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# Inequalities in compliance with the two-dose measles vaccination in Peruvian children aged 12 to 59 months in 2023

## *Desigualdades en el cumplimiento de las dos dosis de vacunación contra el sarampión en niños peruanos de 12 a 59 meses en 2023*

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## RESUMEN

**Objetivos:** El objetivo de este estudio fue evaluar las desigualdades sociodemográficas relacionadas con la cobertura y el cumplimiento de la vacunación de dos dosis contra el sarampión entre los niños peruanos en 2023. **Materiales y métodos:** Se realizó un estudio transversal analítico con datos de una encuesta demográfica y de salud. Se incluyeron madres de entre 15 y 49 años con hijos de entre 12 y 59 meses. Las características sociodemográficas y de salud de estas madres se evaluaron para el análisis de desigualdad mediante el índice de concentración (IC). Este análisis se utilizó para evaluar la desigualdad en la vacunación de la primera dosis y de refuerzo contra el sarampión, que se complementó con el índice de concentración de Erreygers (ICE) y su descomposición. **Resultados:** Se evaluó a 16 526 madres peruanas con al menos un hijo de 12 a 59 meses de edad. Se identificó una cobertura de vacunación de 85,7% y 54,4% para la primera dosis y dosis de refuerzo, respectivamente. La cobertura para ambas dosis fue de 52,1%, y estas disminuyeron entre quienes viven en zonas rurales y regiones selváticas. En el análisis de desigualdad, las madres sin educación o con educación primaria (IC: -0,46), las que viven en regiones de selva (IC: -0,46) y las que viven en zonas rurales (IC: -0,60) mostraron mayor desigualdad en la vacunación. El ICE fue de 0,04, y en su descomposición algunas condiciones como la educación secundaria, vivir en zonas rurales y tener seguro de salud tienen un impacto negativo sobre la desigualdad en la vacunación. **Conclusiones:** Se identificaron mayores desigualdades en la cobertura de vacunación contra el sarampión entre los niños de 12 a 59 meses cuyas madres peruanas residen en zonas rurales o no metropolitanas de Lima, tienen menor nivel educativo y carecen de seguro médico.

**Palabras clave:** Sarampión; Vacuna antisarampión; Monitoreo de las desigualdades en Salud; Inequidades en salud; Disparidades socioeconómicas en salud; Factores socioeconómicos; Perú (Fuente: DeCS-BIREME).

## ABSTRACT

**Objective:** The aim of this study was to evaluate sociodemographic inequities related to the coverage and compliance of the two-dose measles vaccination among Peruvian children in 2023. **Materials and methods:** An analytical cross-sectional study was conducted using data from a Demographic and Health Survey. Mothers aged 15 to 49 with children aged 12 to 59 months were included. Sociodemographic and health characteristics of these mothers were evaluated for inequity analysis using the Concentration Index (CI). This analysis was used to evaluate inequity in vaccination for first and booster doses against measles, and it was complemented with the Erreygers Concentration Index (ECI) and its decomposition. **Results:** Sixteen thousand, five hundred and twenty-six Peruvian mothers with at least one child aged 12 to 59 months were evaluated. Vaccination coverage was 85.7% and 54.4% for the first and booster doses, respectively. The coverage for both doses was 52.1%, and these figures decreased in people living in rural areas and the Amazon rainforest. In the inequity analysis, mothers with no education or only elementary schooling (ECI: -0.46), those living in the rainforest (ECI: -0.46), and those living in rural areas (ECI: -0.60) exhibited greater inequity in vaccination rates. The ECI was 0.04, and in their decomposition, some conditions, such as high school education, living in rural areas, and having health insurance, have a negative impact on vaccination inequity. **Conclusion:** Greater inequities in measles vaccination coverage were identified among Peruvian children aged 12-59 months whose mothers reside in rural or non-metropolitan areas of Lima, have lower education levels, and lack health insurance.


**Keywords:** Measles; Measles vaccine; Healthcare disparities; Health inequities; Socioeconomic factors; Peru (Source: MeSH-NLM).

## INTRODUCTION

Immunization is one of the most effective measures for preventing diseases, as it prevented between 3.5 and 5 million deaths annually worldwide until 2023[1]. In these prevented infections, measles is highly contagious among children[2]. In many countries, the measles, mumps, and rubella (MMR) vaccine is distributed free in population[3]. Similarly, in Latin America, including Peru, the measles vaccines are acquired through the Pan American Health Organization (PAHO) Revolving Fund and are distributed at no cost to children under 6 years of age[2,4]. The first dose is usually given at 12 months of age, followed by a booster dose 6 months later at 18 months of age, as per the vaccination schedule recommended by the Ministry of Health of Peru[5].

