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Vitamin B_{12} serostatus in Colombian children and adult women: results from a nationally representative survey

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Abstract
Objective: Vitamin B_{12} deficiency is associated with many adverse health outcomes and is highly prevalent worldwide. The present study assesses the prevalence of vitamin B_{12} deficiency and marginal deficiency in Colombian children and women and examines the sociodemographic correlates of serum vitamin B_{12} concentrations in these groups.
Design: Cross-sectional, nationally representative survey.
Setting: Colombia.
Subjects: Children <18 years old (n 7243), pregnant women (n 1781), and non-pregnant women 18–49 years old (n 499).
Results: The overall prevalence of vitamin B_{12} deficiency (serum vitamin B_{12} <148 pmol/l) and marginal deficiency (serum vitamin B_{12} = 148–221 pmol/l) was, respectively, 6·6 % (95 % CI 5·2 %, 8·3 %) and 22·5 % (95 % CI 21·1 %, 23·9 %). Pregnant women had the highest prevalence of deficiency (18·9 %; 95 % CI 16·6 %, 21·5 %) compared with non-pregnant adult women (18·5 %; 95 % CI 4·4 %, 53·1 %) and children (2·8 %; 95 % CI 2·3 %%, 3·3 %). In multivariable analyses among children, mean serum vitamin B_{12} was positively associated with female sex (12 pmol/l higher compared with males; P = 0·004), secondary or higher education of the household head (12 pmol/l higher compared with primary or less; P = 0·009) and food security (21 pmol/l higher compared with severe food insecurity; P = 0·003). In multivariable analyses among pregnant women, mean serum vitamin B_{12} was positively associated with education of the household head and inversely associated with living in the National territories, Eastern or Pacific regions.
Conclusions: The prevalence of vitamin B_{12} deficiency and marginal deficiency in Colombian women and children is substantial. The burden falls largely on adult women, those with lowest education and those living in the poorest, most rural regions of the country.

Keywords
Vitamin B_{12}
Deficiency
Prevalence
Representative survey
Colombia

Vitamin B_{12} plays an important role in neurocognitive development and function(1), and its deficiency has been associated with a number of poor health outcomes including anaemia, congenital malformations, neurological deficits and hyperhomocysteinaemia(2–5). Animal foods, fortified foods and supplements are the main sources of vitamin B_{12}. Consequently, vitamin B_{12} deficiency may be more prevalent in vegetarians, vegans, and people living in low-income communities where they may have limited purchasing power to acquire animal food sources or may not have access to fortified foods or supplements.

Some studies suggest that vitamin B_{12} deficiency and marginal deficiency are highly prevalent worldwide(6). In the few countries where nationally representative data exist, the prevalence of vitamin B_{12} deficiency (serum vitamin B_{12} < 130 to <150 pmol/l) ranges from 11 % to 15 % in women from Germany, the UK(6) and Vietnam(7), to 31 % among elderly from the UK. Regional surveys found vitamin B_{12} deficiency in 49 % of adults in India, 40 % of children in Kenya, 28 % of pregnant women in Nepal and 20 % of women in New Zealand(6). Vitamin B_{12} deficiency is also of public health concern in Latin America. In nationally representative studies conducted in Argentina(8), Chile(9), Costa Rica(10), Venezuela(11) and Mexico(12,13), the prevalence of vitamin B_{12} deficiency was, respectively, 3·4–4·7 %, 8·5 %, 5·3 %, 11·4 % and 25–30 %. High prevalences of deficiency, ranging from 13 % to 82 %, were reported in non-nationally representative studies conducted in Cuba(14) and Guatemala(15,16).

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Only one study to date has investigated the prevalence of vitamin B_{12} deficiency in Colombia, a country lacking a vitamin B_{12} fortification policy where disparities in food purchasing power remain wide. Among schoolchildren from low- and middle-income families in Bogotá, the prevalence of vitamin B_{12} deficiency (serum vitamin $B_{12} < 148$ pmol/l) and marginal deficiency (serum vitamin $B_{12} \geq 148$ and <222 pmol/l) was 1·6 % and 15·0 %, respectively[17]. In this population, low vitamin B_{12} concentrations were associated with poverty and low intake of animal food sources. While results from this investigation suggest that vitamin B_{12} deficiency is a non-negligible public health problem in this setting, its results cannot be generalized to the whole country. A nationally representative sample would be needed to evaluate the vitamin B_{12} status of Colombians. Furthermore, it would allow the examination of vitamin B_{12} status in particularly vulnerable population groups including pregnant women and women of reproductive age. Our study aimed to estimate the prevalence of vitamin B_{12} deficiency and marginal deficiency using serum concentrations of vitamin B_{12} in a nationally representative sample of Colombian women and children. In addition, we investigated the sociodemographic correlates of serum vitamin B_{12} concentrations in these groups.

