (Ecuador Ministry of Health. Encuesta Nacional de Salud y Nutricion, 2012). Similarly, RBC folate concentrations among children under 5 years in our study (354.2 nmol/L, respectively) were lower than those reported from the US post-folic acid fortification (2011–2016; 1110 nmol/L).

Several countries have reported or measured prevalence of vitamin B12 deficiency or marginal vitamin B12 deficiency. Our data indicated greater prevalence of vitamin B12 deficiency compared to that reported by Congo (> 1%), Mexico (7.3%), the US (>3%) and Venezuela (11.8%), but lower prevalence compared to Colombia (20.2%) and Nepal (30.2%) (Cuevas-Nasu et al., 2012; Garcia-Casal et al., 2008; Harvey-Leeson et al., 2016; Pfeiffer et al., 2013). Similarly, vitamin B12 concentrations in our study were lower (235.1 pmol/L) than those reported by the US post-folic acid fortification (804 pmol/L), Mexico (516.3 pmol/L), and Nepal (528–684 pmol/L) (Cuevas-Nasu et al., 2012; Garcia-Casal et al., 2008; Harvey-Leeson et al., 2016; Neufeld et al., 2012; Ng'eno et al., 2017; Pfeiffer et al., 2013).

High vitamin B12 deficiencies in Guatemala, and possibly in other low- and middle-income countries, may correlate with a lower intake of animal products (Allen, 2004; Casterline et al., 1997). Countries with lower prevalence of vitamin B12 deficiency generally have a higher intake of animal products or include vitamin B12 in their food fortification programs. Guatemala's fortification program to date does not include vitamin B12.

The potential consequences of the high prevalence of folate and vitamin B12 deficiency in Guatemala, and mostly among the youngest age groups (aged 6–23 months), are significant. The 12–24 months post-natal period for children is characterized by high nutritional requirements and rapid physical and brain growth. Failure to provide essential nutrients during the critical period of brain development may result in lifelong deficits in brain function despite subsequent nutrient repletion (Black, 2008). Because of the need to deliver these essential micronutrients to children early in their lives, Guatemala's fortification program may consider prioritizing policies that could ensure adequate micronutrients during this crucial time, e.g., mandatory fortification of all size packages of maize flour and surveillance systems to monitor impact of the fortification program. Data from this study can be used to establish a baseline by which Guatemala can measure its progress moving forward.

This study has several strengths. To our knowledge, this is the first study in Guatemala to assess folate and vitamin B12 status among children under 5 years of age at the national and regional levels. There are limited national population-based data for children in low- and middle-income countries on folate and vitamin B12 concentrations based on the microbiologic assay, which is the WHO recommended method for determining blood folate concentrations. We utilized rigorous laboratory methods to conduct biochemical analyses on our blood samples, and we implemented the most recently recommended folate and vitamin B12 cutoffs for deficiency (Rogers et al., 2018). This study was designed and implemented using strict standardized population-based sampling to reduce biases in the selection of households and individuals and standardized field and laboratory methodologies to ensure proper handling of biological samples. Population-level data such as that presented here is critical to researchers and policymakers to identify the areas of highest need for public health intervention.

Study limitations include a lack of additional biomarkers for vitamin B12 for improved status assessment and a lack of data regarding dietary intake, which is an important factor for nutrient status assessment. While there has been a lag time between data collection and dissemination, the country has seen no changes to its fortification policies during this period, and the data remain relevant for targeting vulnerable populations and policy formation purposes.

Conclusions

Our study revealed a high prevalence of RBC folate and serum vitamin B12 deficiencies in children aged 6–59 months in Guatemala. Younger children were more likely to have folate deficiency and indigenous children and those from the poorest households were more likely to have vitamin B12 deficiency. Identifying areas of highest need and sociodemographic factors that predict micronutrient status can help guide effective interventions. Since our study is the first to provide national and regional prevalence estimates for folate and vitamin B12 deficiency in Guatemala, it can serve as a baseline to assess changes in these deficiencies over time.