In 2019, the World Health Organization (WHO) estimated 869,770 cases and 207,500 deaths due to measles[6]. The global immunization rate declined by 5% from 2019 to 2021, possibly due to factors such as vaccine hesitancy, disruptions in healthcare services, or logistical challenges[7]. This situation, worsened by the COVID-19 pandemic, mainly affected low- and middle-income countries. This was due to political and financial crises faced by governments in acquiring vaccine supplies, as well as vaccine skepticism among the population[8]. Only 7 out of 40 countries attained a minimum coverage of 95% to prevent measles outbreaks in 2024, highlighting the persistent risk of widespread outbreaks in regions with low vaccination rates[9].

In Peru, immunization coverage against measles was estimated at 70.2% and 52% for the first and second doses, respectively, in 2017[10]. However, the decrease in vaccination coverage during the COVID-19 pandemic increases the risk of measles outbreaks[11,12]. However, the evidence on factors associated with measles vaccination is limited to the period before the COVID-19 pandemic. Changes in health policies and living conditions may have contributed to inequalities for complete vaccination doses against measles[13,14]. Therefore, the aim of this study was to evaluate sociodemographic inequalities associated with coverage and compliance to the two-dose measles vaccination among Peruvian children aged 12 to 59 months in 2023.

## MATERIALS AND METHODS

### Study design

We conducted an analytical cross-sectional study using data from the 2023 Demographic and Family Health Survey (or ENDES, in Spanish acronym)[15]. The National Institute of Statistics and Informatics (or INEI, in Spanish acronym) conducts the ENDES survey every year since 2004 in urban and rural areas throughout 25 of Peru's regions. This country has a diverse geographic region (coast, highlands, and jungle), and the third part of its population is concentrated in Lima, the capital of Peru[16]. We evaluated the immunization with two doses against measles in all children aged 12 to 59 months registered in the survey of Peruvian mothers aged 15 to 49 years, who responded to questions about sociodemographic characteristics and health issues like insurance affiliation.

### Variables related to the mothers

Sociodemographic and health characteristics of mothers were evaluated, such as age group (15 to 29 and 30 to 49 years old), educational level (no education or primary, secondary, or higher), wealth index (poorest, poor, middle, rich, and richest), area of residence (rural and urban), and natural region of residence

(Metropolitan Lima, rest of the coast, highlands, and jungle). We also evaluated the ethnicity reported by the mothers (white or mestizo, Quechua or Aimara, Afro-Peruvians, and native or others). Additionally, health-related aspects like insurance affiliation (yes or no) were evaluated (Appendix 1).

### Immunization against Measles

We evaluated if children aged 12 to 59 months received the initial dose of measles vaccination and the booster or second dose of measles vaccination. A child was considered to have received the doses if the vaccination was recorded on the card, with the date documented, or if the mother reported the immunization (Appendix 1). According to the national vaccination scheme in Peru, the first dose against measles is provided at 12 months, while the second dose is provided at 18 months. However, both doses can be applied to five-year-old children, but for this reason we did not evaluate a specific age group on children, especially considering that since the measles outbreaks in Peru, immunization sweeps against this disease have been established as a strategy for children under 5 years of age[5].

### Statistical analysis

The statistical analysis was conducted using Stata ® Version 17.0 (Stata Corp., TX, USA), incorporating the survey design of the ENDES with the "svy" command. Categorical variables were described using frequencies and percentages along with their respective 95% confidence intervals. We also analyze the differences in the proportion of children who received the first, second, or both doses of measles vaccination in the different categories of the study variables.

### Inequality analysis

The inequality analysis was conducted using concentration curves to assess the compliance of the doses of measles vaccination based on socioeconomic status, ranging from the poorest to the richest following the WHO framework of social determinants of health inequalities[17]. The Concentration Index (CI) was calculated to measure inequality in the distribution of measles vaccination doses based on socioeconomic status[18,19]. Additionally, the Erreygers Concentration Index (ECI) was used to provide a fairer assessment of inequality in the distribution of measles vaccination doses based on socioeconomic status. The analysis was carried out considering the weights and sample design of the DHS. This inequality measure indicates greater inequality with higher values. Values higher than zero show a concentration of inequality in the population with a better wealth index, while values lower than zero indicate a concentration of inequality in the population with the worst wealth index[20].

We also conducted a decomposition of the Erreygers Concentration Index to assess how each sociodemographic characteristic contributed to inequality in measles vaccination doses based on socioeconomic status[21]. This method was performed with the following formula:

$$ECI = \sum_{k} 4\,[\,\beta_k\, X_k\, C_k] + \; Residual$$

Where $\beta_k$ is the marginal effect or the difference between ECI in categories in the variables. While $X_k$ is a representation of each variable or the mean of variables included for decomposition, and elasticity is the responsiveness of the outcome to changes in $X_k$. Also, the Ck is the concentration index of each explanatory variable. The contribution of each variable is represented by the formula in brackets, while the explanation of all ECI is compounded by the individual contribution of each variable[22].

