Micronutrient deficiencies according to sociodemographic factors and nutritional status among Panamanian children aged six to 59 months in 2019: a cross–sectional population–based study

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Summary

Background Micronutrient deficiencies have serious lifelong consequences. This study aimed to estimate the prevalence of anaemia, iron deficiency anaemia, iron deficiency, and vitamin A deficiency, according to sociodemographic factors and nutritional status among Panamanian children aged six to 59 months in 2019.

Methods We used data from the National Health Survey of Panama (ENSPA), a population–based, cross–sectional study, with a nationally representative subsample to evaluate haemoglobin, C–reactive protein (CRP), ferritin, and retinol levels among children aged six to 59 months. The data are shown weighted.

Findings A total of 625 children representing a population of 62,100 children (females 45.0%, 27,971/62,100; 95% CI: 37.3–53.1), aged six to 59 months were assessed. Nationally, the prevalence of anaemia was 15.5% (9604/62,100; 95% CI: 11.5–20.6), iron deficiency anaemia was 8.0% (4950/62,100; 95% CI: 5.1–12.2), iron deficiency was 26.2% (16,259/62,100; 95% CI: 20.7–32.5), and vitamin A deficiency was 3.4% (2087/62,100; 95% CI: 2.1–5.3). Children from indigenous areas exhibited a higher prevalence of all micronutrient deficiencies studied, and nationally 40.9% (2316/5656; 95% CI: 22.1–62.9) of the children with overweight/obesity exhibited at least one micronutrient deficiency.

Interpretation Our results highlight important disparities in the prevalence of nutritional deficiencies among children in different living areas. Public health strategies should focus on these vulnerable populations, as the first years of life are crucial for adequate growth and development.

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Keywords: Micronutrient deficiencies; Anaemia; Iron deficiency; Vitamin A deficiency; Panama

Introduction

Globally, one in every two children under five years of age has at least one micronutrient deficiency. Over 340 million children suffer from hidden hunger.[1] The visible effects of micronutrient deficiencies may not initially be clinically evident, however their consequences affect the health and development of children. The main micronutrient deficiencies observed in this population are anaemia, iron deficiency anaemia, iron deficiency and vitamin A deficiency.

Compared with the rest of the population, children under five years of age have the highest prevalence of anaemia.[2] The global prevalence of anaemia among children aged six to 59 months was 39.8% in 2019.[3] The consequences of anaemia at this age may be irreversible if not treated, and include impaired growth and

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Research in context

Evidence before this study

Before undertaking this study, evidence about micronutrient deficiencies in children under five was reviewed in November–December 2023 using the terms "micronutrient deficiencies", "anaemia", "iron deficiency anaemia", "iron deficiency", "vitamin A deficiency", "double burden of malnutrition", "nutritional status" "under five", "preschool children", and "Latin America region", without applying a year filter, in PubMed/Medline and Google Scholar. Additionally, reports from UNICEF and the WHO databases were considered as reference frameworks. The prevalence of vitamin A deficiency and anaemia in Panama dates back more than 10 years while the prevalence of iron deficiency has only been evaluated in prioritized districts (characterized by high levels of poverty and anaemia) in the country.

Monitoring micronutrient deficiencies, especially considering the different stages of the nutrition transition that countries are experiencing, and the socioeconomic inequities affecting vulnerable populations, is essential for public health program development.

Added value of this study

Findings from the present article showed the current national prevalence of anaemia, iron deficiency anaemia, iron deficiency, and vitamin A deficiency among Panamanian children aged six to 59 months by sociodemographic factors and nutritional status. This article highlights the disparities among children from different living areas and living conditions, and the presence of micronutrient deficiencies even among children with overweight or obesity.

Implications of all the available evidence

Our results suggest the need to prioritize interventions among children from indigenous areas, as they present the highest prevalence of all the micronutrient deficiencies assessed in the present study. Considering the relatively high prevalence of iron deficiency among children with overweight or obesity, there is a need to revise and redirect health policies and programs according to the current situation.

cognitive development.[4–6] Anaemia may be caused by diverse factors such as nutritional deficiencies, inflammation, infectious diseases, obesity, and inherited blood disorders.[2] The most frequent cause of anaemia among children under five years of age is dietary iron deficiency.[2] which can be caused by insufficient iron intake, altered iron absorption, or increased iron demand and losses.[7] Iron deficiency affects numerous physiological processes, having serious clinical consequences even in the absence of anaemia.[8]

Although the incidence of vitamin A deficiency is decreasing worldwide, it is still common in developing countries and resource–poor regions.[9,10] In low– and middle–income countries, the prevalence of vitamin A deficiency in children under five years of age was 19.5% in 2019.[11] Vitamin A plays an important role in physiological functions such as cell development, metabolism, immune competency, vision and reproduction.[9] Vitamin A deficiency is the main cause of blindness in children and can also lead to dermatological and immune impairment, increasing the risk of death from common childhood diseases such as diarrhoea.[9]

Panama is a country with 4,064,780 inhabitants located at the southernmost end of Central America. When the ENSPA was conducted, the political–administrative subdivisions comprised 13 first level administrative divisions, including ten administrative divisions called provinces and three "comarcas" which are political administrative figures of constitutional rank, unique to the American territory. The comarcas are territories administered by traditional indigenous authorities and have special laws to guarantee dual functioning, which means that the indigenous administration is on a par with national authorities in the rest of the Panamanian territory.[12]

Panama is home to several Native American peoples, such as Ngäbe, Buglé, Guna, Emberá, Wounaan, Bri Bri, Naso Tjërdi, and Bokota.[13] According to the World Bank, Panama remains one of the most unequal countries in the world, with significant poverty among indigenous peoples and Afro–Panamanians.[14]

Before the National Health Survey of Panama (ENSPA) in 2019,[15] the most recent nationally representative data on anaemia and vitamin A deficiency dated back to 1999.[16] The prevalence of vitamin A deficiency in children aged 12–59 months was 9.4%, and the prevalence of anaemia in children aged 12–23 months and 24–35 months was 52.5% and 39.7%, respectively.[16] Since then, several public health strategies for the prevention and control of micronutrient deficiencies have been implemented.[17,18] Additionally, a strategy for nutritional status monitoring to evaluate child growth standards and anaemia was implemented in 2014 and 2017, with a sampling design based on the health care centres of the Ministry of Health.[19,20] Concerning the population estimation of iron deficiency using serum ferritin and C–reactive protein (CRP) levels, only one study in 2006 was conducted in prioritized districts of Panama (second level administrative divisions with a higher level of poverty and anaemia prevalence according to the 1997 Living Standards Survey).[21]

The presence of micronutrient deficiencies is not exclusive to children with visible undernourishment. A child with overweight or obesity can also exhibit micronutrient deficiencies. This phenomenon is known as the double burden of malnutrition and is an emerging condition that results from modern diets and is characterized by high consumption of ultra–processed, energy–dense food, which is usually low in micronutrients.[22] An association between obesity and iron deficiency has been reported and is associated with chronic inflammation.[23] These children may experience the consequences of malnutrition from two directions: impaired development and altered metabolism.[1,24] The double burden of malnutrition needs to be addressed in a timely manner, since micronutrient deficiencies and their consequences may be overlooked in this population.

Updated nationally representative micronutrient deficiency assessments have long been overdue in Panama. These assessments are crucial for identifying vulnerable populations, developing targeted public health policies, and implementing adequate interventions. Additionally, assessing the double burden of malnutrition is important for monitoring whether strategies aimed at improving undernutrition are well targeted. Therefore, the aim of this study was to estimate the prevalence of anaemia, iron deficiency anaemia, iron deficiency, and vitamin A deficiency according to sociodemographic factors and nutritional status among Panamanian children aged six to 59 months in 2019.

