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RESEARCH ARTICLE

A 4-years Geographical Prevalence Trend Study of Peruvian Childhood Anemia

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Abstract:

Background:

Childhood anemia in Peru is categorized as a moderate public health problem. However, there are some regions in Peru where this nutritional condition is still considered severe.

Objective:

To study the evolution of the prevalence of anemia in children aged 6 months to 5 years at different regional levels in Peru during the 2015-2018 period.

Methods:

The spatial analysis was carried out using publicly available data from the Information System of Nutritional Status, which is managed by the Peruvian Ministry of Health, and a geographical information system software. Linear regression was used to assess the trend of the prevalences.

Results:

An overall downward trend of the prevalence of childhood anemia was observed at a national level during the 4-years under study. At natural and administrative regional levels, we noticed downward trends occurring at different rates. As of 2018, the natural region of the coast where more urban areas are located, presents the lowest prevalence (30%), while the natural region of the jungle has the highest one (36.9%). We have also alarmingly observed the presence of a cluster of high prevalences in the eastern side of Peru.

Conclusion:

We suggest that diverse risk factors might be producing the high prevalence in the cluster as well as other administrative regions across Peru: the education of the family, consumption of cow's milk, parasitic infections and the practice of mining activities. The aforementioned risk factors pose a threat to Peruvian public health and also the environment.

Keywords: Anemia, Children, Prevalence, Geographic Information Systems, Risk Factors, Peru.

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1. INTRODUCTION

Approximately 50% of anemia worldwide is due to iron deficiency, which is also the main cause of this condition among children in developing countries [1, 2]. In the Latin American region, Haiti and Bolivia are the countries that show the highest prevalence (65% and 61.3%, respectively) of anemia among children under 5 years of age, making this nutritional problem a severe one in these two nations [3, 4]. In Peru, childhood anemia is considered a moderate public health problem with a prevalence of 34% [3].

Geographical Information System (GIS), among its numerous applications, allows us to study spatial patterns of diseases and helps to establish relationships with social, demographic, natural and economic factors at different jurisdictional levels [5]. For instance, the spatial distribution of anemia in India at various geographical scales has been widely studied [6 - 8]. The prevalence of anemia among children under 5 years of age has been mapped in six states from southern India using a GIS package [7]. Because anemia is classified as a severe public health problem in this country, the authors of the study put forward a new categorization of the public health significance based on the one provided by the World Health Organization (WHO) to establish which districts

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within each southern state required the highest priority for anemia control. A study of the north-eastern states from India could determine, by using two geospatial data analysis packages (QGIS and GeoDA), which were the districts with the highest and lowest prevalence of childhood anemia as well as spotting clusters of districts of low and high prevalences [8]. Another study in India at a smaller geographical extent was done in the district of Darjeeling, located in the state of West Bengal [6]. By using geostatistical methods, pallor prevalence could be estimated for different villages of the district where not enough data could be collected and thus producing a complete map of pallor prevalence for the Darjeeling district. With these maps, the authors of the study suggested a link between elevation and pallor prevalence, which is an indicator of anemia.

At a country level in the African nation of Ghana, it was possible to visualize in a childhood anemia map that the northern regions (Upper West and Upper East) presented the highest incidence of this condition [9]. The authors of the study attributed the high prevalence due to the concentration of rural areas in these two regions, where poverty rates are high and the education level is poor. In Angola, geostatistical modelling was used to produce a high-resolution anemia risk map of the Dande municipality [10]. This served to identify the communities at the highest risk of anemia. Among the Latin American nations, the ArcGIS package has been used to map the prevalence of anemia in the population of children under 5 years of age living in four municipalities of rural Honduras [11]. The authors of the aforementioned study were also able to determine some associated risk factors (*e.g*., children's age, underweight, meat consumption, etc.) with childhood anemia.