### Ethical aspects

The study was conducted by analyzing data from ENDES, a national survey administered with informed consent from participants. Additionally, the study ensured participant confidentiality by not including information that would allow the identification of participants in the research. For this reason, we did not request the evaluation of an ethics committee, but the study was conducted respecting all the principles of bioethics in research.

## RESULTS

Among the 20,840 households evaluated in 2023 for the ENDES, it was only included 16,526 Peruvians mothers with at least one child aged 12 to 59 months (Appendix 2). In these children, the vaccination coverage was 85.7% (95%CI: 84.9 to 86.5) for the first dose and 54.4% (95%CI: 53.3 to 55.5) for the booster dose against measles. The mother's characteristics revealed that coverage for the first dose was lower in those who identify as native or other ethnic groups and without health insurance. This coverage was lower for the booster dose against measles (Table 1). However, in this second dose, only the educational level, wealth index, natural region and area of residence did not determinate statistical differences in vaccine coverage (p>0.05).

Additionally, it was identified that 52.1% (95%CI: 51.0 – 53.1) of children aged 12 to 59 months completed both doses of vaccination against measles (Table 2). In this case, those who live in jungle regions and rural areas show lower coverage but no statistical differences (p>0.05). In this context, the concentration curves for the first dose vaccines against measles were lower (CI: 0.01, 95%CI: 0.01 to 0.02, p<0.001), but note were significant in the context of booster dose vaccines against measles (Figure 1A and 1B). Furthermore, the coverage of both doses of measles vaccination does not show differences among wealth index categories (Figure 1C). The concentration curve for this case did not show a significant concentration index (Figure 1D).

In the analysis of inequality in the completion of the two doses of measles vaccination mediated by wealth quintile, it was identified

**Table 1.** Characteristics of mothers and children according to coverage of the first and second doses of measles vaccine

| Mother's Characteristics | First doses (n=14,045) | | | Second doses (n=8,877) | | |
|---|---|---|---|---|---|---|
| | Proportion according to characteristics | First dose coverage* (12 to 59 months) | p-value | Proportion according to characteristics | Second dose coverage* (12 to 59 months) | p-value |
| | n (%*) | %* (95%CI) | | n (%*) | %* (95%CI) | |
| Age group (years) | | | | | | |
| 15 to 29 | 5827 (40.5) | 83.4 (82.2 to 84.5) | <0.001 | 3594 (39.9) | 51.9 (50.3 to 53.5) | <0.001 |
| 30 to 49 | 8218 (59.5) | 87.7 (86.8 to 88.6) | | 5283 (60.1) | 56.2 (54.8 to 57.6) | |
| Educational level | | | | | | |
| No education or elementary | 2274 (15.1) | 80.6 (78.4 to 82.6) | <0.001 | 1485 (15.6) | 52.7 (50.1 to 55.3) | 0.080 |
| High school | 6807 (46.7) | 85.1 (84.0 to 86.1) | | 4253 (46.7) | 53.9 (52.4 to 55.4) | |
| University | 4964 (38.2) | 89.4 (88.3 to 90.4) | | 3139 (37.7) | 55.8 (54.1 to 57.6) | |
| Wealth index | | | | | | |
| Poorest | 3911 (23.8) | 81.6 (79.9 to 83.2) | <0.001 | 2470 (24) | 51.9 (49.8 to 53.9) | 0.089 |
| Poor | 3701 (23.2) | 85 (83.4 to 86.4) | | 2374 (23.6) | 54.8 (52.8 to 56.7) | |
| Middle | 2869 (20.3) | 88.2 (86.6 to 89.7) | | 1803 (20.1) | 55.5 (53.2 to 57.7) | |
| Rich | 2181 (18.4) | 87.3 (85.4 to 88.9) | | 1358 (18.3) | 55 (52.5 to 57.5) | |
| Richest | 1383 (14.2) | 90.3 (88.2 to 92.0) | | 872 (13.9) | 56.2 (52.9 to 59.4) | |
| Natural region | | | | | | |
| Metropolitan Lima | 1698 (27.5) | 87.2 (85.6 to 88.7) | <0.001 | 1073 (26.9) | 54.3 (51.8 to 56.9) | 0.174 |
| Rest of the Coast | 4294 (27.8) | 87.7 (86.1 to 89.1) | | 2744 (28.2) | 56 (53.9 to 58.0) | |
| Highlands | 4547 (26.6) | 85.7 (84.4 to 87.0) | | 2882 (26.7) | 54.3 (52.4 to 56.2) | |
| Jungle | 3506 (18.1) | 81.8 (80.0 to 83.4) | | 2178 (18.2) | 52.3 (50.2 to 54.4) | |
| Area of residence | | | | | | |
| Urban | 10 050 (75.7) | 86.7 (85.9 to 87.5) | <0.001 | 6331 (75.4) | 54.8 (53.5 to 56.0) | 0.266 |
| Rural | 3995 (24.3) | 83.4 (81.6 to 85.1) | | 2546 (24.6) | 53.3 (51.2 to 55.5) | |
| Ethnicity | | | | | | |
| Mestizo or white | 6988 (56.9) | 87.3 (86.3 to 88.2) | <0.001 | 4418 (56.4) | 54.8 (53.3 to 56.3) | <0.001 |
| Quechua or Aimara | 4393 (26.6) | 85.5 (84.2 to 86.7) | | 2782 (26.7) | 54.4 (52.5 to 56.4) | |
| Afro-Peruvian | 1575 (13.7) | 86.1 (83.8 to 88.1) | | 1024 (14.3) | 56.5 (53.4 to 59.6) | |
| Native or others | 447 (2.8) | 69.1 (63.3 to 74.4) | | 248 (2.6) | 39.9 (34.7 to 55.5) | |
| Health insurance | | | | | | |
| No | 817 (6.6) | 77.5 (73.7 to 81.0) | <0.001 | 480 (6.1) | 45.2 (41.2 to 49.3) | <0.001 |
| Yes | 13218 (93.4) | 86.4 (85.6 to 87.1) | | 8377 (93.9) | 55.1 (54.0 to 56.2) | |