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Significance

What is already known on the subject?

Micronutrient deficiencies, folate and vitamin B12 deficiencies can have detrimental effects in pregnant women and children such as birth defects, impaired brain development and growth leading to developmental delays, stunting, and poor neurocognitive function.

What does this study add?

Micronutrient fortification is a public health approach to address vitamin deficiencies in a population and is useful strategy to ameliorate in a population the devastating effects of micronutrient deficiencies in children.

Table 1

Characteristics of study population, 2009–2010, Encuesta Nacional de Micronutrientes (ENMICRON), Guatemala

Characteristics	n	Weighted Percent (%)	95% CI
National	1246	100	
Area			
Urban	525	39.6	32.4, 47.3
Rural	721	60.4	52.7, 67.6
Ethnicity			
Indigenous	472	44.9	38.6, 51.4
Non-Indigenous	774	55.1	48.6, 61.4
Sex			
Male	619	48.8	44.6, 53.0
Female	627	51.2	47.0, 55.4
Child's age (months)			
6–11	107	11.1	8.5, 14.2
12–23	346	33.3	29.4, 37.5
24–35	332	28.4	24.3, 32.9
36–47	241	15.5	12.8, 18.6
48–59	220	11.7	9.5, 14.4
Respondent's age			
15–19	84	8.3	5.5, 12.0
20–24	289	23.8	19.9, 28.3
25–29	366	27.2	23.6, 31.1
30–34	263	18.1	15.4, 21.3
35–39	162	14.6	11.3, 18.7
40–44	62	5.6	3.8, 8.2
45–49	20	2.4	1.2, 4.6
Respondent's education			
No education	295	30.6	25.4, 36.3
Elementary	681	52.0	47.0, 56.9
Secondary	231	15.7	12.8, 19.2
High school or above	39	1.7	0.9, 3.0
Household wealth index			
Lowest tertile	512	45.6	39.7, 51.2
Middle tertile	480	35.1	30.7, 39.9
Highest tertile	254	19.3	15.4, 24.2
Region			
Metropolitana	102	20.0	16.2, 24.4
Norte	97	8.9	6.8, 11.6
Nor-Oriente	191	8.7	6.9, 10.9
Sur-Oriente	153	7.6	6.3, 9.1

Characteristics	n	Weighted Percent (%)	95% CI
Central	188	11.6	9.4, 14.2
Nor-Occidente	90	20.9	18.5, 23.7
Sur-Occidente	356	18.5	14.7, 22.9
Petén	69	3.8	2.6, 5.4

CI confidence interval

Table 2

Prevalence of red blood cell folate deficiency, 2009–2010, Encuesta Nacional de Micronutrientes (ENMICRON), Guatemala

Variable	Red blood cell folate deficiency						
	n	Weighted percent (%)	95% CI	PRR unadjusted	95% CI	PRR adjusted[a]	95% CI
National	1245[b]	33.5	29.1, 38.3				
Area							
Urban	525	26.7	20.5, 34.0	0.7	0.5, 0.9[c]	0.9	0.7, 1.2
Rural	720	38.1	32.1, 44.4	Referent	–	Referent	–
Ethnicity							
Indigenous	472	38.3	30.6, 46.6	1.3	1.0, 1.7	1.2	0.9, 1.6
Non–Indigenous	773	29.6	24.8, 34.9	Referent	–	Referent	–
Sex							
Male	618	35.4	28.9, 42.3	1.1	0.9, 1.4		
Female	627	31.8	26.2, 38.0	Referent	–		
Child's age (months)							
6–11	107	46.6	32.9, 60.9	2.3	1.5, 3.6[c]	2.0	1.3, 3.1[c]
12–23	345	37.0	29.1, 45.7	1.8	1.2, 2.7[c]	1.6	1.1, 2.3[d]
24–35	332	33.6	25.9, 42.4	1.7	1.1, 2.6[d]	1.4	0.9, 2.2
36–47	241	26.9	18.7, 37.1	1.3	0.8, 2.1	1.2	0.8, 1.9
48–59	220	20.3	14.5, 27.7	Referent	–	Referent	–
Respondent's age							
15–19	84	37.3	26.2, 49.9	5.5	1.4, 22.5[c]	3.8	1.1, 13.3[d]
20–24	288	37.6	27.7, 48.5	5.6	1.4, 22.3[c]	4.2	1.2, 14.2[c]
25–29	366	33.2	25.6, 41.8	4.9	1.2, 20.1[d]	3.3	0.9, 11.4
30–34	263	33.8	25.3, 43.5	5.0	1.2, 20.6[d]	3.5	1.01, 12.3[d]
35–39	162	32.0	22.3, 43.5	4.7	1.2, 19.5[d]	3.1	0.9, 10.9
40–44	62	27.7	16.9, 41.8	4.1	0.9, 18.4	2.7	0.7, 10.1
45–49	20	6.7	1.6, 23.9	Referent	–	Referent	–