In Peru, there are three natural regions which were defined due to their weather and biodiversity [12]; the coast, the highlands (where the Peruvian Andes reside) and the jungle (part of the Amazon rainforest). Within these natural regions there are administrative regions (or also known in Peru as departments), making a total of 25 across Peru [13]. In view of the context of the national plan put forward by the Peruvian Ministry of Health (MINSA), to significantly reduce childhood anemia by the year 2021 [14], in the present study we aimed at analyzing the behaviour of this condition among the population of children aged 6 months to 5 years at national, natural and administrative regional levels during the 2015-2018 period.

2. MATERIAL AND METHODS

2.1. Source of Information

Publicly available data of the prevalence of anemia in Peruvian children aged 6 months to 5 years for the 4 years under study were obtained from the Information System of Nutritional Status [SIEN; 15]. The SIEN is in charge of collecting and organizing information about the nutritional status of children under 5 five years of age and pregnant women who attend public healthcare facilities regulated by the MINSA.As the data is available to the public it was not necessary to have the approval of an Independent Ethics Committee (IEC). In order to collect blood samples from children, healthcare facilities register the hemoglobin levels by using hemoglobinometers; mainly the Hemo Control EKF Analyzer and the HemoCueHb 201. In the annual reports provided by the SIEN for the years 2015, 2016, 2017 and 2018 a total of 7,920, 7,926, 7,938 and 7,959 healthcare facilities, respectively, were considered. Prevalence of childhood anemia is provided by the SIEN in Microsoft Excel spreadsheets. A map of Peru divided in its 25 departments was downloaded from the database of global administrative areas (GADM; https://gadm.org/).

2.2. Spatial Analysis

The ArcGIS version 10.5 software (developed by Environmental Systems Research) was used for the spatial analysis. The map from GADM as shapefile was imported into ArcGIS for geoprocessing. In order to add data from the Excel spreadsheets into the attribute tables of the map from GADM, we used the Join Data method. For this, we had to ensure that there was a common column in the tables for the join, which in this case was the departments' names column. Afterwards, it was possible to generate 4 maps of the spatial distribution of childhood anemia for each year within the 2015-2018 period.

In order to categorize the public health significance of childhood anemia in each department, we followed the criteria of the WHO for populations [16]. If the prevalence is ≤4.9% then anemia is not considered a public health problem; if the prevalence is ≥5.0% and ≤19.9% then it is mild; it is moderate if the prevalence is ≥20.0% and ≤39.9%; finally, if the prevalence is ≥40.0% then it is regarded as a severe condition.

To assess better the trend of the prevalence of childhood anemia at different geographical scales, we treated our prevalence data points as time series and calculated best-fit lines using linear regression. Our considered simple linear model is:

$$y = \beta_0 + \beta_1 x, \quad (1)$$

where y represents our prevalences, x the years, β and $\beta_1$are the intercept and slope of the best-fit lines, respectively. The regression analysis was done using the library SciPy (https://www.scipy.org/) from the programming language Python. Here we used the optimization subpackage from SciPy, as it has been indicated to be well suited for minimizing objective functions [17].

The conducted research is not related to either human or animal use.

3. RESULTS

In Fig. (**1**), the spatial distribution of the prevalence of childhood anemia in Peru at an administrative regional level over the 2015-2018 period can be observed. At first sight, a general trend seen in the four maps is the decrease of prevalence in several departments. In the year 2015, childhood anemia was classified as a moderate public health problem in a total of 9 departments (Amazonas, Cajamarca, Callao, Ica, Lambayeque, Moquegua, San Martin, Tacna, and Tumbes), whereas in the rest of them, 16, it was regarded as a severe condition. In 2016, this nutritional problem improved in 6 departments (Apurimac, Ayacucho, Huancavelica, Huanuco, Lima and Piura), where childhood anemia passed from being considered severe to a moderate condition. On the other hand, in this same year, the coastal departments of Lambayeque and Tumbes suffered a setback, with childhood anemia being categorized as a severe problem. In 2017, the prevalence of anemia in children under 5 years decreased in 3 departments (Arequipa, Pasco, and Tumbes) to the degree of making this nutritional problem a modest one. In 2018, childhood anemia was categorized as modest in 4 more departments (Ancash, Junin, Lambayeque and Loreto). Moreover, two administrative regions, Huanuco and Moquegua, saw further progress; being anemia in children under 5 years classified as a mild condition. A very compelling and worrisome observation, especially more visible in 2018, is the existence in the eastern side of Peru of a spatial cluster of high prevalences of childhood anemia made up of the administrative regions of Cusco, Madre de Dios, Puno and Ucayali with 40%, 46%, 43.1%, and 47.9%, respectively.