Methods

Setting

The ENSPA 2019 was a nationwide, population based, cross–sectional study designed to assess the general health status and the prevalence of several diseases in the Panamanian population divided into two age groups, zero to 14 years old and 15 years old and older. The geographic distribution of eligible residents was identified through the last national census (2010).

A complex randomized, tri–phased, and stratified cluster sampling method was used. In the first phase, the primary sampling units (PSUs) were randomly selected using an implicit geographic stratification, according to the political-administrative codification of the country considering the division by living area (urban, rural, or indigenous). In the second phase, occupied private dwellings were randomly selected from the previously selected PSUs. In the third phase of sampling, a resident of the occupied private dwellings was randomly selected from each age group. The results of the ENSPA were representative of the population at the country level, including living areas.

Living area was classified according to the definitions used by the National Institute of Statistics and Census (INEC) of Panama into urban (localities with at least 1500 inhabitants with electricity, public water supply, sewage system, paved streets, primary and secondary schools, commercial establishments, and social and recreational centres); rural (localities with less than 1500 inhabitants who do not have all or most of the characteristics defined as belonging to the urban area category); and indigenous (all demarcated populated places within the indigenous comarcas).[15]

Blood sampling was performed in a randomly selected subsample, of the original study sample. This subsample was selected through a simple random sampling of proportions for each age group (six to 59 months, five to nine years, ten to 14 years, 15–59 years, and 60 years and older). This subsample was also representative at the national and living area levels.

Furthermore, for children under five years old, primary sampling units that contained the target population were intentionally added within the domains of the ENSPA, given the low Panamanian fertility rate. The sample and weights were generated by the INEC of Panama. Data collection was carried out between June and December of 2019. The ENSPA 2019 has been previously described,[25,26] and a detailed description is found on their website in the Spanish language.[15]

For the present study, data were extracted from the questionnaires developed for the ENSPA study (specifically, the questionnaire for children under 15 years old and the household questionnaire).[15]

Participants

For the present study, a total of 625 children, representing a weighted population of 62,100 children aged six to 59 months, were assessed (Fig. 1). Children under six months old were excluded from blood sampling due to a higher sampling difficulties, higher risks, and a lack of reference values for micronutrient deficiencies in this age group. Children with missing or invalid information on micronutrient and anthropometric data, children with oedema, and preterm children were also excluded from the analyses.

Blood sampling

For children aged six to 59 months total blood count, and serum levels of CRP, ferritin, and retinol were assessed. After the questionnaire data collection, the children and their caregivers were summoned and transported to their assigned health care centres for blood sample collection. All the laboratory personnel were trained to follow a standardized procedure for sample extraction, handling, storage, and transportation. Blood samples were drawn with the child seated on and held by their parent or caregiver. Blood was collected by venepuncture after cleaning the site with an alcohol swab and was distributed as follows: four ml into a tube without anticoagulant and two ml into a tube with anticoagulant (EDTA). As required for Vitamin A metabolite analysis, the tubes were wrapped in aluminium foil immediately after blood extraction to

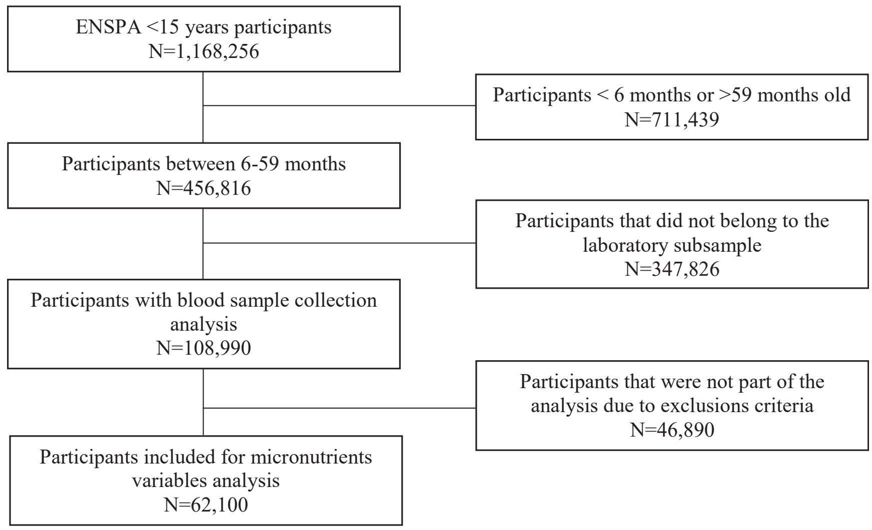

Fig. 1: Flowchart summarizing the inclusion and exclusion criteria (children with missing or invalid information on micronutrient and anthropometric data, with oedema or children born pre-term) for participation. N = Weighted population.

ensure photoprotection. Sample processing was carried out at the same centre where the sample was extracted. The tubes without anticoagulant were centrifuged at 3500 rpm for 10 min for serum separation and divided into cryovials within 2 h of collection according to cold chain specifications; for Vitamin A photoprotection was ensured by using opaque amber cryovials. Samples were then retrieved and transported by Hospital Nacional (ISO 15189 certified contractor responsible for the sample analyses) to their worksite in containers at a maximum of −20 °C for Vitamin A cryovials and at four to eight °C for the other tubes and cryovials. Biochemical and haematological analyses were conducted within 48 h.

For the present study haemoglobin (g/dl), CRP (mg/dl), ferritin (ng/ml), and retinol (mcg/dl) levels were assessed in children aged six to 59 months. Haemoglobin was assessed by photometric methods using an automated haematological Ruby Abbot analyser; serum CRP was determined by nephelometry using a Minineph analyser; serum ferritin was determined by chemiluminescence using an Architect Ni1000 analyser; and serum retinol was determined by high–performance liquid chromatography.

All pre–analytical, analytical, and post–analytical procedures were conducted following the Laboratory Manual Guide prepared by ENSPA National Coordinators.[15]

Anthropometric measurements

Anthropometric measurements were performed in the households of the participants at the time of the survey. The anthropometric data included weight, which was measured using a portable digital scale (SECA Model 874dr), and height, which was measured using a stadiometer (SECA Model 213I) equipped with a level (Hamburg, Germany), or length, which was measured using an infantometer (SECA Model 417) with a solid measurement board that was foldable and portable with a fixed stop for the head and a mobile stop for the feet. The protocol used for the anthropometric measurements has been previously described.[15] For children under two years old, weight was determined using the two–in–one function of the scale that allowed us to weigh children held in their parent's arms. Length was measured in the lying position with the infantometer for children under two years old; for children aged two years and older, height was assessed in a standing position with the stadiometer.

For all anthropometric measurements, two repeated measurements were performed by two trained health personnel, with an absolute maximal accepted difference between measurements of 0.5 kg for weight and 0.5 cm for height/length. When the difference between the two measurements was higher than the maximal accepted error, a third measurement was performed, and the average of the two closest measurements was recorded and used for the analysis.

Exposures

Sociodemographic characteristics

Age was measured in months and sex assigned at birth was reported by the parents or caregiver as male or female. Living area was divided into urban, rural, and indigenous. Household monthly income quartiles were calculated based on the household's monthly incomes. Overcrowding was defined as more than three people per habitable room within a household.[27] The household dietary diversity score was defined as the number of food groups eaten over the previous 24 h by any member of the household, including cereals, roots and tubers, legumes, vegetables, fruits, eggs, meat, seafood and fish, dairy, fats, natural condiments, and sugars. The household dietary diversity was then divided into three levels: low diversity (zero to three points), medium diversity (four to six points), and high diversity (seven to 12 points).[28]

Nutritional status

Wasting was defined as a weight–for–height/length Z score more than two standard deviations (SDs) below the median value of the World Health Organization (WHO) Growth Standards; stunting was defined as a height/length–for–age Z score more than two SDs below the median value; and overweight and obesity were defined as a weight–for–height/length Z score above two and three SDs, respectively.[29]

The Z scores were calculated using the macro in SPSS (IBM SPSS Statistics, version 25). Height/length–for–age Z scores below minus six and above six and weight–for–height/length Z scores below minus five and above five were considered extreme values and were excluded from the analyses.