Methods

Study population

The Colombian National Nutrition Survey (ENSIN) was conducted in 2010 by the Colombian Institute of Family Welfare (Instituto Colombiano de Bienestar Familiar). Details of the survey have been published elsewhere[18]. In brief, participants were selected to represent 99 % of the country's population using a multistage stratified sampling scheme. All municipalities from the thirty-two departments in the country were grouped into strata based on similar geographic and sociodemographic characteristics. One municipality was randomly chosen from each stratum, with probability proportional to the population size. Clusters of about ten households each were then randomly chosen from within these strata and household members were invited to participate. The survey included 50 670 households, representing 4987 clusters from 258 strata.

Trained personnel administered questionnaires to the head of the household to obtain information on demographic characteristics, measures of food insecurity and wealth. Anthropometric measurements were obtained in all household members with the use of standardized techniques and calibrated instruments. Height was measured with the use of a stadiometer (Diseños Flores S.R. Ltda, Bogotá, Colombia), to the nearest millimetre. Weight was measured on SECA 872 scales to the nearest 100 g. In a random sub-sample of participants, blood was collected by venepuncture and serum was separated into aliquots. All samples were stored in liquid nitrogen until processing at the National Institute of Health of Colombia. Serum vitamin B_{12} was quantified in these samples using the method of direct chemiluminescence (ADVIA Centaur equipment, Siemens). This method offers high sensitivity and is less costly, easier to implement and safer than microbiological, chromatographic or spectrophotometric assays[19].

The study was conducted according to the guidelines laid down in the Declaration of Helsinki. Consent for participation in the survey was obtained by the Colombian Institute of Family Welfare prior to enrolment[18]. The Health Sciences and Behavioral Sciences Institutional Review Board at the University of Michigan determined that analyses of these anonymized data were exempt from review.

Data sources

The survey included 188 599 people. Serum vitamin B_{12} was quantified in a random re-weighted sub-sample (*n* 9523) of children 1–17 years of age and women 18–49 years of age. They constituted the final analytical sample. There were 7243 boys and non-pregnant girls aged <18 years, 1781 pregnant women and 499 non-pregnant women aged ≥18 years.

The main outcomes of interest were mean serum vitamin B_{12} concentrations (pmol/l) and the prevalence of vitamin B_{12} deficiency (serum concentration <148 pmol/l) and marginal deficiency (serum concentration ≥148 and <222 pmol/l). Adequate concentration of serum vitamin B_{12} was defined as ≥222 pmol/l.

We examined vitamin B_{12} status according to sociodemographic and anthropometric characteristics. Food security status was measured using a modified version of the Community Childhood Hunger Identification Project[20], which has been previously adapted for and validated in a Colombian population[21]. There are twelve questions, addressed to the head of the household, regarding food insecurity experienced within the past 30 d due to lack of money for food. Only seven questions are asked to households without children. Response options for each question ('no', 'seldom', 'sometimes' or 'always') were assigned codes 0, 1, 2 or 3, respectively. Codes were added through all responses and the sum was categorized into a four-level variable: food secure (sum = 0), mild food insecurity (sum = 1–7 or 1–12 in households without or with children, respectively), moderate food insecurity (sum = 8–14 or 13–24) or severe food insecurity (sum ≥ 15 or ≥25). Wealth was measured using a survey designed for the international Demographic and Health Surveys[22]. A continuous index representing household wealth was quantified by principal component analysis of various socio-economic indicators including household assets, type of flooring, number of bedrooms per person and mode of transportation. This variable was categorized into quintiles. In adults, BMI was estimated from measured weight and height as kg/m^2. In children (age < 18 years), we estimated height- and BMI-for-age *Z*-scores with the use of the WHO growth standard[23] or reference[24] for children and adolescents if 60 months of age or older.