95%CI: 95% Confidence interval
* Weighted estimate for the complex survey sample.

that mothers without education or only elementary (CI: -0.46), living in jungle regions (CI: -0.46) or in rural areas (CI: -0.60) and identifying as a native or other ethnic group show higher inequality. However, those mothers who live in Metropolitan Lima (CI: 0.43), who studied in university (CI: 0.39), and without health insurance (CI: 0.27) shower lower inequality related to completion of the two doses of measles vaccination (Table 2).

In the assessment of inequality in measles vaccination with one and/or two doses using the Erreygers Concentration Index (ECI), it was found that vaccination inequality for the first dose concentrated in the children of mothers who identify as native or others ethnic group (ECI: 0.24), without health insurance (ECI: 0.21), and who live in the jungle (ECI: 0.12). This context was similar in the vaccination inequality for the

**Table 2.** Characteristics of mothers and children and inequality in compliance with the two doses of measles vaccination

| Mother's Characteristics | Proportion according to characteristics | Complete vaccination Doses (n=8,514) | | Inequality in compliance with the two doses of measles vaccination against measles | |
|---|---|---|---|---|---|
| | n (%*) | %* (95%CI) | P-value | Concentration Index (95%CI) | p-value |
| Age group (years) | | | | | |
| 15 to 29 | 3406 (39.3) | 49.1 (47.4 to 50.7) | <0.001 | -0.12 (-0.15 to -0.08) | <0.001 |
| 30 to 49 | 5108 (60.7) | 54.6 (53.2 to 56.0) | | 0.08 (0.06 to 0.10) | <0.001 |
| Educational level | | | | | |
| No education or elementary | 1407 (15.5) | 50.1 (47.5 to 52.7) | 0.023 | -0.46 (-0.50 to -0.42) | <0.001 |
| High school | 4071 (46.5) | 51.6 (50.1 to 53.1) | | -0.13 (-0.16 to -0.10) | <0.001 |
| University | 3036 (38) | 54 (52.2 to 55.8) | | 0.39 (0.36 to 0.42) | <0.001 |
| Natural region | | | | | |
| Metropolitan Lima | 1036 (27.1) | 52.7 (50.1 to 55.2) | 0.126 | 0.43 (0.40 to 0.47) | <0.001 |
| Rest of the coast | 2634 (28.1) | 53.7 (51.6 to 55.7) | | 0.02 (-0.04 to 0.08) | 0.536 |
| Highlands | 2765 (26.7) | 52.1 (50.2 to 54.0) | | -0.31 (-0.36 to -0.26) | <0.001 |
| Jungle | 2079 (18.1) | 49.8 (47.7 to 51.9) | | -0.46 (-0.53 to -0.39) | <0.001 |
| Area of residence | | | | | |
| Urban | 6088 (75.6) | 52.7 (51.5 to 54.0) | 0.136 | 0.23 (0.20 to 0.25) | <0.001 |
| Rural | 2426 (24.4) | 50.8 (48.7 to 53.0) | | -0.60 (-0.64 to -0.57) | <0.001 |
| Ethnicity | | | | | |
| Mestizo or white | 4240 (56.5) | 52.6 (51.1 to 54.1) | <0.001 | 0.14 (0.11 to 0.16) | <0.001 |
| Quechua or Aimara | 2662 (26.7) | 52.1 (50.1 to 54.1) | | -0.09 (-0.15 to -0.03) | 0.002 |
| Afro-Peruvian | 994 (14.4) | 54.7 (51.5 to 57.8) | | -0.25 (-0.31 to -0.20) | <0.001 |
| Native or others | 226 (2.4) | 36.0 (31.0 to 41.2) | | -0.36 (-0.48 to -0.24) | <0.001 |
| Health insurance | | | | | |
| No | 470 (6.2) | 44.1 (40.0 to 48.3) | <0.001 | 0.27 (0.18 to 0.35) | <0.001 |
| Yes | 8036 (93.8) | 52.7 (51.6 to 53.8) | | -0.02 (-0.02 to -0.01) | <0.001 |