Water, sanitation and hygiene characteristics

Water, sanitation and hygiene characteristics included drinking water source status, sanitation system, and adequate hygiene. Drinking water source was defined as the principal source from which drinking water was obtained and was categorized as improved or unimproved according to its degree of safety, based on the WHO Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) 2017.[30] The sanitation system refers to the method used for managing or disposing of waste from households and is categorized as improved or unimproved depending on the level of safety.[30] Hygiene was considered adequate if the caregiver responded "always" to hand washing before eating and after toilet use. Hygiene was considered inadequate if the person responded with a lower frequency (never, rarely, sometimes, or almost always) to any of the corresponding queries.

Access to health care

Access to health care was evaluated based on growth checkup compliance responses. Adequacy of growth checkups was established based on Panamanian Guides for integrated care of boys and girls from birth to nine years of age.[31]

Comorbidities

Information about the occurrence of diarrhoea and acute respiratory infections in the last two weeks was collected from the ENSPA questionnaire for children under 15 years old.[15]

Nutrition

The consumption of foods rich in sodium among children aged six to 23 months was evaluated based on whether the child had consumed any processed meat such as ham, sausage, or chorizo, or the caregiver added salt or any artificial condiments, such as soy sauce, Worcestershire sauce, or broth, to their food in the last 24 h. For children aged 24–59 months, sodium–rich food consumption was evaluated based on whether the children had eaten any high-sodium or high–salt processed food in the last 24 h, such as instant soups, salty snacks, or processed cold cuts.

Sweetened beverage consumption was assessed among children aged six to 59 months based on whether the children consumed any sweetened beverages, such as juices, sodas, water with honey, dough water, rice water, tea, coffee, malt, nectar, or soft drinks in the last 24 h.

Iron–rich food consumption, children's dietary diversity, and food frequency were assessed only among children aged six to 23 months. Iron–rich food consumption was assessed based on whether the children had consumed the Ministry of Health of Panama's (MINSA) fortified corn cream or cereal, meat, chicken, fish, duck, or viscera in the last 24 h.[32]

The children's dietary diversity was defined as the number of food groups eaten in the last 24 h, with one point assigned to each group. These food groups included cereals, roots and tubers, legumes, fruits and vegetables, meats, eggs, dairy, and fats. A dietary diversity equal to or higher than four was considered adequate.[32]

Food frequency was defined as the number of meals eaten in a day. For children aged six to eight months, a food frequency equal to or higher than three was considered adequate. For children aged nine to 23 months, a food frequency equal to or higher than four was considered adequate.[33]

Outcomes

Anaemia was defined as haemoglobin levels below 11 g/dl.[34] Iron deficiency was determined based on CRP and serum ferritin levels. For children with CRP concentrations below or equal to 0.5 mg/dl, iron deficiency was defined as ferritin levels below 12 ng/ml. For those with CRP concentrations above 0.5 mg/dl, iron deficiency was defined as ferritin levels below 30 ng/ml.[35] Iron deficiency anaemia was defined by the presence of both anaemia and iron deficiency. Vitamin A deficiency was defined as serum retinol levels below 20 mcg/dl.[36] Any of the micronutrient deficiencies studied was defined as having at least one of the following: anaemia, iron deficiency anaemia, iron deficiency, or vitamin A deficiency. Finally, double burden of malnutrition was defined as the coexistence of overweight or obesity and any of the micronutrient deficiencies studied (anaemia, iron deficiency anaemia, iron deficiency, or vitamin A deficiency) in the same child.

Statistical analysis

The medians and interquartile range (IQR) were reported for continuous variables, and point estimates (%) with their 95% confidence intervals (CIs) were reported for categorical variables. Prevalence and general characteristics are presented as weighted values considering a complex sampling design. Weights were constructed by the INEC as the inverse of the probability of selection by PSU, and then through a post-stratification step were adjusted for non–response, the country's own demographic estimates, and calibrated by sex; more information can be found in the ENSPA Report of Results.[15] The Pearson Chi–square test with Rao–Scott adjustment was used for comparisons of outcome prevalence between categories of factor variables. For continuous variables the adjusted Wald F test was used. All calculations were performed using the complex sample module of SPSS software (IBM SPSS Statistics, version 25).

Statement of ethics

Ethical approval to conduct this study was obtained from the Ethics Review Committee of the Gorgas Memorial Institute for Health Studies (749/CBI/ICGES/9 August 2017). All participants were informed about the objectives of this study and the caregivers of the children provided written informed consent. The laboratory test results were sent to the families. Children who presented clinical indications were referred to the public health care network. The study adhered to the STROBE guidelines.[37]

Role of funding source

The funder had no role in the development of the study design, implementation, analyses, or manuscript submission.

Results

The final study sample represented a total of 62,100 children aged six to 59 months. Fig. 1 presents the flowchart of participant selection according to the inclusion and exclusion criteria. No statistically significant differences were observed for the variables of age group, sex, and living area when comparing all the children in the laboratory subsample before any children were excluded with the group of participants included in the present analysis (Supplementary Table S1).

The weighted baseline characteristics of the children at the national level and by living area are presented in Table 1. Four out of five children from indigenous areas (82.2%, 5703/6938; 95% CI: 69.7–90.3) had a household monthly income in the first quartile (≤124 United State Dollars (USD)). Overcrowding was four and seven times higher in indigenous areas (60.1%, 4173/6938; 95% CI: 45.2–73.4) than in urban (14.5%, 4579/31,571; 95% CI: 8.2–24.3) and rural areas (8.7%, 2044/23,591; 95% CI: 4.7–15.5), respectively. The vast majority of the children at the national level had a high household dietary diversity score. On the other hand, less than half of the children from indigenous areas were from a family with a high household dietary diversity score. The prevalence of stunting was highest among children from indigenous areas, while the prevalence of overweight/obesity was highest among children from urban areas, followed by those from indigenous areas. The vast majority of the children from indigenous areas had unimproved sanitation systems. Additionally, diarrhoea episodes were more than twice as common (22.1%, 1510/6938; 95% CI: 11.8–37.6) in children from indigenous areas than in those from urban (7.3%, 2218/31,571; 95% CI: 4.2–12.1) and rural areas (9.7%, 2266/23,591; 95% CI: 5.4–16.9). The prevalence of sodium-rich food and sweetened beverage consumption was highest among children from rural areas (64.5%, 14,555/23,591; 95% CI: 51.4–75.8 and 82.2%, 18,534/23,591; 95% CI: 73.0–88.7, respectively). Three out of four children from urban and rural areas and two out of five children from indigenous areas had consumed iron–rich food in the last 24 h. Approximately one in four children from indigenous areas had adequate dietary diversity, and none of them had an adequate food frequency (0.0%).

The results of the weighted biomarker levels and micronutrient deficiency prevalence at the national level and by living area are presented in Table 2. The prevalence of anaemia in children from indigenous areas (45.2%, 3138/6938; 95% CI: 31.1–60.2) was more than three times higher than that in children from urban (13.0%, 4101/31,571; 95% CI: 7.8–20.8) and rural areas (10.0%, 2365/23,591; 95% CI: 5.5–17.5), and iron deficiency with or without anaemia was present in more than half (60.8%, 4217/6938; 95% CI: 46.0–73.8) of the children in indigenous areas. The iron deficiency and iron deficiency anaemia prevalence were the lowest among children from rural areas. The prevalence of vitamin A deficiency was higher in children from indigenous areas (11.7%, 809/6938; 95% CI: 5.2–24.2) than in those from other living areas (urban: 1.1%, 361/31,571; 95% CI: 0.4–3.0, and rural: 3.9%, 917/23,591; 95% CI: 2.0–7.4).