Data analysis

All analyses were conducted with the use of the complex survey design routines of the Stata statistical software package version 12. We estimated weighted prevalences of vitamin B_{12} deficiency and marginal deficiency for boys and non-pregnant girls <18 years, pregnant women and non-pregnant women ≥18 years. Next, we estimated mean vitamin B_{12} serum concentrations and their standard errors by levels of predictors including age, sex, socio-economic status indicators, urbanicity and region of origin. Linear regression models were used to estimate adjusted mean differences between groups and 95 % confidence intervals, with vitamin B_{12} serum concentration (pmol/l) as the dependent variable and sociodemographic variables as the predictors. In addition, we conducted tests for linear trend by introducing a variable representing categories of ordinal correlates as a continuous predictor into the models, accounting for the complex survey design. All analyses were conducted separately for boys and non-pregnant girls <18 years and for pregnant women. Analyses of vitamin B_{12} correlates could not be conducted among non-pregnant women ≥18 years because of small sample size.

Results

Mean serum vitamin B_{12} concentration was 302 (SE 4) pmol/l; the prevalence of vitamin B_{12} deficiency and marginal deficiency was, respectively, 6·6 % (95 % CI 5·2 %, 8·3 %) and 22·5 % (95 % CI 21·1 %, 23·9 %). Among children (age <18 years), pregnant women and adult non-pregnant women, prevalence of vitamin B_{12} deficiency was 2·8 % (95 % CI 2·3 %, 3·3 %), 18·9 % (95 % CI 16·6 %, 21·5 %) and 18·5 % (95 % % CI 4·4 %, 53·1 %), respectively (Fig. 1). Prevalence of marginal vitamin B_{12} deficiency in the same groups was 18·2 % (95 % CI 17·0 %, 19·5 %), 41·0 % (95 % CI 38·0 %, 44·1 %) and 18·8 % (95 % CI 7·7 %, 39·2 %).

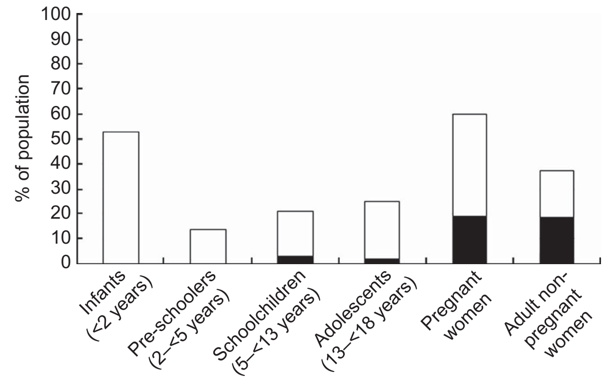

Fig. 1 Prevalence of vitamin B_{12} deficiency (serum concentration < 148 pmol/l; ■) and marginal deficiency (serum concentration ≥ 148 and < 222 pmol/l; □) in Colombian children and women, National Nutrition Survey 2010. Infants, *n* 16; pre-schoolers, *n* 84; schoolchildren, *n* 6908; adolescents, *n* 235; pregnant women, *n* 1781; adult non-pregnant women, *n* 499

Next, we examined correlates of serum vitamin B_{12} in children (Table 1). In bivariate analyses, mean serum vitamin B_{12} was significantly positively related to female sex, education of the household head, wealth, food security, and living in urban areas or in Bogotá and the Central or Atlantic regions. After multivariable adjustment, serum vitamin B_{12} was 12 pmol/l higher in girls than boys ($P = 0·004$). Children whose parents had at least secondary education had mean serum vitamin B_{12} concentration 12 pmol/l (95 % CI 3, 21 pmol/l; $P = 0·009$) higher than those whose parents had only primary education or less. There was a monotonic positive relationship of serum vitamin B_{12} with food security; compared with children from households without food insecurity, serum vitamin B_{12} was on average 21 pmol/l lower ($P = 0·003$) in children from households with severe food insecurity. The associations with wealth index and geographic area were attenuated in multivariable analysis and became non-statistically significant. Mean serum vitamin B_{12} was not associated with child's age or height-for-age *Z*-score. There was an inverse, non-statistically significant relationship between BMI-for-age *Z*-score and mean serum vitamin B_{12} concentration.