In Fig. (**2**), the behaviour of the prevalence of anemia in children between 6 months and 5 years at national and natural regional levels is shown. Our estimated best-fit lines follow also quite well the trends of the data points. Overall, a downward trend can be observed. However, it is relevant to notice that for the highlands, the decrease of childhood anemia has occurred at a faster pace than the other two natural regions. In 2015, the prevalence of childhood anemia in the highlands was 48.2%±8.9%, while in 2018 this decreased to 32%±7.6%; revealing an approximate of 33.6% reduction for the four-years period under study. This significant change is also explained by the calculated slopes of our best-fit lines(Table **1**). The slope of the best-fit line for the highlands is of -5.4, whereas for the coast and the jungle are of -2.9 and -2.7, respectively, which indicates that the prevalence of childhood anemia in these two natural regions is occurring at a lower pace. In Table **1**, the decrease in percentages of the prevalence of childhood anemia at national, natural and administrative regional levels between 2015 and 2018 is shown.

In Fig. (**3**), we can visualize the evolution of childhood anemia in each of the 25 administrative regions. As observed, there is a general downward trend in almost all of the departments, although this may be happening fast in some and slow in others. An alarming result of our best-fit lines is that shown for the coastal administrative regions of Lambayeque and Callao, where the slopes of their best-fit lines are very close to zero; -0.6 and 0.9, respectively (Table **1**). This could mean that childhood anemia can worsen or not show any improvement at all in these two departments in the coming years. For the rest of the departments the slopes are considerably lower than -1, which would hint to a reduction of childhood anemia in the long-term future.