The weighted prevalence of micronutrient deficiencies by baseline characteristics is depicted in Table 3. At the national level, one out of three children presented at least one of the micronutrient deficiencies assessed in this study. The prevalence of each of these conditions was higher among children aged six to 23 months than among older children. Most of the children from indigenous areas presented at least one of the micronutrient deficiencies studied, and the prevalence of each condition was the highest among these children. Children in the lowest household monthly income

Selected baseline characteristics	Living area							
	National		Urban area		Rural area		Indigenous area	
	N	Weighted percentage % (95% CI)	N	Weighted percentage % (95% CI)	N	Weighted percentage % (95% CI)	N	Weighted percentage % (95% CI)
Total	62,100	100.0	31,571	50.8 (43.1–58.6)	23,591	38.0 (30.3–46.4)	6938	11.2 (8.2–15.1)
Sociodemographic characteristics								
Age (months)								
6–11	6607	10.6 (6.9–16.1)	3624	11.5 (5.9–21.2)	2111	8.9 (4.6–16.6)	872	12.6 (5.5–26.2)
12–23	11,938	19.2 (14.7–24.7)	5150	16.3 (10.5–24.4)	5777	24.5 (16.3–35.1)	1012	14.6 (6.9–28.1)
24–35	14,142	22.8 (17.4–29.2)	6841	21.7 (14.0–32.0)	4234	17.9 (11.4–27.1)	3067	44.2 (30.0–59.4)
36–47	13,425	21.6 (16.7–27.5)	8455	26.8 (19.5–35.6)	3768	16.0 (9.5–25.7)	1201	17.3 (8.8–31.2)
48–59	15,988	25.7 (18.1–35.3)	7501	23.8 (16.5–32.9)	7701	32.6 (17.5–52.6)	785	11.3 (5.1–23.2)
Female sex	27,971	45.0 (37.3–53.1)	12,739	40.3 (31.3–50.1)	11,871	50.3 (35.8–64.8)	3361	48.4 (34.0–63.2)
Household monthly income quartile (USD; $)								
First quartile (≤124)	17,118	28.5 (22.9–34.8)	4530	14.8 (9.3–22.7)	6884	30.5 (20.7–42.5)	5703	82.2 (69.7–90.3)
Second quartile (125–399)	11,796	19.6 (15.5–24.5)	6199	20.3 (14.7–27.3)	4873	21.6 (14.3–31.2)	724	10.4 (4.9–21.0)
Third quartile (400–699)	19,395	32.3 (24.0–41.8)	11,706	38.3 (28.9–48.5)	7237	32.1 (16.2–53.4)	452	6.5 (2.2–18.0)
Fourth quartile (≥700)	11,801	19.6 (14.1–26.7)	8166	26.7 (17.9–37.9)	3576	15.8 (9.2–26.0)	58	0.8 (0.1–5.9)
Overcrowding	10,796	17.4 (12.8–23.2)	4579	14.5 (8.2–24.3)	2044	8.7 (4.7–15.5)	4173	60.1 (45.2–73.4)
Household dietary diversity								
Low (0–3)	2857	4.6 (2.8–7.4)	655	2.1 (0.6–7.0)	779	3.3 (1.6–6.7)	1423	20.5 (10.8–35.4)
Medium (4–6)	10,256	16.5 (12.6–21.4)	4787	15.2 (10.1–22.1)	2861	12.1 (7.3–19.4)	2609	37.6 (24.2–53.2)
High (7–12)	48,987	78.9 (73.5–83.4)	26,130	82.8 (75.4–88.2)	19,951	84.6 (76.6–90.2)	2906	41.9 (28.3–56.8)
Anthropometric nutritional status								
Wasting	883	1.4 (0.5–3.7)	450	1.4 (0.3–6.8)	415	1.8 (0.6–5.5)	19	0.3 (0.0–1.9)
Stunting	8259	13.3 (9.8–17.9)	2586	8.2 (4.3–15.0)	3037	12.9 (7.9–20.4)	2636	38.0 (24.7–53.4)
Overweight/obesity	5656	9.1 (6.0–13.6)	3424	10.8 (6.3–18.1)	1533	6.5 (3.0–13.6)	699	10.1 (3.6–25.3)
Water, sanitation and hygiene characteristics								
Unimproved drinking water source	6688	10.8 (7.8–14.7)	705	2.2 (0.9–5.3)	2902	12.3 (7.0–20.6)	3081	44.4 (30.5–59.2)
Unimproved sanitation system	19,091	30.8 (24.8–37.4)	6014	19.1 (12.1–28.9)	6485	27.5 (18.7–38.4)	6591	95.0 (83.1–98.7)
Inadequate Hygiene	24,968	50.6 (41.5–59.7)	11,794	46.4 (35.6–57.5)	8737	47.3 (30.6–64.7)	4438	81.1 (63.3–91.5)
Access to healthcare								
Inadequate growth checkups	13,056	21.0 (16.0–27.2)	7572	24.0 (16.3–33.8)	4399	18.6 (12.0–27.8)	1086	15.7 (7.8–29.0)
Comorbidities								
Diarrhoea	5994	9.9 (7.0–13.7)	2218	7.3 (4.2–12.1)	2266	9.7 (5.4–16.9)	1510	22.1 (11.8–37.6)
Acute respiratory infections	23,467	37.8 (29.9–46.4)	9924	31.4 (23.0–41.2)	10,125	42.9 (27.8–59.5)	3418	49.3 (34.7–64.0)
Nutrition								
Sodium rich food consumption	34,456	55.9 (52.4–67.0)	17,729	62.0 (52.0–71.1)	14,555	64.5 (51.4–75.8)	2171	34.1 (21.3–49.7)
Sweetened beverages consumption	42,086	73.2 (66.5–78.9)	19,607	68.6 (58.6–77.1)	18,534	82.2 (73.0–88.7)	3944	61.9 (45.9–75.8)
Iron–rich food consumption[a]	10,428	71.3 (59.4–80.9)	4924	77.4 (57.4–89.7)	4998	72.0 (55.3–84.2)	506	38.5 (13.1–72.2)
Adequate child dietary diversity[a]	10,501	71.8 (58.5–82.2)	4194	65.9 (42.4–83.6)	5960	85.8 (71.5–93.6)	348	26.5 (7.1–63.0)
Adequate food frequency[a]	542	8.0 (3.3–18.1)	164	7.0 (1.4–29.3)	378	9.8 (3.3–25.4)	0	0.0

CI: confidence interval. One thousand nine hundred and ninety (1,990) participants had missing values for household monthly income variable; ninety six (96) for sanitation system; twelve thousand seven hundred and forty (12,740) for adequate hygiene; one thousand three hundred and fifty two (1,352) for diarrhoea; three thousand nine hundred and twenty seven (3,927) for iron–rich food consumption and for food frequency variable, seven thousand seven hundred and nineteen caregivers answered "don't know" to the food frequency question (7,719) and four thousand and three (4,003) participants had missing values. [a]Only in children 6–23 months (N = 18,545). p-values for the comparison of the outcome percentage between categories of factor variables are estimated using Rao-Scott chi -squared test. Source: National Health Survey of Panama (ENSPA) 2019.

Table 1: **Selected baseline characteristics of the children aged six to 59 months at the national level and by living area, Panama, 2019.**

quartile (≤124 USD) had a higher prevalence of anaemia, iron deficiency anaemia, and vitamin A deficiency than did children from the highest income quartile (≥700 USD). Additionally, the prevalence of any of the micronutrient deficiencies studied was higher among children in overcrowded households with unimproved drinking water sources, unimproved sanitation systems, and inadequate hygiene. Children who did not consume iron–rich food in the last 24 h had higher prevalence of anaemia than those who did.