95%CI: 95% Confidence interval
* Weighted estimate for the complex survey sample.

booster dose (Table 3). While the vaccination inequality for both doses concentrated in the children of mothers who identify as native or other ethnic group (ECI: 0.17), without education or elementary (ECI: 0.07), and who live in rural areas (ECI: 0.04).

In the decomposition analysis of vaccination inequality for both doses against measles based on mother´s characteristics show that university education, older aged group and lives in Metropolitan Lima contributes positively against inequality, while living in high school education, living in rural areas, and with health insurance contributes negatively to vaccination inequality (Table 4). In this analysis the ECI modified value was -1.32 showing the concentration of inequality in vaccination coverage for children of mothers in lower wealth index.

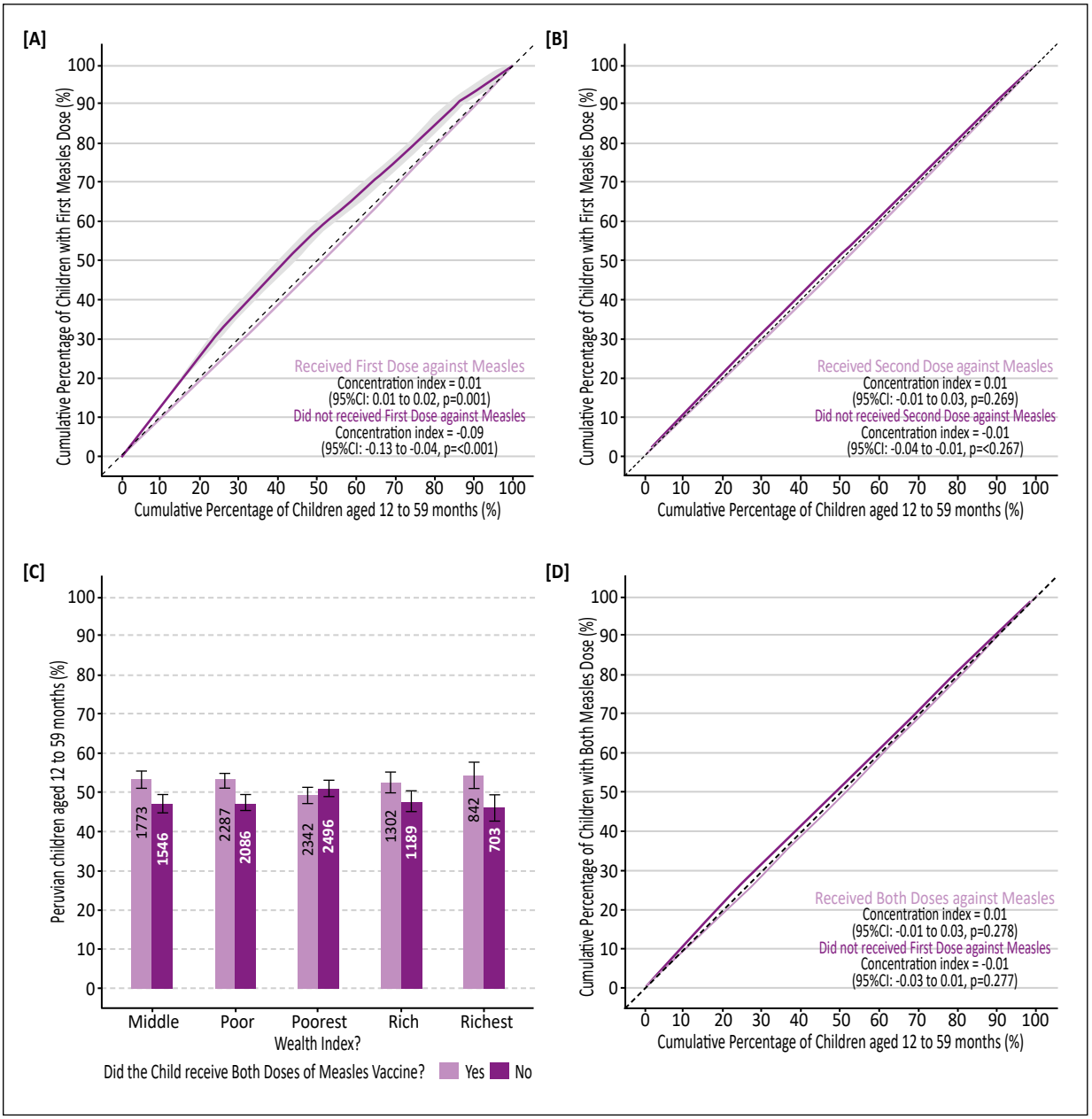
In the assessment of measles immunization coverage across the 25 regions in Peru, it was identified that the coverage was lower in the second dose and for those with both doses compared to the first dose (Figure 2A). While inequality of vaccination coverage was higher for children of mothers in higher wealth index from regions like Amazonas, Ica, Junín, Loreto, and Ucayali (Figure 2B).