Variable	Red blood cell folate deficiency						
	n	Weighted percent (%)	95% CI	PRR unadjusted	95% CI	PRR adjusted[a]	95% CI
Respondent’s education							
No education	294	38.2	30.1, 47.1	3.0	1.3, 7.1[c]	2.3	0.9, 6.4
Elementary	681	35.5	30.1, 41.4	2.8	1.2, 6.5[c]	2.2	0.8, 5.8
Secondary	231	20.4	12.0, 32.5	1.6	0.6, 4.3	1.5	0.5, 4.0
High school or above	39	12.6	5.3, 27.0	Referent	–	Referent	–
Household wealth index							
Lowest tertile	511	42.0	34.3, 50.0	1.8	1.1, 3.1[d]	1.4	0.8, 2.4
Middle tertile	480	28.8	22.6, 35.9	1.3	0.7, 2.2	1.0	0.6, 1.7
Highest tertile	254	22.6	13.3, 35.8	Referent	–	Referent	–
Region							
Metropolitana	102	27.2	16.7, 41.1	Referent	–	Referent	–
Norte	97	46.7	35.8, 57.9	1.7	1.0, 2.9[d]	1.1	0.7, 1.9
Nor–Oriente	191	38.2	28.4, 49.1	1.4	0.8, 2.4	1.1	0.7, 1.8
Sur–Oriente	153	40.2	28.6, 53.0	1.5	0.8, 2.6	1.2	0.8, 1.9
Central	188	41.1	30.7, 52.3	1.1	0.9, 2.6	1.3	0.8, 2.0
Nor–Occidente	89	30.3	23.7, 37.9	1.1	0.7, 1.9	1.0	0.3, 1.2
Sur–Occidente	356	25.4	12.9, 44.0	0.9	0.4, 2.0	0.6	0.3, 1.2
Petén	69	44.3	28.3, 61.6	1.6	0.9, 3.0	1.2	0.7, 2.1

CI confidence interval, *PRR* prevalence risk ratio

[a]Adjusted for area, ethnicity, child’s age, respondent’s age, respondent’s education, household wealth index, and region

[b]Blood samples with sufficient blood volume

[c]p value <0.01

[d]p value <0.05

Table 3

Prevalence of vitamin B12 and marginal vitamin B12 deficiency, 2009–2010, Encuesta Nacional de Micronutrientes (ENMICRON), Guatemala