Table 4 presents the weighted prevalence of micronutrient deficiencies by nutritional status. The

Total	Living area								p-value
	National		Urban area		Rural area		Indigenous area		
	62,100		31,571		23,591		6938		
Biomarkers levels and micronutrient deficiencies	N		N		N		N		
Any of the micronutrient deficiencies studied, N % (95% CI)	21,812	35.1 (28.8–42.0)	9656	30.6 (22.5–40.0)	6470	27.4 (18.6–38.5)	5686	82.0 (68.7–90.4)	<0.0001
Haemoglobin g/dL, median (Q1–Q3)	62,100	12.0 (11.3–12.6)	31,571	12.0 (11.4–12.6)	31,571	12.1 (11.4–12.7)	6938	11.1 (10.7–11.6)	<0.0001
Anaemia, % (95% CI)	9604	15.5 (11.5–20.6)	4101	13.0 (7.8–20.8)	2365	10.0 (5.5–17.5)	3138	45.2 (31.1–60.2)	<0.0001
CRP mg/dL, median (Q1–Q3)	62,100	0.4 (0.0–2.3)	31,571	0.3 (0.0–1.1)	23,591	0.5 (0.0–3.5)	6938	1.3 (0.3–5.1)	0.001
Inflammation, % (95% CI)	26,714	43.2 (35.3–51.4)	11,968	37.9 (28.7–48.1)	10,145	43.4 (28.3–59.8)	4601	66.3 (51.2–78.7)	0.08
Ferritin ng/mL, median (Q1–Q3)	62,100	28.5 (17.3–46.4)	31,571	28.5 (18.1–39.65)	23,591	31.9 (20.9–57.2)	6938	16.8 (8.6–28.0)	0.001
Iron deficiency anaemia, % (95% CI)	4950	8.0 (5.1–12.2)	2555	8.1 (4.0–15.6)	500	2.1 (0.9–5.2)	1869	27.3 (15.8–42.9)	<0.0001
Iron deficiency, % (95% CI)	16,259	26.2 (20.7–32.5)	8014	25.4 (17.9–34.6)	4029	17.1 (10.9–25.8)	4217	60.8 (46.0–73.8)	<0.0001
Retinol mcg/dl, median (Q1–Q3)	62,100	30.0 (26.0–35.0)	31,571	31.0 (27.0–36.0)	31,571	29.0 (23.0–35.0)	6938	28.0 (23.0–34.0)	0.09
Vitamin A deficiency, % (95% CI)	2087	3.4 (2.1–5.3)	361	1.1 (0.4–3.0)	917	3.9 (2.0–7.4)	809	11.7 (5.2–24.2)	0.0002

Q: quartile; CI: confidence interval; CRP: c-reactive protein. Anaemia: Hb < 11 g/dL; Iron deficiency: serum ferritin <12 ng/ml (if CRP ≤ 0.5 mg/dl) or serum ferritin <30 ng/ml (if CRP > 0.5 mg/dl); Iron deficiency anaemia: co-occurring iron deficiency and anaemia; Vitamin A deficiency: serum retinol <20 mcg/dl. One thousand two hundred and five (1,205) participants had ferritin values below the detection limit and were assigned a value of 0.00 ng/ml. Twenty thousand three hundred and ninety nine participants had values for CRP below the detection limit and were assigned a value of 0.00 mg/dl. Two hundred and thirty-one (231) participants from the rural area had missing values for CRP and inflammation due to pre-analytical errors. p-values for the comparison of the outcome prevalence between categories of factor variables are estimated using Rao-Scott chi -squared test, and for continuous variables the adjusted Wald F test was used. Source: National Health Survey of Panama (ENSPA) 2019.

Table 2: **Weighted biomarkers levels and micronutrient deficiencies prevalence among children aged six to 59 months at the national level and by living area, Panama, 2019.**

prevalence of anaemia was more than two times higher among children with wasting and those with stunting than among those who were not. The prevalence of iron deficiency anaemia and iron deficiency was the highest among children with stunting, while the prevalence of vitamin A deficiency did not significantly differ among children classified with wasting, stunting, or overweight/obesity. The weighted prevalence of double burden of malnutrition at the national level was 3.7% (2316/62,100; 95% CI: 1.8–7.8) and was highest among children living in indigenous areas (10.1%, 699/6938; 95% CI: 3.6–25.3), followed by those living in urban areas (4.3%, 1346/31,571; 95% CI: 1.4–12.5), and those living in rural areas (1.2%, 272/23,591; 95% CI: 0.3–4.9).

Discussion

This study assessed the national prevalence of anaemia, iron deficiency anaemia, iron deficiency, and vitamin A deficiency according to sociodemographic factors and nutritional status among Panamanian children aged six to 59 months in 2019. Age, living area, household monthly income, overcrowding status, household dietary diversity score, all water, sanitation and hygiene characteristics, and nutritional status were associated with at least one of the micronutrient deficiencies studied.

According to the results from the ENSPA 2019, the prevalence of anaemia decreased from a severe (52.5%) to a moderate public health problem (25.9%) among children aged 12–23 months and from 39.7% to 16.5% among children aged 24–35 months since the last nationally representative survey in 1999.[16] The prevalence of anaemia among Panamanian children was relatively low compared to the latest national surveys of other countries in the region such as Ecuador (25.7% in 2012), Colombia (27.5% in 2010), and Peru (31.0% in 2015).[38–40]

However, since the 1999 national survey, indigenous populations have presented the highest prevalence of anaemia. Despite Panama's efforts to reduce anaemia in this population,[17,18] anaemia continues to be a severe public health problem among children from indigenous areas. This problem is not exclusive to the Panamanian population. Other countries in the region, such as Mexico, Peru, Bolivia, Colombia, and Guatemala, have found a higher prevalence of anaemia among indigenous children.[40–45] On the other hand, no differences were found between children from urban and rural areas, similar to what was found in Mexico but contrary to Peru, where children from rural areas presented a higher prevalence of anaemia.[42,46]

As expected, children living in vulnerable conditions, such as households in the lower income quartiles, that are overcrowded, with a low household dietary diversity, with unimproved drinking water sources and sanitation systems, and with inadequate hygiene, exhibited the highest prevalence of anaemia.[39,40,43] According to demographic and health survey data from several low– and middle–income countries, children from households in the poorest quintile had the highest prevalence of anaemia, and those from households in the richest quintile had the lowest prevalence of anaemia.[47]

Notably, children from indigenous areas are more likely to experience these poor living conditions. Additionally, the prevalence of inflammation was highest among children from indigenous areas. Parasitosis may