In pregnant women, serum concentrations of vitamin B_{12} were significantly positively associated with education of the household head (Table 2). After adjustment, compared with having less than primary education, university education of the household head was related to on average 24 pmol/l higher serum vitamin B_{12} levels in pregnant women ($P = 0·03$). Living in the National territories, the Eastern or the Pacific regions was associated with significantly lower serum vitamin B_{12} levels than living in other regions. Serum vitamin B_{12} was not significantly associated with age, height, wealth, food insecurity or urbanicity among pregnant women.

Discussion

We estimated the prevalence of vitamin B_{12} marginal deficiency and deficiency in children, pregnant women and adult non-pregnant women in a representative sample of the Colombian population in 2010 using serum concentrations of vitamin B_{12}. We found a substantial combined prevalence of vitamin B_{12} deficiency and marginal deficiency of 28·7 % in these groups. Prevalence of deficiency was close to 20 % among women of childbearing age. Because this figure is above 5 %, vitamin B_{12} deficiency can be characterized as a country-wide public health problem in this subgroup[6].

Our findings are similar to those in other Latin American countries, where high prevalences of vitamin B_{12} deficiency and marginal deficiency were common public health problems in the 1990s[6,25]. A national survey in

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Table 1 Serum vitamin B_{12} concentrations (pmol/l) in Colombian children* (age < 18 years, non-pregnant) according to sociodemographic characteristics

Variable	n†	Mean (pmol/l)	SE (pmol/l)	P‡	Adjusted difference§ (pmol/l)	95 % CI (pmol/l)	P‖
Overall	7243	320	2				
Sex				0·01			0·004
Males	3591	315	3				
Females	3652	325	3		12	4, 19	
Age group				0·15			0·26
Infants (<2 years)	16	266	32		−56	−130, 18	
Pre-schoolers (2–<5 years)	84	312	15		−2	−31, 27	
Schoolchildren (5–<13 years)	6908	321	2				
Adolescents (13–<18 years)	235	290	8		−28	−46, −11	
Height-for-age Z-score¶				0·16			0·77
<−2	799	314	6		−2	−15, 10	
−2 to <−1	2235	316	3		−3	−11, 5	
−1 to 1	3803	323	3				
>1 to 2	247	316	10		−5	−24, 15	
>2	49	311	27		−8	−56, 40	
BMI-for-age Z-score¶				0·08			0·08
<−2	148	336	11		11	−11, 33	
−2 to <−1	803	322	6		−2	−14, 10	
−1 to 1	5004	321	3				
>1 to 2	883	312	6		−9	−21, 3	
>2	295	313	10		−13	−33, 7	
Education of the household head				0·001			0·02
Pre-school or less	654	319	7		3	−11, 17	
Primary (1–5 years)	3553	310	3				
Secondary (6–11 years)	2387	328	4		12	2, 21	
University/technical (>11 years)	575	332	8		15	−1, 32	
Wealth index, quintiles**				0·001			0·08
Q1	2754	311	3		−14	−34, 6	
Q2	1853	314	4		−11	−29, 7	
Q3	1304	321	5		−12	−29, 6	
Q4	862	329	6		−2	−21, 16	
Q5	470	332	8				
Food insecurity in household				< 0·0001			<0·0001
No	2060	331	4				
Mild	2812	319	3		−7	−17, 3	
Moderate	1361	310	4		−20	−32, −8	
Severe	991	307	5		−20	−34, −7	
Urbanicity				< 0·0001			0·09
Urban centre	4412	325	3				
Small village	1749	317	5		2	−13, 16	
Disperse population	1082	301	4		−13	−26, 1	
Country region				0·008			< 0·0001
Bogotá	305	335	9		−14	−34, 7	
Central	1605	341	5				
Atlantic (North)	1574	343	4		1	−11, 13	
National territories (South)	1586	310	4		−32	−46, −18	
Eastern	1184	300	4		−40	−52, −28	
Pacific (West)	989	274	4		−67	−79, −55	

*National Nutrition Survey 2010; *n* 7243.
†Totals may be less than 7243 due to missing values.
‡Test for linear trend for ordinal predictors. For sex, urbanicity and country region, *P* is from ANOVA. All tests incorporated the complex sampling survey design.
§From linear regression models with serum vitamin B_{12} as a continuous outcome and indicator variables for all characteristics presented in the table as predictors. Estimates for education were from a model excluding wealth index and food security, which could be on the causal pathway. Estimates for wealth index excluded food security.
‖Adjusted test for linear trend or ANOVA for ordinal or categorical correlates, respectively.
¶According to the WHO[23,24].
**The wealth index is a composite measure of a household's cumulative living standard. The wealth index is calculated using easy-to-collect data on a household's ownership of selected assets such as televisions and bicycles, materials used for housing construction, type of water supply and sanitation facilities.