Variable	n	Vitamin B12 deficiency						Vitamin B12 marginal deficiency					
		Weighted percent (%)	95% CI	PRR un-adjusted	95% CI	PRR adjusted[a]	95% CI	Weighted percent (%)	95% CI	PRR unadjusted	95% CI	PRR adjusted[a]	95% CI
National	1143[b]	22.5	18.2, 27.5					27.5	23.7, 31.7				
Area													
Urban	490	15.4	10.3, 22.3	0.6	0.4, 0.9[c]	1.2	0.9, 1.6	21.9	16.2, 28.8	0.7	0.5, 0.9[d]	0.9	0.7, 1.2
Rural	653	27.3	21.5, 34.0	Ref	–	Ref	–	31.3	26.5, 36.6	Referent	–	Referent	–
Ethnicity													
Indigenous	428	34.5	27.3, 42.4	2.6	1.9, 3.6[c]	2.1	1.4, 3.0[c]	28.1	22.6, 34.4	1.0	0.8, 1.4	0.9	0.6, 1.3
Non-Indigenous	715	13.1	10.2, 16.8	Ref	–	Ref	–	27.0	21.9, 32.9	Referent	–	Referent	–
Sex													
Male	565	23.5	17.6, 30.7	1.1	0.7, 1.7			30.8	23.8, 38.8	1.3	0.9, 1.8		
Female	578	21.6	15.6, 29.1	Ref	–			24.5	19.8, 30.0	Referent	–		
Child’s age (months)													
6–11	91	35.1	21.2, 52.0	2.4	1.2, 4.8[d]	1.8	1.0, 3.3	23.1	13.6, 36.4	1.3	0.7, 2.4	1.3	0.7, 2.4
12–23	319	21.2	14.9, 29.4	1.5	0.9, 2.3	1.2	0.8, 1.8	36.9	29.3, 45.2	2.1	1.3, 3.2[d]	2.0	1.3, 3.1[d]
24–35	304	26.3	17.8, 37.0	1.8	1.04, 3.2[d]	1.3	0.9, 2.1	21.5	16.0, 28.2	1.2	0.8, 1.8	1.2	0.7, 1.8
36–47	222	15.9	9.9, 24.5	1.1	0.6, 2.1	0.9	0.5, 1.6	29.1	21.7, 37.7	1.6	1.02, 2.6[d]	1.6	1.0, 2.5
48–59	207	14.4	8.9, 22.6	Ref	–	Ref	–	17.9	12.3, 25.4	Referent	–	Referent	–
Respondent’s age													
15–19	79	17.9	8.8, 32.9	1.8	0.4, 8.3			24.1	13.5, 39.2	0.8	0.3, 2.1		

Variable	n	Vitamin B12 deficiency						Vitamin B12 marginal deficiency					
		Weighted percent (%)	95% CI	PRR un-adjusted	95% CI	PRR adjusted[a]	95% CI	Weighted percent (%)	95% CI	PRR unadjusted	95% CI	PRR adjusted[a]	95% CI
20–24	264	22.9	13.2, 36.7	2.4	0.6, 9.9			30.9	21.1, 42.8	1.0	0.3, 3.2		
25–29	339	23.5	16.3, 32.8	2.4	0.6, 9.6			24.2	17.4, 32.6	0.8	0.3, 2.2		
30–34	239	19.5	12.6, 28.9	2.0	0.5, 8.1			31.6	23.7, 40.7	1.1	0.4, 2.7		
35–39	145	27.8	18.7, 39.1	2.9	0.7, 11.6			27.3	16.5, 41.5	0.9	0.3, 2.5		
40–44	57	25.0	12.6, 43.6	2.6	0.6, 11.9			21.2	12.3, 34.1	0.7	0.3, 1.9		
45–49	20	9.7	2.3, 32.3	Referent	–			29.7	10.8, 52.6	Referent	–		
Respondent's education													
No education	263	37.0	26.0, 49.4	3.0	0.9, 9.9			31.4	22.6, 41.9	5.5	2.1, 14.6[c]		
Elementary	633	19.6	15.0, 25.3	1.6	0.5, 5.4			27.9	23.1, 33.4	4.9	2.0, 12.3[c]		
Secondary	214	6.7	3.6, 12.1	0.5	0.1, 2.1			21.2	14.1, 30.6	3.7	1.4, 10.0[c]		
High school or above	33	12.5	3.5, 35.6	Referent	–			5.7	2.3, 13.6	Referent	–		
Household wealth index													
Lowest tertile	462	34.3	27.2, 42.2	5.7	3.0, 10.7[d]	4.4	2.3, 8.3[d]	31.3	25.1, 38.4	2.8	1.2, 3.2[d]	1.6	1.03, 2.4[d]
Middle tertile	445	16.9	11.7, 23.8	2.8	1.4, 5.5[d]	2.4	1.3, 4.4[d]	29.1	23.8, 34.9	1.9	1.2, 2.8[d]	1.6	1.1, 2.4[d]
Highest tertile	236	6.0	3.3, 10.8	Referent	–	Referent	–	16.0	10.0, 24.5	Referent	–	Referent	–
Region													
Metropolitana	100	14.2	6.8, 27.0	Referent	–	Referent	–	19.7	11.3, 31.8	Referent	–	Referent	–
Norte	78	49.4	31.7, 67.3	3.5	1.6, 7.7[d]	1.3	0.7, 2.4	22.5	16.4, 30.2	1.1	0.6, 2.1	1.1	0.6, 2.0
Nor-Oriente	172	16.5	9.4, 27.5	1.2	0.5, 2.8	0.9	0.5, 1.6	34.8	25.4, 45.6	1.8	1.0, 3.2	1.5	0.9, 2.5