Selected baseline characteristics	Micronutrient deficiency									
	Any of the micronutrient deficiencies studied		Anaemia		Iron deficiency anaemia		Iron deficiency		Vitamin A deficiency	
	N; % (95% CI)	p-value	N; % (95% CI)	p-value	N; % (95% CI)	p-value	N; % (95% CI))	p-value	N; % (95% CI)	p-value
Total 62,100	21,812; 35.1 (28.8–42.0)		9604; 15.5 (11.5–20.6)		4950; 8.0 (5.1–12.2)		16,259; 26.2 (20.7–32.5)		2087; 3.4 (2.1–5.3)	
Sociodemographic characteristics										
Age in months										
6–11 (N = 6607)	3611; 54.7 (33.0–74.7)	0.0001	1680; 25.4 (11.0–48.6)	0.009	1108; 16.8 (5.6–40.7)	0.039	2892; 43.8 (23.7–66.0)	0.0009	525; 7.9 (2.7–21.4)	0.08
12–23 (N = 11,938)	6383; 53.5 (40.3–66.2)		3087; 25.9 (16.2–38.6)		1262; 10.6 (5.4–19.5)		4469; 37.4 (26.0–50.5)		571; 4.8 (1.9–11.3)	
24–35 (N = 14,142)	5319; 37.6 (26.1–50.8)		2329; 16.5 (9.7–26.6)		1442; 10.2 (5.1–19.5)		4301; 30.4 (20.1–43.1)		293; 2.1 (1.0–4.5)	
36–47 (N = 13,425)	4161; 31.0 (20.6–43.7)		1869; 13.9 (6.8–26.5)		1137; 8.5 (2.9–22.3)		3329; 24.8 (15.3–37.5)		113; 0.8 (0.2–3.1)	
48–59 (N = 15,988)	2338; 14.6 (8.0–25.3)		639; 4.0 (1.6–9.5)		1; 0.0 (0.0–0.0)		1269; 7.9 (3.7–16.3)		585; 3.7 (1.4–9.0)	
Sex										
Male (N = 34,129)	12,218; 35.8 (28.2–44.2)	0.83	5410; 15.9 (10.7–22.8)	0.85	2620; 7.7 (4.3–13.5)	0.85	8929; 26.2 (19.6–34.0)	0.99	762; 2.2 (1.1–4.7)	0.11
Female (N = 27,971)	9594; 34.3 (24.4–45.8)		4194; 15.0 (9.3–23.2)		2331; 8.3 (4.3–15.7)		7330; 26.2 (17.8–36.9)		1325; 4.7 (2.6–8.5)	
Living area										
Urban (N = 31,571)	9656; 30.6 (22.5–40.0)	<0.0001	4101; 13.0 (7.8–20.8)	<0.0001	2555; 8.1 (4.0–15.6)	<0.0001	8014; 25.4 (17.9–34.6)	<0.0001	361; 1.1 (0.4–3.0)	0.0002
Rural (N = 23,591)	6470; 27.4 (18.6–38.5)		2365; 10.0 (5.5–17.5)		500; 2.1 (0.9–5.2)		4029; 17.1 (10.9–25.8)		917; 3.9 (2.0–7.4)	
Indigenous (N = 6938)	5686; 82.0 (68.7–90.4)		3138; 45.2 (31.1–60.2)		1896; 27.3 (15.8–42.9)		4217; 60.8 (46.0–73.8)		809; 11.7 (5.2–24.2)	
Household monthly income quartile (USD; $)										
First quartile (≤124) (N = 17,118)	8666; 50.6 (40.3–60.9)	0.034	4278; 25.0 (17.4–34.6)	0.05	2068; 12.1 (7.0–20.1)	0.31	6022; 35.2 (26.1–45.5)	0.27	1091; 6.4 (3.5–11.5)	0.002
Second quartile (125–399) (N = 11,796)	3452; 29.3 (21.0–39.2)		986; 8.4 (4.1–16.1)		626; 5.3 (2.1–12.8)		2680; 22.7 (15.4–32.1)		684; 5.8 (2.5–13.0)	
Third quartile (400–699) (N = 19,395)	5290; 27.3 (15.9–42.7)		2728; 14.1 (6.7–27.3)		1560; 8.0 (2.7–21.4)		4069; 21.0 (11.4–35.4)		118; 0.6 (0.2–2.1)	
Fourth quartile (≥700) (N = 11,801)	3864; 32.7 (19.3–49.8)		1260; 10.7 (4.7–22.5)		454; 3.8 (1.3–11.2)		3059; 25.9 (14.1–42.7)		96; 0.8 (0.1–5.7)	
Overcrowding										
Yes (N = 10,796)	6542; 60.6 (44.2–74.9)	0.0004	3365; 31.2 (19.1–46.5)	0.002	2079; 19.3 (9.4–35.3)	0.004	5098; 47.2 (32.1–62.9)	0.001	635; 5.9 (2.4–14.0)	0.16
No (N = 51,304)	15,270; 29.8 (23.5–36.9)		6239; 12.2 (8.4–17.3)		2872; 5.6 (3.3–9.5)		11,162; 21.8 (16.6–28.0)		1451; 2.8 (1.7–4.8)	
Household dietary diversity										
Low (N = 2857)	1709; 59.8 (36.1–79.7)	0.015	756; 26.5 (11.0–51.2)	0.001	547; 19.2 (6.6–44.4)	0.08	1430; 50.1 (27.8–72.3)	0.09	131; 4.6 (1.2–16.0)	0.91
Medium (N = 10,256)	4730; 46.1 (33.6–59.1)		3144; 30.6 (19.8–44.2)		1336; 13.0 (6.3–25.1)		2850; 27.8 (17.7–40.8)		355; 3.5 (1.1–10.6)	
High (N = 48,987)	15,373; 31.4 (24.4–39.3)		5704; 11.6 (7.7–17.2)		3067; 6.3 (3.4–11.2)		11,980:; 24.5 (18.3–31.8)		1601; 3.3 (1.9–5.5)	
Water, sanitation and hygiene characteristics										
Drinking water source status										
Unimproved (N = 6688)	3925; 58.7 (42.8–73.0)	0.002	2665; 39.8 (25.9–55.6)	<0.0001	1138; 17.0 (8.4–31.3)	0.034	1937; 29.0 (17.4–44.0)	0.68	785; 11.7 (5.7–22.8)	0.0002
Improved (N = 55,412)	17,887; 32.3 (25.7–39.6)		6939; 12.5 (8.7–17.8)		3812; 6.9 (4.0–11.5)		14,323; 25.8 (20.0–32.7)		1301; 2.3 (1.3–4.2)	
Sanitation system										
Unimproved (N = 19,091)	9743; 51.0 (40.3–61.6)	0.0005	4896; 25.6 (17.4–36.2)	0.002	2497; 13.1 (7.1–22.9)	0.05	6676; 35.0 (25.6–45.7)	0.036	1367; 7.2 (4.0–12.5)	0.0004
Improved (N = /42,913)	11,973; 27.9 (21.0–36.1)		4612; 10.7 (6.9–16.3)		2453; 5.7 (3.1–10.4)		9583; 22.3 (16.2–29.9)		624; 1.5 (0.7–3.2)	
Adequate hygiene										
No (N = 24,968)	9782; 39.2 (30.3–48.9)	0.035	3998; 16.0 (10.7–23.3)	0.29	1637; 6.6 (3.5–12.0)	0.76	6824; 27.3 (19.8–36.4)	0.16	1322; 5.3 (3.0–9.2)	0.0009
Yes (N = 24,392)	5846; 24.0 (15.5–35.2)		2615; 10.7 (5.5–19.8)		1340; 5.5 (2.1–13.8)		4519; 18.5 (11.4–28.7)		206; 0.8 (0.3–2.5)	

(Table 3 continues on next page)

