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Socioeconomic inequalities and measles immunization coverage in Ecuador: A spatial analysis

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A B S T R A C T

Introduction/Background: Inequalities in measles immunization coverage facilitate the onset of outbreaks. This study aimed to quantify socioeconomic inequalities associated with measles immunization coverage at the population level.
Methods: An ecological study was performed using two datasets: the results of a measles immunization survey performed in Ecuador, in 2011, and socioeconomic data from the 2010 census, aggregated by canton. The survey included 3,140,799 people aged 6 months to 14 years living in 220 cantons of Ecuador. Vaccinated children were considered those who received at least one dose of vaccine against measles. Multiple spatial regression was performed to identify socioeconomic inequalities associated with measles immunization coverage. The slope index of inequality and the relative index of inequality were calculated.
Results: Vaccination coverage against measles was inversely associated with unsatisfied basic needs in urban areas ($P < 0.01$) and the proportions of indigenous and African-Ecuadorian residents in the canton ($P = 0.015$), and directly associated with unemployment rate in the canton ($P = 0.037$). The distribution of immunization coverage across the cantons was heterogeneous, indicating spatial dependence. The non-immunization rate was 71% higher in the poorer cantons than in the upper stratum cantons (prevalence ratio 1.71; 95%CI: 1.69–1.72). A difference of 10.6 percentage points was detected in immunization coverage between cantons with the best vs. worst socioeconomic level, according to the slope index of inequality. The relative index of inequality revealed that immunization coverage was 1.12 times higher in cantons with the highest socioeconomic level vs. cantons with the lowest socioeconomic level.
Conclusions: The spatial dependence between measles vaccination coverage and socioeconomic disparities suggests clusters of vulnerable populations for outbreaks. Health and social inequalities must be considered to achieve and maintain measles elimination.

1. Introduction

Immunization against measles resulted in a marked decline in childhood morbidity and mortality [1,2], with a significant reduction in the global mortality in children younger than five years old, in 2000–2010. It is estimated that during that during this period, immunization against measles prevented 9.6 million deaths [3].

However, immunization strategies have failed to reach *outskirts*' populations in developing countries [4]. In 2008, approximately 24 million children did not receive the first dose of measles vaccination in routine immunization programs [2], which represents one out of five children in the world [5].

Low immunization coverage in specific population groups [6–8], has aggravated the measles outbreaks in the past decade. Characteristics such as low family income [9], parental schooling, lack of access to the health care network, migration [8–12], and beliefs about vaccination risks have decreased measles vaccine coverage [13]. Therefore, outbreak prevention depends mainly on high vaccine coverage in the general population and particularly in poor pooled populations [14]. Effective immunization efforts also depend on the reduction of disparities in vaccine coverage [3], which seems to be associated with socioeconomic level and inequalities in health care access [6].

Among the recommended actions to eliminate measles, Ecuador, a country located in northwestern South America, introduced

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routine measles vaccination more than three decades ago. As a result, the last cases of autochthonous measles occurred in 1996. However, two cases were imported in 2001 and 2008, and a new measles outbreak emerged in 2011. Such outbreak was spread to nine out of the 24 provinces of Ecuador, and 329 cases were confirmed between June 2011 and July 2012; the B3 and D4 genotypes of measles were identified [15]. The highest incidence occurred in children in the first year of life and 98% of the cases had no prior history of vaccination against measles [15]. The cases of measles were concentrated in parishes, the smallest territorial unit, mainly urban, with high rate of children less than one-year-old, larger indigenous population, and lower rates of vaccination against measles and attendance to antenatal visits [16]. In addition to the low vaccine coverage found in the outbreak [16], other characteristics may have played a role and should be identified to detect vulnerable populations. Thus, we carried out a population-level analysis to identify indicators of socioeconomic inequality associated with variations in measles immunization coverage, as well as to quantify differences in immunization coverage among socioeconomic strata.

2. Materials and methods

2.1. Study design and population

An ecological study was performed using two datasets: results from a national immunization survey conducted in 2011–2012 during the measles outbreak in Ecuador with children aged 6 months to 14 years; and data from the 2010 demographic census. All data were aggregated by canton (second-level administrative-territorial subdivision). Of 224 cantons in Ecuador, 220 were analyzed. Two cantons were excluded in the Galapagos Islands and two in the province of Manabí, because no information was available for spatial analysis of these locations. Due to the nature of the data, the need for informed consent was waived.