## DISCUSSION

This study evaluated inequalities in measles vaccination against measles according to sociodemographic characteristics of Peruvian mothers with children aged 12-59 months. The study shows that differences in measles vaccination coverage are

linked to factors like the educational level, area of residence, and health insurance of Peruvian mothers with children aged 12-59 months. This disparity may stem from insufficient infrastructure or limited access to vaccination services, as observed in Mexico[23]. Addressing these challenges could enhance current child immunization strategies by improving the availability and distribution of vaccines in rural areas to lessen geographical disparities[24]. All these inequalities could contribute to reducing vaccination coverage and increasing the measles outbreak in Peru, which has seen a rise in new cases in recent years[12].

In the sociodemographic inequalities, those mothers with higher education show low inequalities in the vaccination of their children. This is because mothers with higher education often have a better understanding of vaccination importance, more healthcare resources, and consequently, higher rates of childhood immunization, similar to countries like Brazil[25]. In addition, this aspect represents an opportunity for investment in health education programs, and the implementation of systematic text message reminders has proven to be effective in closing these vaccination inequalities[26].




CI: Concentration Index, 95%IC: Confidence Interval

**Figure 1**. Inequalities in compliance with measles vaccination doses for Peruvian children in 2023. **[A]** Concentration curves for the coverage of the first dose of the measles vaccine. **[B]** Concentration curves for the coverage of the second dose of the measles vaccine. **[C]** Coverage of both doses of the measles vaccine by wealth index. **[D]** Concentration curves for the coverage of both doses of the measles vaccine.

The health insurance shows contradictory impacts for inequalities in measles vaccination. This could be explained in the Peruvian context because the national immunization program is assumed by the Health Ministry with a community approach to guarantee free access to vaccines; this health program facilitates access and minimizes financial barriers[27]. However, the main difference lies in the coverage and quality of the insurance because the Peruvian population is affiliated with one of five different health provider systems with different quality of the health services provided, where the immunization scheme is not always prioritized[28-32].

In Latin America, access to public health insurance or free vaccination programs has been key to improving coverage in some countries, but the ethnicity is frequently omitted and this study show how a those native mothers have greater inequalities for vaccination on their children[33,34], this could be related to worse sociodemographic conditions in this Peruvian population, who also had lower access to healthcare service and resources[35]. Also, the lower education is a common issue in this population and could be related to this lower vaccination, for this reason educational strategies in communities with lower levels of

**Table 3.** Decomposition of vaccination inequality against measled related to sociodemographic characteristics of Peruvian mothers with children aged 12 to 59 months

| Mother's Characteristics | Inequality in the reception of both doses against measles in children (ECI: 0.04, 95%CI: 0.01 to 0.06, p=0.011) | | | |
|---|---|---|---|---|
| | Marginal Effect | Elasticity | $C_k$ | Contribution (%) |
| Age group | | | | |
| 15 to 17 years old | Ref. | | | |
| 30 to 49 years old | -0.01 | 0.12 | 0.18 | 67.77 |
| Educational level | | | | |
| No education or elementary | Ref. | | | |
| High school | -0.07 | 0.03 | -0.23 | -22.19 |
| University | -0.07 | 0.05 | 0.55 | 91.26 |
| Natural region | | | | |
| Metropolitan Lima | Ref. | | | |
| Rest of the coast | -0.03 | 0.03 | 0.12 | 11.21 |
| Highlands | 0.02 | 0.01 | -0.29 | -7.58 |
| Jungle | 0.09 | 0.01 | -0.27 | -1.38 |
| Area of residence | | | | |
| Urban | Ref. | | | |
| Rural | 0.01 | 0.01 | -0.62 | -22.52 |
| Ethnicity | | | | |
| Mestizo or white | Ref. | | | |
| Quechua or Aimara | -0.03 | -0.01 | -0.17 | 1.15 |
| Afro-Peruvian | -0.01 | 0.01 | -0.10 | -4.07 |
| Native or others | 0.15 | -0.02 | 0.01 | 4.16 |
| Health insurance | | | | |
| No | Ref. | | | |
| Yes | -0.11 | 0.29 | -0.06 | -51.04 |
| Summary of ECI | | | -0.88 | 66.77 |
| Residual (unexplained) | | | -0.44 | 33.23 |
| Corrected ECI | | | -1.32 | |

ECI: Erreygers concentration index weighted for the complex sample by wealth quintile, Elasticity = [βk * $\bar{x}$k /μ], Ck: Concentration index of the evaluated variable, Ref. Category used as reference for estimation in the decomposition model.