Selected baseline characteristics	Micronutrient deficiency									
	Any of the micronutrient deficiencies studied		Anaemia		Iron deficiency anaemia		Iron deficiency		Vitamin A deficiency	
	N; % (95% CI)	p-value	N; % (95% CI)	p-value	N; % (95% CI)	p-value	N; % (95% CI))	p-value	N; % (95% CI)	p-value
(Continued from previous page)										
Access to healthcare										
Adequate growth controls										
Yes (N = 49,044)	17,166; 35.0 (27.8–43.0)	0.94	7477; 15.2 (10.9–20.9)	0.86	3830; 7.8 (4.8–12.4)	0.87	12,718; 25.9 (19.8–33.2)	0.87	1277; 2.6 (1.5–4.6)	0.06
No (N = 13,056)	4646; 35.6 (23.8–49.4)		2128; 16.3 (8.2–29.8)		1120; 8.6 (2.9–22.9)		3541; 27.1 (16.8–40.7)		810; 6.2 (2.9–12.7)	
Comorbidities										
Diarrhoea										
Yes (N = 5994)	2637; 44.0 (29.0–60.2)	0.26	1032; 17.2 (8.6–31.4)	0.74	636; 10.6 (4.1–24.8)	0.54	2157; 36.0 (22.2–52.5)	0.19	545; 9.1 (3.6–21.4)	0.008
No (N = 54,754)	18,719; 34.2 (27.4–41.7)		8318; 15.2 (10.9–20.8)		4224; 7.7 (4.7–12.4)		13,957; 25.5 (19.7–32.3)		1246; 2.3 (1.3–4.0)	
Acute respiratory infections										
Yes (N = 23,467)	8703; 37.1 (24.9–51.1)	0.68	3953; 16.8 (9.9–27.3)	0.66	2524; 10.8 (5.5–20.0)	0.23	6713; 28.6 (18.4–41.6)	0.56	758; 3.2 (1.4–7.1)	0.90
No (N = 38,633)	13,109; 33.9 (27.2–41.3)		5651; 14.6 (10.2–20.6)		2427; 6.3 (3.4–11.2)		9547; 24.7 (18.9–31.6)		1328; 3.4 (2.0–6.0)	
Nutrition										
Sodium rich food consumption										
Yes (N = 34,456)	10,739; 31.2 (22.9–40.8)	0.31	4419; 12.8 (8.1–19.7)	0.36	1725; 5.0 (2.3–10.6)	0.19	7823; 22.7 (16.0–31.1)	0.37	619; 1.8 (0.8–3.8)	0.17
No (N = 23,047)	8744; 37.9 (29.1–47.6)		3917; 17.0 (11.2–24.9)		2135; 9.3 (5.3–15.8)		6454; 28.0 (20.1–37.6)		849; 3.7 (1.8–7.4)	
Sweetened beverages consumption										
Yes (N = 42,086)	13,242; 31.5 (24.2–39.7)	0.21	5732; 13.6 (9.3–19.5)	0.52	2592; 6.2 (3.4–11.0)	0.54	9463; 22.5 (16.6–29.7)	0.18	1031; 2.4 (1.3–4.4)	0.81
No (N = 15,417)	6242; 40.5 (29.2–52.9)		2605; 16.9 (9.7–27.9)		1268; 8.2 (4.0–16.1)		4815; 31.2 (21.0–43.8)		438; 2.8 (1.0–8.1)	
Iron-rich food consumption[a]										
Yes (N = 10,428)	5022; 48.2 (33.2–63.5)	0.19	1578; 15.1 (7.9–27.1)	0.006	672; 6.4 (2.7–14.5)	0.20	4049; 38.8 (24.9–54.9)	0.69	163; 1.6 (0.4–6.4)	0.09
No (N = 4190)	2731; 65.2 (43.9–81.8)		1922; 45.9 (25.9–67.3)		608; 14.5 (5.3–34.1)		1417; 33.8 (18.0–54.2)		314; 7.5 (1.7–27.0)	
Child dietary diversity[a]										
Adequate (N = 10,501)	5334; 50.8 (36.6–64.9)	0.58	2420; 23.0 (13.4–36.7)	0.79	1045; 10.0 (4.8–19.4)	0.52	3892; 37.1 (24.8–51.2)	0.94	275; 2.6 (0.8–8.2)	0.58
Inadequate (N = 4117)	2418; 58.7 (34.3–79.5)		1079; 26.2 (10.1–52.9)		234; 5.7 (1.1–24.8)		1573; 38.2 (16.5–66.0)		202; 4.9 (0.7–28.5)	
Food frequency[a]										
Adequate (N = 542)	375; 69.1 (29.4–92.3)	0.44	245; 45.2 (11.8–83.6)	0.43	96; 17.7 (2.3–66.7)	0.50	226; 41.6 (10.3–81.6)	0.69	0; 0.0	0.69
Inadequate (N = 6281)	3321; 52.9 (36.0–69.1)		1742; 27.7 (14.8–45.8)		551; 8.8 (3.2–22.0)		2062; 32.8 (19.9–49.1)		163; 2.6 (0.6–10.5)	

Percentages and frequencies are based on weighted data and accounted for sampling design. CI: confidence interval; Household dietary diversity score was classified as Low:0–3; Medium: 4–6 and High: 7–12. [a]Only in children 6–23 months. p-values for the comparison of the outcome prevalence between categories of factor variables are estimated using Rao-Scott chi -squared test. Source: National Health Survey of Panama (ENSPA) 2019.

Table 3: **Weighted prevalence of micronutrient deficiencies among children aged six to 59 months by baseline characteristics Panama, 2019.**

be another possible factor that contributes to the higher prevalence of anaemia among these children, since poor living conditions have been associated with a higher prevalence of infection and reinfection with parasites,[48,49] furthermore, higher CRP levels are frequently reported in children with these infections.[50] This combination of intestinal inflammation and micronutrient deficiencies results in altered intestinal structure and function and further affects nutrient absorption. Micronutrient deficiencies have several important immediate and long term consequences for child health outcomes. Moreover, anaemia, iron deficiency anaemia, and iron deficiency affect cognitive and motor development and growth and cause physical and behavioural symptoms such as weakness, fatigue, and irritability. In the long term, these deficiencies can cause a reduction in school achievement and productivity in adult life.[5,8] Vitamin A deficiency, on the other hand, can cause issues such as visual impairment, immune system impairment, and impaired growth and development.[9]

We found a higher prevalence of anaemia in younger children, similar to the results others have reported.[42,46] This finding should be taken into consideration when developing public health strategies since early childhood is a crucial window for adequate growth and development, with significant and permanent repercussions in adult life.[51]

Adequate feeding practices are important factors in the prevention of anaemia. A higher prevalence of anaemia was found among children without iron–rich food consumption in the last 24 h (45.9% vs. 15.1%), which is consistent with the fact that iron deficiency is usually the main cause of anaemia among this group.[2] Additionally, several studies in low– and middle–income countries have demonstrated that higher dietary diversity is associated with a reduced risk of micronutrient deficiencies.[52] A study carried out in Mexico revealed that the consumption of haem iron sources was the principal dietary factor associated with a lower risk of anaemia.[53]

Interestingly, there were no significant differences in the prevalence of iron deficiency anaemia or iron deficiency between children with and without iron–rich food consumption. These results could be explained by the fact that, in addition to adequate nutrient intake, the ability to absorb these nutrients is important for preserving iron reserves, and conditions such as diarrhoea and chronic gut inflammation can prevent this preservation from occurring.[54] Although the result was not significant, a higher prevalence of anaemia, iron deficiency anaemia, and iron deficiency was found in children who presented diarrhoea in the last two weeks.

Petry and colleagues reported that the proportion of anaemia associated with iron deficiency is lower in countries with an anaemia prevalence higher than 40%, especially in rural populations and in countries with high inflammation exposure.[55] Nevertheless, in our