Mexico (1999) showed that the combined prevalence of deficiency and marginal deficiency in children and women reached approximately 40 %[13]. However, a more recent nationally representative survey in Argentina (2007) demonstrated that the prevalence of deficiency in women was 3·4 %, much lower than the figure reported here[8]. Only one previous study had examined vitamin B_{12} status in Colombia. Among low- and middle-income children from Bogotá, the combined prevalence of deficiency and marginal deficiency reached 17 % in 2006[17], similar to the figure found for this age group and city in the present survey.

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Table 2 Serum vitamin B_{12} concentrations (pmol/l) in Colombian pregnant women* according to sociodemographic characteristics

Variable	*n*†	Mean (pmol/l)	SE (pmol/l)	*P*‡	Adjusted difference§ (pmol/l)	95 % CI (pmol/l)	*P*‖
Overall	1781	221	3				
Age (years)				0·97			0·74
<18	245	220	8		−3	−20, 14	
≥18	1536	221	4				
Height (cm)				0·40			0·28
<150	350	227	8		5	−14, 23	
150–154	522	223	6				
155–159	506	217	7		−4	−21, 12	
160–164	279	216	7		−8	−26, 9	
≥165	100	227	12		1	−22, 25	
Education of the household head				0·03			0·09
Pre-school or less	139	212	9		−7	−26, 12	
Primary (1–5 years)	757	216	4				
Secondary (6–11 years)	669	218	6		−4	−18, 10	
University/technical (>11 years)	190	245	10		24	2, 46	
Wealth index, quintiles¶				0·07			0·98
Q1	708	213	4		4	−28, 36	
Q2	431	217	6		9	−22, 39	
Q3	327	217	8		7	−26, 40	
Q4	188	236	10		16	−15, 46	
Q5	127	228	12				
Food insecurity in household				0·25			0·68
No	601	228	6				
Mild	687	214	5		−11	−27, 6	
Moderate	297	222	7		0	−20, 20	
Severe	193	215	8		−6	−27, 15	
Urbanicity				0·03			0·28
Urban centre	1146	223	4				
Small village	421	222	7		13	−5, 32	
Disperse population	214	207	5		−1	−16, 14	
Country region				<0·0001			<0·0001
Bogotá	100	249	14		14	−20, 48	
Central	360	238	7				
Atlantic (North)	436	230	5		−4	−20, 12	
National territories (South)	418	215	7		−26	−45, −7	
Eastern	237	200	5		−36	−52, −19	
Pacific (West)	230	177	5		−59	−75, −43	

*National Nutrition Survey 2010; *n* 1781.
†Totals may be less than 1781 due to missing values.
‡Test for linear trend for ordinal predictors. For urbanicity and region, *P* is from ANOVA. All tests incorporated the complex sampling survey design.
§From linear regression models with serum vitamin B_{12} as a continuous outcome and indicator variables for all characteristics presented in the table as predictors. Estimates for education were from a model excluding wealth index and food security, which could be on the causal pathway. Estimates for wealth index excluded food security.
‖Adjusted test for linear trend or ANOVA for ordinal or categorical correlates, respectively.
¶The wealth index is a composite measure of a household's cumulative living standard. The wealth index is calculated using easy-to-collect data on a household's ownership of selected assets such as televisions and bicycles, materials used for housing construction, and type of water supply and sanitation facilities.

The potential consequences of vitamin B_{12} deficiency are substantial at the individual and population levels. Deficiency of vitamin B_{12} may result in anaemia, congenital malformations, neurological deficits and hyperhomocysteinaemia[2–5]. Fortification of food vehicles with vitamin B_{12} is a useful public health nutrition intervention to curb vitamin B_{12} deficiency at the population level. In Colombia, although a policy of wheat flour fortification with micronutrients has been in effect since 1996, vitamin B_{12} is not included. The results of the present study support the notion that wheat flour fortification with vitamin B_{12} should be considered at the national level.