Variable	n	Vitamin B12 deficiency						Vitamin B12 marginal deficiency					
		Weighted percent (%)	95% CI	PRR un-adjusted	95% CI	PRR adjusted[a]	95% CI	Weighted percent (%)	95% CI	PRR unadjusted	95% CI	PRR adjusted[a]	95% CI
Sur-Oriente	147	25.0	16.6, 35.7	1.8	0.8, 3.9	1.3	0.8, 2.0	31.2	22.1, 42.0	1.6	0.9, 2.9	1.3	0.8, 2.3
Central	183	21.6	15.1, 30.0	1.5	0.7, 3.3	0.9	0.5, 1.6	29.0	20.7, 38.9	1.5	0.8, 2.7	1.3	0.8, 2.2
Nor-Occidente	311	17.7	12.8, 23.9	2.1	0.9, 5.0	0.7	0.4, 1.4	27.5	21.7, 34.2	1.6	0.8, 3.2	1.4	0.7, 2.6
Sur-Occidente	85	29.4	16.2, 47.3	1.2	0.6, 2.7	0.7	0.4, 1.2	32.3	20.2, 47.4	1.4	0.8, 3.2	1.2	0.7, 2.0
Petén	67	16.5	7.2, 33.3	1.2	0.4, 3.3	0.5	0.2, 1.1	29.7	18.7, 43.6	1.5	0.8, 3.0	1.3	0.6, 2.4

CI confidence interval, *PRR* prevalence risk ratio

[a] Adjusted for area, ethnicity, child's age, household wealth index, and region

[b] Blood samples with sufflcient blood volume

[c] p value <0.01

[d] p value <0.05

Table 4

Red blood cell folate concentrations geometric means and geometric ratios by population characteristics, 2009–2010, Encuesta Nacional de Micronutrientes (ENMICRON), Guatemala