**Table 4.** Inequality in compliance with the two doses of measles vaccination in children between 12 and 59 months of age

| Mother's Characteristics | Received first dose (n=14,045) | | Received second dose (n=8,877) | | Received both doses (n=8,514) | |
|---|---|---|---|---|---|---|
| | ECI (95%CI) | p-value | ECI (95%CI) | p-value | ECI (95%CI) | p-value |
| Age group | | | | | | |
| 15 to 17 years old | 0.07 (0.04 to 0.10) | <0.001 | 0.03 (-0.01 to 0.07) | 0.120 | 0.03 (0.00 to 0.17) | 0.068 |
| 30 to 49 years old | 0.05 (0.03 to 0.07) | <0.001 | 0.02 (-0.01 to 0.05) | 0.283 | 0.02 (-0.01 to 0.44) | 0.214 |
| Educational level | | | | | | |
| No education or elementary | 0.04 (0.00 to 0.08) | 0.063 | 0.07 (0.02 to 0.12) | 0.006 | 0.07 (0.02 to 0.08) | 0.005 |
| High school | 0.03 (0.01 to 0.06) | 0.008 | 0.01 (-0.03 to 0.04) | 0.721 | 0.01 (-0.02 to 1.04) | 0.527 |
| University | 0.02 (0.00 to 0.05) | 0.099 | 0.01 (-0.03 to 0.05) | 0.519 | 0.01 (-0.03 to 1.01) | 0.510 |
| Natural region | | | | | | |
| Metropolitan Lima | 0.01 (-0.02 to 0.05) | 0.459 | 0.01 (-0.04 to 0.07) | 0.604 | 0.01 (-0.04 to 1.26) | 0.637 |
| Rest of the coast | 0.06 (0.03 to 0.09) | <0.001 | -0.01 (-0.06 to 0.04) | 0.65 | 0.00 (-0.05 to 1.78) | 0.909 |
| Highlands | 0.03 (0.00 to 0.06) | 0.051 | 0.03 (-0.01 to 0.07) | 0.107 | 0.03 (-0.01 to 0.38) | 0.180 |
| Jungle | 0.12 (0.09 to 0.16) | <0.001 | 0.10 (0.06 to 0.14) | <0.001 | 0.11 (0.07 to 0.11) | <0.001 |
| Area of residence | | | | | | |
| Urban | 0.05 (0.04 to 0.07) | <0.001 | 0.03 (0.00 to 0.06) | 0.068 | 0.03 (0.00 to 0.13) | 0.049 |
| Rural | 0.05 (0.02 to 0.07) | <0.001 | 0.03 (0.00 to 0.06) | 0.093 | 0.04 (0.01 to 0.08) | 0.022 |
| Ethnicity | | | | | | |
| Mestizo or white | 0.04 (0.02 to 0.06) | <0.001 | 0.02 (-0.02 to 0.06) | 0.179 | 0.03 (-0.01 to 0.07) | 0.118 |
| Quechua or Aimara | 0.01 (-0.01 to 0.03) | 0.338 | 0.00 (-0.04 to 0.04) | 0.891 | 0.00 (-0.04 to 0.04) | 0.918 |
| Afro-Peruvian | 0.05 (0.01 to 0.09) | 0.033 | 0.01 (-0.07 to 0.09) | 0.778 | 0.01 (-0.07 to 0.09) | 0.717 |
| Native or others | 0.24 (0.16 to 0.32) | <0.001 | 0.19 (0.09 to 0.29) | 0.001 | 0.17 (0.07 to 0.27) | 0.001 |
| Health insurance | | | | | | |
| No | 0.21 (0.13 to 0.29) | <0.001 | 0.15 (0.05 to 0.25) | 0.002 | 0.14 (0.04 to 0.24) | 0.118 |
| Yes | 0.05 (0.03 to 0.07) | <0.001 | 0.03 (0.01 to 0.05) | 0.039 | 0.03 (0.01 to 0.05) | 0.918 |

ECI: Erreygers concentration index; 95%CI: 95% Confidence interval

education to promote better understanding and commitment to vaccination, and child monitoring programs as effective strategies to reduce inequalities in vaccination coverage[36,37].

However, it is also important to mention that the study had some limitations because it was not possible to address mothers' perceptions about not vaccinating their children or the difficulties, they faced in seeking to complete the vaccination schedule. Furthermore, we cannot establish causality due to the lack of temporality inherent to the cross-sectional design; the possibility of recall bias or social desirability, as many of the data were self-reported by participants, which could have affected accuracy; only variables collected in the survey were included, which could have left out other relevant factors. There is also a possibility of interviewer bias influencing the collection of responses.