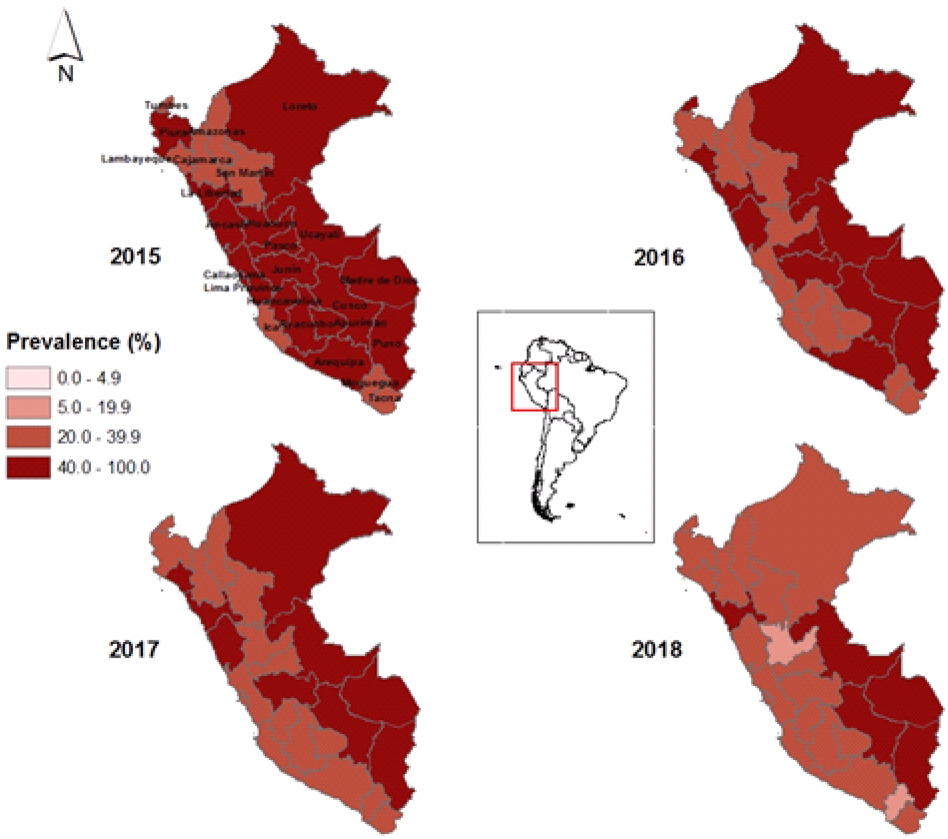

Fig. (1). Spatial distribution of the prevalence of anemia among Peruvian children aged 6 months to 5 years over the 2015-2018 period. The inset shows where Peru is located within South America.

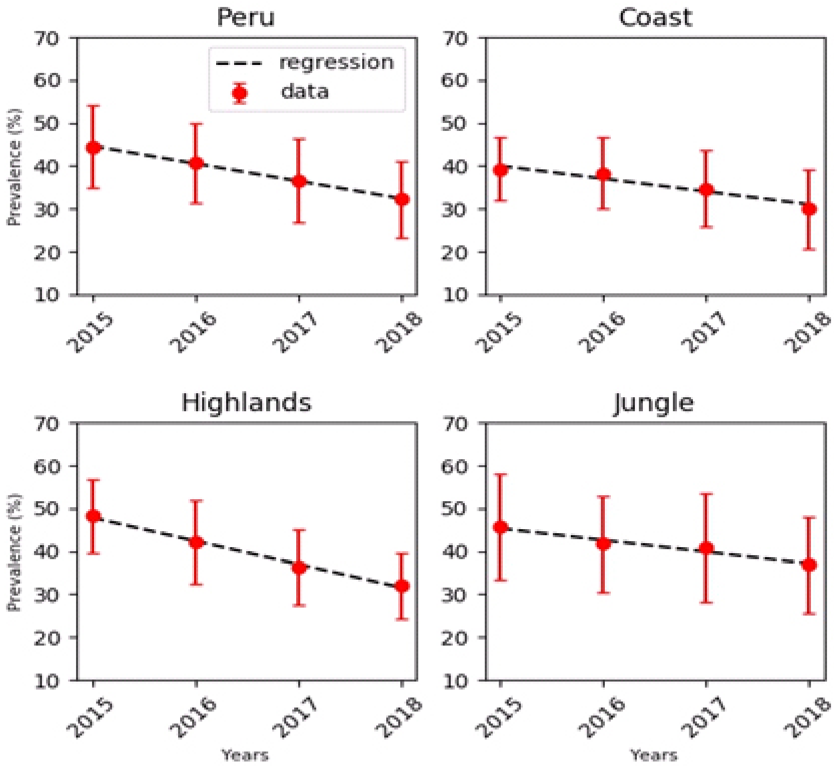

Fig. (2). Trends of the prevalence of anemia in children aged 6 months to 5 years of age at national and natural regional levels during the 2015-2018 period. The red points represent our calculated prevalence of childhood anemia based on data from SIEN, whereas the black-dashed lines are our estimated best-fit lines (Eq.1).

Table 1. Change in percentages of the prevalence of Peruvian childhood anemia over 2015-2018 period along with the slopes estimated for each best-fit line at national, natural and administrative regional levels.