Variable	Red blood cell folate concentrations (nmol/L)						
	n	GM (Unadjusted)	95% CI	GM ratio (Unadjusted)	95% CI	GM ratio (Adjusted)[a]	95% CI
National	1245[b]	354.2	340.3, 372.4				
Area							
Urban	525	391.5	365.0, 419.9	1.2	1.1, 1.3[c]	1.0	0.9, 1.1
Rural	720	333.6	317.3, 350.7	Referent	–		–
Ethnicity							
Indigenous	472	333.6	311.1,357.8	0.9	0.8, 0.9[c]	0.9	0.9, 1.0
Non-Indigenous	773	376.1	357.8, 391.5	Referent	–		
Sex							
Male	618	350.7	330.3, 372.4	0.9	0.9, 1.0		
Female	627	361.4	343.8, 350.7	Referent	–		
Child's age (months)							
6–11	107	330.3	284.3, 383.7	0.9	0.7, 1.0[d]	0.9	0.7, 1.0[d]
12–23	345	347.2	323.8, 376.4	0.9	0.8, 1.0[d]	0.9	0.8, 1.0
24–35	332	357.8	334.0, 376.1	0.9	0.8. 1.0[d]	0.9	0.8, 1.0
36–47	241	365.0	333.6, 399.4	0.9	0.8, 1.0	0.8	0.7, 1.1
48–59	220	391.5	368.7, 415.7	Referent	–	Referent	–
Respondent's age							
15–19	84	376.1	340.4,411.6	0.9	0.8, 1.0[d]	0.9	0.7, 0.9[d]
20–24	288	354.2	333.6, 376.1	0.8	0.7, 0.9[c]	0.8	0.7, 0.9[c]
25–29	366	345.1	314.2, 376.1	0.8	0.7, 1.0[d]	0.8	0.7, 0.9[d]
30–34	263	343.8	313.7, 379.6	0.8	0.7, 0.9[c]	0.8	0.7, 0.9[c]
35–39	162	357.8	327.0, 391.5	0.8	0.7, 1.0[d]	0.9	0.7, 1.0
40–44	62	403.4	354.2, 454.9	0.9	0.8, 1.1	0.9	0.8, 1.1

Variable	Red blood cell folate concentrations (nmol/L)						
	n	GM (Unadjusted)	95% CI	GM ratio (Unadjusted)	95% CI	GM ratio (Adjusted)[a]	95% CI
45–49	20	437.0	383.7, 492.7	Referent	–	Referent	–
Respondent's education							
No education	294	333.6	311.1,354.2	0.8	0.6, 0.9[c]	0.8	0.7, 0.9[d]
Elementary	681	350.7	330.3, 368.7	0.8	0.7, 1.0[d]	0.9	0.8, 1.1
Secondary	231	419.9	391.5,450.3	0.9	0.8, 1.2	0.9	0.8, 1.2
High school or above	39	445.8	368.7, 533.8	Referent	–		
Household wealth index							
Lowest tertile	511	320.5	301.9, 343.8	0.8	0.7, 0.9[c]	0.8	0.7, 0.9[d]
Middle tertile	480	368.7	343.8, 395.4	0.9	0.8, 1.0[d]	0.9	0.8, 1.0
Highest tertile	254	424.1	383.7, 468.7	Referent	–	Referent	–
Region							
Metropolitana	102	395.4	350.7, 445.8	Referent	–	Referent	–
Norte	97	323.8	295.9, 357.8	0.8	0.7, 0.9[d]	1.0	0.8, 1.2
Nor-Oriente	191	336.9	301.9, 357.8	0.8	0.7, 1.0	0.9	0.8, 1.1
Sur-Oriente	153	333.6	299.0, 372.4	0.8	0.7, 1.0[d]	0.9	0.8, 1.0
Central	188	330.3	308.0, 357.8	0.8	0.7, 1.0[d]	0.9	0.8, 1.0
Nor-Occidente	89	368.7	320.5, 424.1	0.9	0.8, 1.1	1.1	0.9,1.2
Sur-Occidente	356	361.4	337.0, 391.5	0.9	0.8, 1.0	1.0	0.9,1.2
Petén	69	320.5	284.3, 361.4	0.8	0.7, 1.0[d]	0.9	0.8, 1.1

GM geometric mean, *CI* confidence interval, *PRR* prevalence risk ratio

[a]Adjusted for area, ethnicity, child's age, respondent's age, respondent's education, household wealth index, and region

[b]Blood samples with sufficient blood volume

[c]p value <0.01

[d]p value <0.05

Table 5

Serum vitamin B12 concentrations geometric means and geometric ratios by population characteristics, 2009–2010, Encuesta Nacional de Micronutrientes (ENMICRON), Guatemala