	Micronutrient deficiency condition									
	Any of the micronutrient deficiencies studied		Anaemia		Iron deficiency anaemia		Iron deficiency		Vitamin A deficiency	
	N; % (95% CI)	p-value	N; % (95% CI)	p-value	N; % (95% CI)	p-value	N; % (95% CI)	p-value	N; % (95% CI)	p-value
Total 62,100	21,812; 35.1 (28.8–42.0)		9604; 15.5 (11.5–20.6)		4950; 8.0 (5.1–12.2)		16,259; 26.2 (20.7–32.5)		2087; 3.4 (2.1–5.3)	
Anthropometric nutritional status										
Any anthropometric malnutrition										
Yes (N = 14,799)	8401; 56.8 (45.0–67.8)	<0.0001	4112; 27.8 (18.2–39.9)	0.002	1685; 11.4 (5.2–23.1)	0.29	5563; 37.6 (26.3–50.4)	0.023	742; 5.0 (2.2–11.1)	0.26
No (N = 47,301)	13,411; 28.4 (21.9–35.8)		5492; 11.6 (7.8–16.9)		3266; 6.9 (4.1–11.5)		10,696; 22.6 (17.0–29.5)		1345; 2.8 (1.7–4.9)	
Wasting										
Yes (N = 883)	598; 67.7 (24.9–93.0)	0.12	355; 40.2 (7.0–85.7)	0.21	0; 0.0	0.56	96; 10.8 (1.3–52.7)	0.32	147; 16.7 (2.1–65.6)	0.08
No (N = 61,217)	21,214; 34.7 (28.3–41.6)		9249; 15.1 (11.1–20.2)		4950; 8.1 (5.2–12.4)		16,164; 26.4 (20.9–32.8)		1940; 2.8 (1.6–4.7)	
Stunting										
Yes (N = 8259)	5487; 66.4 (51.7–78.6)	<0.0001	3276; 39.7 (25.7–55.5)	<0.0001	1375; 16.6 (6.8–35.2)	0.06	3323; 40.2 (26.2–56.0)	0.037	594; 7.2 (2.9–16.9)	0.07
No (N = 53,841)	16,325; 30.3 (24.0–37.5)		6328; 11.8 (8.1–16.7)		3576; 6.6 (4.0–10.7)		12,937; 24.0 (18.4–30.7)		1492; 2.8 (1.6–4.7)	
Overweight/obesity										
Yes (N = 5656)	2316; 40.9 (22.1–62.9)	0.57	481; 8.5 (2.8–23.3)	0.24	310; 5.5 (1.4–18.8)	0.56	2145; 37.9 (19.5–60.6)	0.21	0; 0.0	0.26
No (N = 56,444)	19,496; 34.5 (28.0–41.7)		9123; 16.2 (11.8–21.7)		4640; 8.2 (5.2–12.8)		14,114; 25.0 (19.5–31.4)		2087; 3.7 (2.3–5.8)	

Percentages and frequencies are based on weighted data and accounted for sampling design. CI: confidence interval; Stunting and wasting were defined according to the cut-off points of the World Health Organization Growth Standards. p-values for the comparison of the outcome prevalence between categories of factor variables are estimated using Rao-Scott chi -squared test. Source: National Health Survey of Panama (ENSPA) 2019.

***Table 4:* Weighted prevalence of micronutrient deficiencies by nutritional status among children aged six to 59 months at national level, Panama, 2019.**

results iron deficiency anaemia (8.0%) accounted for half of the anaemia prevalence (15.5%). Furthermore, the prevalence of iron deficiency with or without anaemia in Panama (26.2%) was more than double than that in Mexico (10.0%).[42] However, the sample in the Mexican study did not include children under 12 months of age, which was the group with the greatest prevalence in our sample.

The vitamin A deficiency prevalence in children aged 12–59 months reported in 1999 was 9.4%,[16] while in 2019, the estimated prevalence among children aged six to 59 months was 3.4%. However, despite this decrease, vitamin A deficiency among children living in indigenous areas remains a concern, and our results indicated that vitamin A deficiency represents a moderate public health problem in this population.[36] The national prevalence of vitamin A deficiency in our study was similar to that reported by Mexico (4.7%).[42] Additionally, in Mexico, the prevalence of vitamin A deficiency in indigenous children was double (8.1%) that in non–indigenous children (3.7%).[42] Additionally, similar to our study, in Peru, the prevalence of vitamin A deficiency was higher among children from rural areas (19.5%) than among children from urban areas (9.7%).[46]

Other studies have shown that when national databases are used, lower prevalence rates of anaemia in children are reported compared to studies focused specifically on indigenous communities.[45] Using national–level data offers reliable information only for large geographic areas, providing valuable information at the national level, but is ineffective for local governments. Therefore, in Latin American countries national databases may underestimate the prevalence of anaemia and micronutrient deficiencies among vulnerable populations, which could exacerbate this problem. Therefore, it is also necessary to generate more specific information for each country, including representative data for the indigenous populations of the country.[45]

As expected, children with wasting or stunting presented a higher prevalence of most of the micronutrient deficiencies studied than did those without wasting or stunting. Similar findings have been observed in Mexican children, where the prevalence of anaemia was higher in children affected by wasting and stunting than in those without these conditions.[56] However, micronutrient deficiencies are not exclusive to children with visible undernutrition. Although anaemia, iron deficiency anaemia, and vitamin A deficiency were less prevalent in children with overweight or obesity, iron deficiency in these children was similar to that in children with stunting. This finding indicated that having a diet that generates a positive energy balance does not necessarily ensure the intake of sufficient amounts of all micronutrients. In fact, the double burden of malnutrition is proposed to be a result of the nutrition transition, characterized by higher intakes of energy–dense food and lower intakes of micronutrient–rich food.[57] Additionally, it has been hypothesized that the chronic inflammation generated by excess weight can alter iron metabolism creating an aggravating association.[23] Furthermore, the double burden of malnutrition was higher in children from indigenous areas, which highlights the vulnerability of this population. Similarly, in Guatemala, indigenous children presented a higher prevalence of double burden of malnutrition than did nonindigenous children.[44] Further studies of the double burden of malnutrition in this vulnerable population are necessary.

This study has several limitations. The cross–sectional design of this study emphasizes the exploratory nature of the results, causality assessment is not warranted. As in other studies with blood sampling, potential errors in pre–analytical, analytical, and post–analytical procedures may be sources of bias; however, all procedures followed a standardised method. The exclusion of observations with missing data may have introduced bias into our estimates, potentially exaggerating disparities between groups and introducing limitations to the analysis, which make generalization less reliable. To provide further context, the age, sex and living area of all the children in the laboratory subsample, without any exclusions, are described in the Supplementary material. Ferritin levels may be elevated in children with obesity, since this condition is characterized by a chronic inflammatory state,[23] however, adjustments for iron deficiency and iron deficiency anaemia classification were made according to CRP levels to address this issue.[35]

The results presented in this study are nationally representative. The ENSPA 2019 is the first nationally representative study to assess ferritin and CRP levels. This is the first study to assess anaemia, iron deficiency anaemia, iron deficiency, and vitamin A deficiency by sociodemographic factors and nutritional status among Panamanian children.

Anaemia, iron deficiency anaemia, iron deficiency, and vitamin A deficiency are present among children aged six to 59 months, especially younger children, and in those living in indigenous areas, with low incomes, poor living conditions and inadequate water, sanitation, and hygiene factors. Our results highlight important disparities in the prevalence of nutritional deficiencies between living areas and the importance of implementing adequate public health strategies focused on these vulnerable populations, as the first years of life represent a crucial window of opportunity for adequate growth and development.

Additionally, the most serious indicators of the double burden of malnutrition are observed in indigenous populations where stunting persists, overweight and obesity prevalence are relatively high, and micronutrient deficiency prevalence is high.

Although national programs to reduce micronutrient deficiencies, such as iron and vitamin A supplementation and fortification[17] and maternal–child complementary feeding,[18] exist in Panama, these programs have not been comprehensively evaluated. Access to health services with quality prenatal and growth and development checkups from pregnancy to at least the first two years of life, may be deficient in indigenous areas. The availability of micronutrient supplements and adherence to these programs have not been assessed. Access to fortified foods should also be determined, as these foods may not be part of the dietary pattern of the most vulnerable populations, such as indigenous children. Therefore, the evaluation and reinforcement of these programs are still needed, especially for accessing and implementing these programs in vulnerable populations.

Contributors
AS contributed to the conceptualization, investigation, data curation, formal analysis, and writing of the original draft. FF, JD, RR, and RM contributed to the conceptualization, methodology, and writing—review and editing. RM contributed to the validation and supervision. AS and RM directly accessed the datasets and verified the data reported in the manuscript and are responsible for the decision to submit the manuscript.

Data sharing statement
The general results, study protocol, manuals, and datasets from the ENSPA study are publicly available in Spanish language at https://www.gorgas.gob.pa/wp-content/uploads/external/SIGENSPA/Inicio.htm.

Declaration of interests
The authors have no conflicts of interest to declare.

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Appendix A. Supplementary data
Supplementary data related to this article can be found at https://doi.org/10.1016/j.lana.2024.100932.

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