-	2015 (%)	2018 (%)	% Change (2015-2018)	β_1
Peru	44.5	32.3	-27.4	-4.1
Coast	39.2	30	-23.5	-2.9
Highlands	48.2	32	-33.6	-5.4
Jungle	45.7	36.9	-19.3	-2.7
Amazonas	29.4	21.3	-27.6	-2.6
Ancash	47.1	37.7	-19.9	-2.9
Apurimac	44	26.8	-39.1	-5.9
Arequipa	46.4	28.2	-39.2	-6.3
Ayacucho	43.9	23.7	-46	-6.4
Cajamarca	37.3	30.4	-18.5	-2.3
Callao	31.3	33	5.4	0.9
Cusco	56.9	40	-29.7	-5.7
Huancavelica	43.7	34.2	-21.7	-3.1
Huanuco	40	17.8	-55.5	-7.4
Ica	37.3	21.6	-42.1	-5.4
Junin	49.1	37.7	-23.2	-4.5
La Libertad	56.2	46.6	-17.1	-3.3
Lambayeque	39.6	38.3	-3.3	-0.6
Lima	40.5	32.1	-20.7	-2.7

-	2015 (%)	2018 (%)	% Change (2015-2018)	β_1
Loreto	51.9	38.8	-25.2	-4.2
Madre de Dios	55.2	46.2	-16.3	-1.8
Moquegua	34.4	19.8	-42.4	-4.8
Pasco	52.8	32.4	-38.6	-6.9
Piura	42.2	23.6	-44	-6
Puno	69.2	43.1	-37.7	-8.7
San Martin	35.6	30.1	-15.5	-2.3
Tacna	33.4	20.1	-39.8	-4.6
Tumbes	38.2	34.9	-8.6	-1.8
Ucayali	56.5	47.9	-15.2	-2.6