In conclusion, there were greater vaccination coverage inequalities for measles among children aged 12-59 months whose mothers reside in rural or non-metropolitan areas of Lima, have lower education levels, and lack health insurance. This underscores the critical necessity of targeted interventions to enhance vaccination coverage among vulnerable populations, especially in rural areas and among women with limited education. Improving the vaccination program is essential to mitigate the increased risk of measles outbreaks. Moreover, this presents an inequality analysis method that could be annually utilized to assess how various enhancements in the Peruvian vaccination program alleviate health disparities in children's vaccination.

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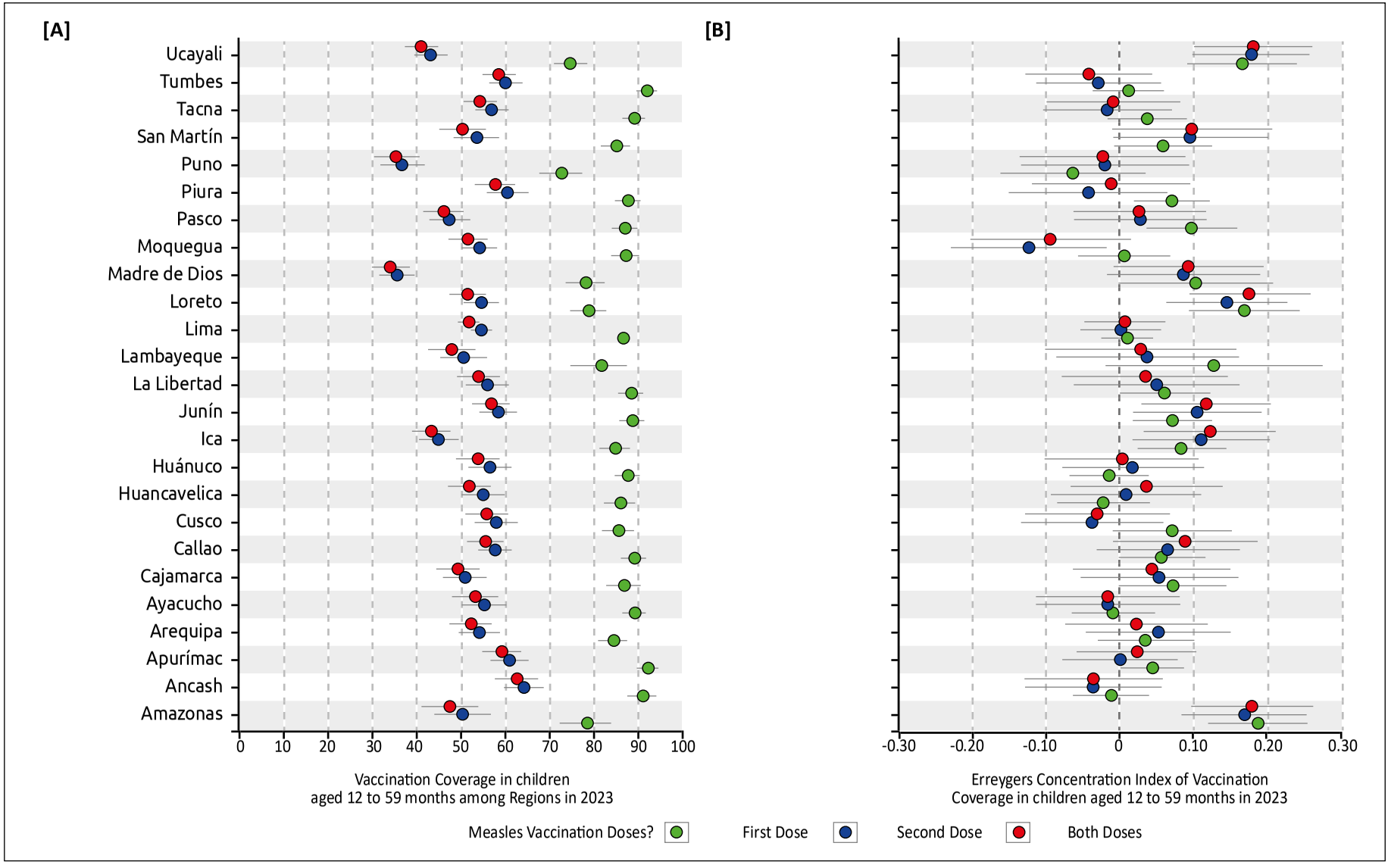


**Figure 2.** Regional distribution of inequality in compliance of doses against measles vaccination for Peruvian children in 2023. **[A]** Vaccination coverage in children aged 12 to 59 months among regions. **[B]** Erreygers concentration index of vaccination coverage in children aged 12 to 59 months.



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