Variable	Serum vitamin B12 concentrations (pmol/L)						
	n	GM (Unadjusted)	95% CI	GM ratio (Unadjusted)	95% CI	GM ratio (Adjusted)[a]	95% CI
National	1143[b]	235.1	221.4, 249.6				
Area							
Urban	490	281.5	257.2, 304.9	1.3	1.2, 1.5[c]	1.0	0.9, 1.1
Rural	653	208.5	194.4, 223.6	Referent	–	Referent	–
Ethnicity							
Indigenous	428	196.4	181.2, 214.9	0.7	0.6, 0.8[c]	0.8	0.7, 0.9[c]
Non-Indigenous	715	270.4	254.7, 287.1	Referent	–	Referent	–
Sex							
Male	565	228.1	212.7, 244.7	0.9	0.9, 1.04		
Female	578	242.2	223.6, 262.4	Referent	–		
Child's age (months)							
6–11	91	206.4	175.9, 242.5	0.7	0.6, 0.9[c]	0.8	0.7, 0.96[d]
12–23	319	230.4	208.5, 254.7	0.8	0.7, 0.9[c]	0.9	0.8, 0.9[d]
24–35	304	219.2	200.3, 242.5	0.8	0.7, 0.9[c]	0.9	0.8, 0.9[c]
36–47	222	267.7	232.7, 308.0	0.9	0.8, 1.1	1.0	0.9, 1.1
48–59	207	275.9	249.6, 308.0	Referent	–	Referent	–
Respondent's age							
15–19	79	237.5	202.3, 275.8	0.8	0.6, 1.2		
20–24	264	228.1	204.4, 275.9	0.8	0.6, 1.1		
25–29	339	247.1	223.6, 275.9	0.9	0.6, 1.2		
30–34	239	232.5	212.7, 254.7	0.8	0.6, 1.2		
35–39	145	212.7	188.7, 242.5	0.7	0.5, 1.1		
40–44	57	242.2	186.8, 314.2	0.8	0.5, 1.3		
45–49	20	284.3	254.4, 395.4	Referent	–		

Variable	Serum vitamin B12 concentrations (pmol/L)						
	n	GM (Unadjusted)	95% CI	GM ratio (Unadjusted)	95% CI	GM ratio (Adjusted)[a]	95% CI
Respondent's education							
No education	263	183.1	167.3, 202.3	0.5	0.4, 0.6[c]	0.7	0.5, 0.9[c]
Elementary	633	244.5	228.1, 262.4	0.6	0.5, 0.8[c]	0.8	0.6, 1.0
Secondary	214	308.0	281.5, 341.3	0.8	0.6, 1.03	0.9	0.7, 1.1
High school or above	33	379.9	311.1, 468.7	Referent	–		
Household wealth index							
Lowest tertile	462	190.6	175.9, 204.4	0.5	0.5, 0.6[c]	0.6	0.5, 0.7[c]
Middle tertile	445	247.1	230.4, 265.1	0.7	0.6, 0.8[c]	0.7	0.6, 0.8[c]
Highest tertile	236	350.7	314.2, 387.6	Referent	–	Referent	–
Region							
Metropolitana	100	292.9	252.1, 340.3	Referent	–	Referent	–
Norte	78	172.4	142.6, 208.5	0.6	0.5, 0.7[c]	0.8	0.7, 1.0
Nor-Oriente	172	257.2	230.4, 287.1	0.9	0.7, 1.1	1.1	0.9, 1.2
Sur-Oriente	147	217.0	188.7, 252.1	0.7	0.6, 0.9[c]	0.9	0.7, 1.0
Central	183	221.4	200.3, 247.1	0.8	0.6, 0.9[c]	0.9	0.8, 1.1
Nor-Occidente	85	239.8	219.2, 262.4	0.8	0.7, 0.9[d]	1.0	0.9, 1.1
Sur-Occidente	311	211.2	179.4, 278.8	0.7	0.6, 0.9[c]	1.0	0.9, 1.2
Petén	67	229.8	196.4, 269.0	0.8	0.6, 0.9[d]	1.0	0.8, 1.3

GM geometric mean, *CI* confidence interval

[a]Adjusted for area, ethnicity, child's age, household wealth index, and region

[b]Blood samples with sufficient blood volume

[c]p value <0.01

[d]p value <0.05