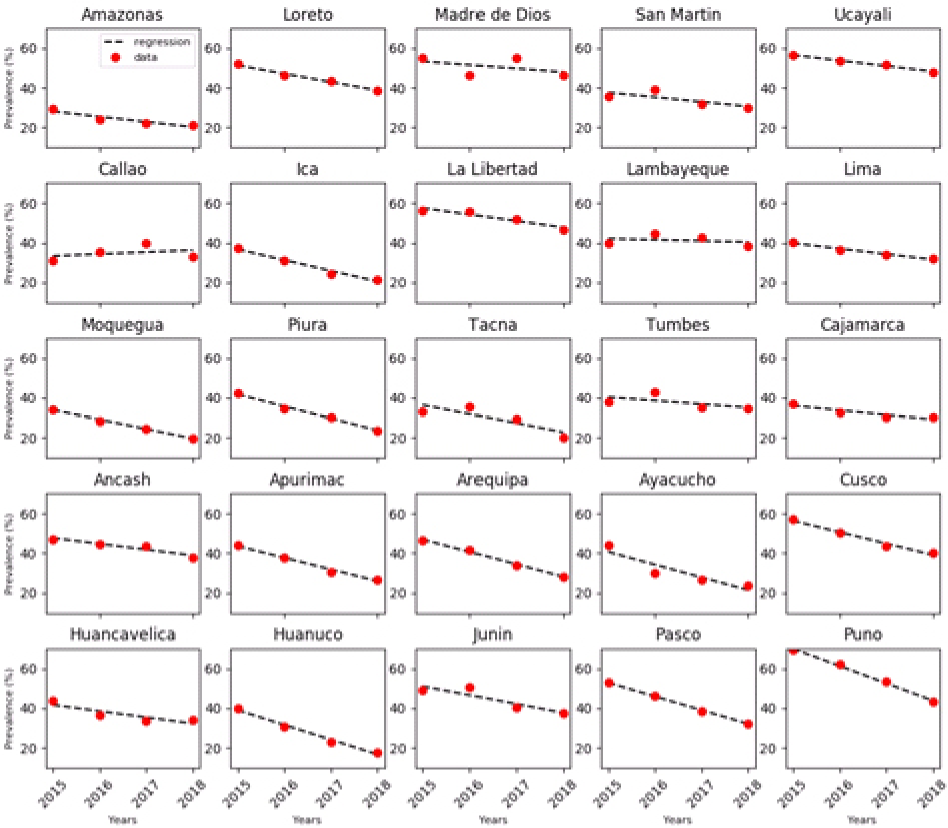

Fig. (3). Trends of the prevalence of anemia in children aged 6 months to 5 years of age at an administrative regional level during the 2015-2018 period. The red points represent the prevalence of childhood obtained from SIEN, whereas the black-dashed lines are our estimated best-fit lines (Eq.1).

4. DISCUSSION

During the 4 years under study, two departments from the highlands (Cusco and Puno) and two from the jungle (Madre de Dios and Ucayali) maintained a prevalence of childhood anemia higher than 40%, making this condition a severe public health problem in them. Additionally, due to their proximity to each other, they form a spatial cluster of high prevalence, which suggests that childhood anemia may be caused by the same risk factors within the cluster.

A study of 6 rural communities located in the district of Huancarani, Cusco, revealed that the education of the parents was significantly associated with childhood anemia [18]. Another study of 12 villages from the Ollantaytambo district, Cusco, has pointed out that besides the education of the parents, deficiency of iron in their daily diet and the introduction of cow's milk post-breastfeeding were strongly associated with this nutritional problem [19]. It is well known that the introduction of cow's milk at a very early age has detrimental effects on infants [20]. The districts of Huancarani and Ollantaytambo are located in isolated regions of Cusco, and in the aforementioned studies of these two districts, anemia in the surveyed children population was categorized as a severe public health problem. Hence, the high prevalences of childhood anemia in Cusco and Puno between 2015 and 2018 are the very likely product of considerable Andean communities living in isolation, where there are limited family education and lack of iron in their daily diets. It has been indicated as well that these two departments live the second and third largest portions of the Peruvian rural population [21].

Ucayali and Madre de Dios have the highest prevalence (47.9% and 46%, respectively) among the 25 Peruvian departments. It has been put forward that in similar Amazon areas, anemia is mainly due to iron deficiency, specifically due to impaired iron absorption [22]. Even though the communities in the Amazon regions have daily diets based on carbohydrates, proteins, and fruits, it is quite possible that their diets also contain components (*e.g.*, fibre, phenols, and phytates) that impair the assimilation of iron [23, 24].

The release of toxic substances into the environment is also a very compelling factor that can contribute to childhood anemia especially in rural communities living close to mining regions [25 - 28]. Very recently in a study of a population of children under 12 years living in 23 rural communities and close to mining concessions in the department of Madre de Dios, it has been suggested that exposure to methylmercury through contaminated fish consumption increases the risk of developing anemia [28]. Madre de Dios is considered a hotspot for gold mining (part of it being illegal) in Peru, and this is not only bringing about concerns for the public health in this region but also pose hazards to its existent rich biodiversity in this region [29, 30]. Another metal, which is released due to mining activities is lead and it is well known that this can induce anemia [25 - 27]. On the other hand in the department of Ucayali, which is also affected by illegal mining, it has been indicated that helminth parasites should be taken into consideration as a cause of anemia [31]. Parasitic diseases are known to lead to iron loss [32]. In the province of Coronel Portillo, Ucayali, a survey of 14,245 children with anemia under 5 years has revealed that 69.3% of them had the Giardia Lamblia parasite which is associated with the development of this disease [31]. Overall, we can then suggest that similar causes are at work in the other departments (Amazonas, Loreto, and San Martin) of the Peruvian jungle. For instance, a study has pointed out lead exposure in the northern part of Loreto due to oil extraction activities [33]. Hence, the combination of several risk factors in the Peruvian jungle is echoed in the fact that this natural region presents still the highest prevalence (36.9%) of childhood anemia in the year 2018 (Table **1**).