We had the opportunity to examine the associations of several sociodemographic and anthropometric indicators with vitamin B_{12} serostatus. While age was not related to vitamin B_{12} status in children, boys had lower serum vitamin B_{12} concentrations compared with girls. The sex difference in vitamin B_{12} status could be due to increased requirements for boys than girls at times of accelerated growth[17]. It is also possible that boys have lower intake of vitamin B_{12} from animal food sources, but lack of systematically collected dietary information in the survey prevented us from examining this potential mechanism. Indicators of socio-economic status were positively associated with serum vitamin B_{12} concentrations in children, consistent with results from a previous study of schoolchildren from Bogotá[17]. In addition, children living in urban areas and in geographic regions with greater economic and structural development in general had higher serum concentrations than those from rural and poorer areas. This socio-economic-related variation in vitamin B_{12} status in children is likely due to access to animal food sources, which tend to be the most expensive items of the family shopping basket. Adherence to an 'animal protein' dietary pattern was strongly positively related to vitamin B_{12} serostatus in children from this setting[17].

We found an inverse trend between children's BMI-for-age Z-score and serum vitamin B_{12} concentrations ($P=0·08$), consistent with previous studies of adults and children[26–29]. In a study of Israeli children, obesity was associated with a fourfold higher risk of low serum vitamin B_{12} concentrations (<181·5 pmol/l)[29]. The inverse association of serum vitamin B_{12} concentrations with BMI could be a result of increased consumption of carbohydrates and fats at the expense of animal-source protein among obese children. They may also have increased vitamin B_{12} requirements than non-obese children due to their larger body size. Whether vitamin B_{12} deficiency could lead to obesity cannot be determined by cross-sectional surveys. Future examination of this question is critical because vitamin B_{12} is a cofactor in methylation reactions and DNA hypomethylation has been related to faster weight gain in children[30]. In addition, vitamin B_{12} is also a cofactor in the synthesis of methionine from homocysteine; thus, vitamin B_{12} deficiency or marginal deficiency may lead to hyperhomocysteinaemia, which has been associated with the development of insulin resistance in prepubertal children[31] and also predicts the development of morbidity and mortality from CVD[32].

Women had a higher prevalence of vitamin B_{12} deficiency or marginal deficiency than children. This was possibly due to their greater nutritional requirements that may not be met through dietary sources. The recommended daily intake of vitamin B_{12} in women above the age of 14 years is 2·4 μg/d, compared with 1·8 μg/d for children aged 9–13 years and 1·2 μg/d for children aged 4–8 years[33]. Furthermore, malabsorbtion of food-bound vitamin B_{12} increases with age and may account in part for a higher prevalence of deficiency in adults. Pregnant women had the highest prevalence of vitamin B_{12} deficiency and marginal deficiency of the groups studied, and they also have the highest requirements; their recommended daily intake is 2·6 μg/d[33]. In pregnant women, like in children, education of the household head and living in regions with greater economic and structural development were positively associated with serum vitamin B_{12} concentrations. However, other socio-economic indicators including the wealth index and food security were not related to vitamin B_{12} serostatus among pregnant women. These null associations could be due to lack of variability in vitamin B_{12} concentrations given the high prevalence of deficiency and marginal deficiency in this group. It is also possible that the impact of socio-economic status on vitamin B_{12} varies within households. For example, mothers may prioritize providing animal food sources to their children when they are insufficient for the whole family[34]. As a result, variables like household food insecurity may not fully capture the situation of women in the survey.

We found substantial geographic and urban/rural differences in vitamin B_{12} status of children and pregnant women. The lowest concentrations were found in rural areas and in country regions with traditionally poorer living conditions, as measured with the Human Development Index[6]. The mechanisms to explain a positive association of the Human Development Index with vitamin B_{12} serostatus may be related to food security, purchasing power to obtain animal food sources and prevalence of intestinal parasites that may interfere with vitamin B_{12} absorption.