2.2. Sources of data

The national immunization survey was performed as a result of the measles outbreak happening in Ecuador in 2011–12, with 329 confirmed cases until 2012 [15,16]. For the survey, health teams visited all Ecuador households in urban and rural census tracts, identifying measles cases and immunization status. Vaccines were also administered to non-immunized individuals. If nobody was at home, the team returned repeatedly until a family member could be contacted. Previous immunization status was confirmed by checking the immunization record card, or, if the card was not available, based on self-report. The health teams visited 3,152,835 households and identified 3,140,799 of the target children, which is, between 6 months and 14 years of age [17], corresponding to 76% of the target population [18]. There were 24% of households in which no information was obtained due to lack of inhabitants, despite the number of contact attempts made by the teams of interviewers. Information from this survey was aggregated by canton [17]. Data from immunization survey was made available by authorization of the Ministry of Health.

For the present study, socioeconomic information was obtained for each canton from the 2010 demographic census, performed by the Ecuador National Institute for Statistics and Censuses (INEC) [18]. Census data are publicly available in http://www.ecuadorencifras.gob.ec/base-de-datos-censo-2010/.

2.3. Study variables

- Previous measles immunization: the proportion of individuals aged 6 months to 14 years who had been vaccinated before the activities of 2011–12 outbreak intervention, in relation to the total canton inhabitants in the age range. Pre-outbreak immunization coverage was 84.3%. Considering the vaccines given during the survey, the final coverage reached 99.4%.
- Unsatisfied basic needs (UBN) of urban cantons according to the INEC: the proportion of households with at least one unsatisfied basic need in relation to the total canton households [19]. Five unsatisfied basic needs were considered: households made of unusual materials such as walls made of cardboard or non-varnished cane, dirt floor, among others; absence of sanitation; children 6–12 years old in the household not attending school; head of family with fewer than 3 years of schooling, or ratio of total number of family members to number of currently employed family members ≥ 3; and overcrowding (more than three people sharing one bedroom).
- Percentage of the population between 15 and 17 years old attending to high school in the canton.
- Percentage of the population self-identifying as indigenous or African-Ecuadorian in the canton, calculated by the sum of indigenous and African-Ecuadorian individuals divided by the total canton population.
- Employment rate of the economically active age group (15–60 years), calculated as the number of employed individuals in relation to the total population in the age group.

2.4. Data analysis

Descriptive analysis included means, standard deviation, median, maximum and minimum values. The spatial distribution of the variables across the cantons was represented as cartograms. The association between socioeconomic variables and measles immunization coverage was tested using Pearson's correlation and spatial multiple linear regression for verification of the model assumptions. Results from Pearson's correlation were compared with those of the Spearman's correlation; because we did not find differences in the value or direction of the correlations, we presented the results of the Pearson's correlation.

Spatial analysis employed adjacency matrices. The presence of spatial autocorrelation was detected by testing the results of multiple regression with the Moran I statistic, with significance established as $P < 0.05$. Because spatial autocorrelation was detected, conditional autoregressive (CAR) analysis (spatial error model) was performed for adjustment of variables using OpenGeoDa (Version 1.4.6, GeoDa Center, Tempe, AZ, USA). Goodness of fit of the model according to Akaike information criterion was considered. After that, local spatial correlation was tested to identify groups of cantons with significant differences in immunization coverage (high vs. low coverage).

The analysis of social inequalities in immunization coverage consisted of several steps. Firstly, principal components analysis was used to summarize socioeconomic variables (UBN, schooling, employment rate, and ethnicity) creating a unified socioeconomic score. This unified score was in turn used to generate an intermediate quantitative variable named ridit [20], which expresses the relative position of the canton with respect to socioeconomic level, considering the size of the population. After that, a slope index of inequality and a relative index of inequality were estimated [20,21]. The slope index of inequality expresses the absolute difference on immunization coverage between the canton with the highest socioeconomic score (the highest ridit) and the canton with the lowest socioeconomic score (the lowest ridit). The relative index of inequality was calculated as the quotient between these maximum and minimum values, indicating how many times the immunization rate in the canton with the highest socioeconomic level exceeded that of the lowest socioeconomic level, both measured by the ridit. The Epidat (Versão 4.1, http://www.sergas.es/