Our estimated prevalence of childhood anemia on the coast is the lowest among the three natural regions during the 2015-2018 period (Table **1**). This agrees well with a plethora of studies that argue that urban areas present a lower prevalence of childhood anemia than rural ones [34-37]. In Peru, there are more urban areas in the coast than the highlands and the jungle. As populations in urban areas present better socio-economical status than rural ones, they are in the position of having better jobs which translate in more means to have access to iron-rich food [35]. Thus, it is quite likely that the observed decrease in the prevalence of childhood anemia in the departments of the coast between 2015 and 2018 is due to the considerable number of its urban areas.

In general, the tendency of anemia among Peruvian children under 5 years is a decreasing one, at a national level in 2015 was 44.5% and in 2018 32.3% (Table **1**). This reduction can be attributed to the result of the heavy investment the Peruvian government has done in past years on the program of supervision of growing and development (CRED). This program consists of evaluating children every 6 months and providing them with iron supplements and counseling to their families when needed [38]. Nevertheless, there are some departments where this condition is still severe and hence in urgent need of intervention. In the highlands' departments where consumption of cows' milk is preferred, fortification of this with ferrous gluconate can aid in reducing anemia [39]. Another strategy, which is crucial for the overall children population in Peru suffering from anemia is family education. By educating parents, and to some extent the children themselves, on dietary management, practices of hygiene (*e.g.* handwashing) and waste management, it has been shown that families are more aware and knowledgeable of the causes that can bring about this disease [40]. With regard to parasitic infections associated with anemia, which has been reported in regions of the Peruvian jungle, deworming is the best strategy to follow [41].

The mining sector in Latin America is constantly on the rise. Peru, which is one of the global leading exporters in copper, gold, lead, and silver [42], attracts numerous mining projects (legal and sometimes illegal), which in many occasions threaten the environment and the public health. In Madre de Dios and some other departments where mining activity is established, the children living nearby communities are at high risk of developing anemia due to exposure to metals. Therefore, the Peruvian Ministry of Energy and Mines (MINEM) must strengthen its regulations and provide better policies to control how the mining sector is operating close to rural communities, where the danger is that children can be exposed to metals like lead or methylmercury.

The limitation of this study is that the prevalence were estimated considering only public healthcare centers (managed by the MINSA) that provide health services for approximately 60% of the Peruvian population [43]. Despite this drawback, we believe that our results are representative of the overall current situation of childhood anemia in Peru. This is because a considerable part of the children population who attend these facilities belong mainly to low socio-economic status households or urban and rural areas where anemia is more likely to develop.

CONCLUSION

To sum up, our findings reveal that at a national level in Peru the prevalence of childhood anemia has been steadily decreasing during the 2015-2018 period. However, the rates of decline for each natural region are not the same. As of 2018, the natural region of the jungle presents the highest prevalence of childhood anemia with 36.9%, whereas the coast (where most urban areas from Peru are located) presents the lowest prevalence (30%). Our maps reveal as well the constant presence of a cluster of high prevalences on the eastern side of

Peru. A cluster which is made up of two departments from the highlands and two from the jungle. Several known risk factors (*e.g.*, cows' milk, education of the family and parasitic infections) are likely to be contributing to the development of this nutritional problem in this cluster and other administrative regions of Peru. Alarmingly, we notice also that mining activities are a strong risk factor to be considered in association with childhood anemia in Peru, specifically in those communities living nearby mining projects (intensively happening in Madre de Dios). Further interventions of the MINSA is suggested, especially in regions where anemia is still severe and also the active participation of the MINEM is required to decrease the release of metals that threaten not only the public health but also the environment.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article is available in the Information System of Nutritional Status at https://web.ins.gob.pe/index.php/es/alimentacion-y-nutricion/vigilancia-alimentaria-y-nutricional/vigilancia-del-sistema-de-informacion-del-estado-nutricional-en-%20EESS.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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