There are several strengths to our study. It is the first description of vitamin B_{12} status in Colombia using a nationally representative sample. Second, serum vitamin B_{12} is a valid biomarker of intake[17]. Third, we had an opportunity to identify specific population subgroups where vitamin B_{12} deficiency is a particularly serious problem. The study also has some limitations. First, it is based on a prevalence survey, which prevents us from establishing temporal relationships between vitamin B_{12} serostatus and the sociodemographic correlates examined. Second, folate status indicators were not available in the survey. The effects of vitamin B_{12} deficiency may mask those of inadequate folic acid status and it is important to consider both nutrients simultaneously[35]. Serum folate concentrations in children were high in the Bogota School Children Cohort[17], and high folate levels combined with low vitamin B_{12} concentrations were associated with anaemia in the same study[36] and with anaemia and cognitive impairment in studies among the elderly[37]. These findings cannot be generalized to other areas of the country where folate deficiency may be more prevalent. In addition, the policy to fortify wheat flour with micronutrients including folic acid has not been formally evaluated. Thus, there are strong justifications for measuring folate in the next national nutrition survey in Colombia. Third, the survey did not measure vitamin B_{12} serum concentrations in men >18 years or in the elderly. Due in part to decreased gastric acidity and food-bound malabsorption of vitamin B_{12}, the elderly are at an increased risk for vitamin B_{12} deficiency[33]. It would be critical to include this high-risk subgroup in future surveys. Fourth, due to sample size limitations, we could not examine the associations of vitamin B_{12} with sociodemographic characteristics in non-pregnant adult women.

Measuring serum vitamin B_{12} concentrations at the population level is practical and relatively inexpensive, and has been implemented in a number of nationally representative surveys. Nevertheless, the use of serum vitamin B_{12} as a proxy of vitamin B_{12} status requires consideration. This measurement represents both vitamin B_{12} intake and stores and not necessarily the vitamin available to tissues; thus, low values may not capture developing deficiencies. Instead, low serum vitamin B_{12} concentrations may be indicative of long-term low intake or absorption abnormalities[33], whereas concentrations of vitamin B_{12} metabolites such as total homocysteine, methylmalonic acid (MMA) or holotranscobalamin may be more sensitive indicators of deficiency status. Furthermore, the sensitivity and specificity of serum vitamin B_{12} as an indicator of vitamin B_{12} status vary according to age, concentrations of the binding protein and other factors[38,39]. In the elderly, for example, a high proportion of people with normal serum concentrations of vitamin B_{12} may present with neurological abnormalities caused by vitamin B_{12} deficiency[39]. Low serum concentrations of vitamin B_{12} also lack sensitivity to identify persons who underutilize the vitamin due to genetic defects on MMA-CoA mutase, transcobalamin II, or enzymes in the pathway of cobalamin adenosylation[33,40,41].

The use of specific cut-off points of serum vitamin B_{12} to define deficiency and marginal deficiency also deserves comment. We used the conventionally accepted cut-off points of <148 pmol/l (deficiency) and 148–222 pmol/l (marginal deficiency). While these cut-off points may be considered somewhat arbitrary, there is a pathophysiological rationale to their use. MMA and homocysteine concentrations associated with anaemia, megaloblastosis and neuropathy decrease substantially when serum vitamin B_{12} concentrations are greater than 148 pmol/l[37,42], even in the absence of clinical manifestations. Because pregnant women, the elderly and young children may have elevated MMA levels in the presence of vitamin B_{12} concentrations >148 pmol/l[43,44], a second cut-off point is necessary to capture probable (or marginal) deficiency. Infants and young children with serum vitamin B_{12} concentrations <222 pmol/l have lower Hb concentrations and higher MMA levels than children with higher vitamin B_{12} values[16,45,46]. Thus, a range of 148–222 pmol/l is conventionally used to indicate marginal deficiency that may later lead to severe deficiency. Although there is some variability in the choice of serum vitamin B_{12} cut-off points to define deficiency, those used in the present study allow for cross-comparisons with other nationally representative surveys and previous reports in this population.

Conclusion

In conclusion, vitamin B_{12} deficiency and marginal deficiency are non-negligible public health problems in Colombian children and women. The prevalence of vitamin B_{12} deficiency is particularly high in pregnant women. Socioeconomic status of the family, urbanicity and geographic region are strong predictors of vitamin B_{12} serostatus.

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