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Measles Vaccination Coverage in Northeastern States, India: Inequality and Spatial Distribution Perspective

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Abstract
Background: Measles is a highly contagious viral disease which remains a major cause of death among young children globally, despite the availability of a safe and effective vaccine. It is among the major cause of child death which can be prevented by a vaccine. Despite immunization interventions taken up by government and non-government organizations, NFHS-4 assessed measles vaccination coverage in northeastern states, India holds 68.3% coverage which is much lower than the 95% coverage level required for elimination. The region is physically isolated from the rest of the country due to mountain terrains, poor infrastructure and also inhabited by numerous tribal and ethnic groups with diverse socio-cultural practices, lack of awareness and education. This paper attempts to identify the socio-economic factors and to quantify their contributions in generating inequalities in measles vaccination coverage and explore the spatial pattern of measles vaccination coverage across different geographical areas of northeastern states.
Data and Methods: The data used in this study has been taken from the National Family Health Survey-4 (2015-2016). Binary logistic regression, log-binomial regression and concentration index decomposition techniques were used to quantify and explain the degrees of inequality. Exploratory Spatial Data Analysis (ESDA) techniques, Moran's-*I* and LISA, was applied to analyse the spatial patterns in vaccination coverage across the districts and identify those areas with statistically significant clustering of high and low values, as well as spatial outliers.
Results: The results of concentration index decomposition revealed that the inequality in measles vaccination coverage is highest among poorest classes of the society (50.8%). Religion (21.6%), mother's education (17.6%) and birth order (8.5%) were found to be important contributors to this inequality. Through spatial analysis, striking variation in measles vaccination coverage was observed among the northeastern states. The lowest percentage was observed in the East Kameng district of Arunachal Pradesh and the highest in South and North districts of Sikkim. The Moran's-*I* value (0.35) shows a non-significant positive spatial autocorrelation at the district level.
Conclusion: To improve the immunization coverage and to reduce the socio-economic inequalities in the northeastern states, focus must be channelled to the vulnerable sections of the society and regions where the actual reach of health programs are poor. The poor households need to be uplifted through income-generating programs and policies. Programs and policymakers should shift their concern from achieving 'average' lower vaccination coverage to 'distribution' of the schemes to needy sections of the society.

Keywords: child health, concentration index, decomposition, inequality, measles vaccination and northeastern states

Introduction

Children of today are the future of tomorrow. Ensuring their healthy growth and development has to be the priority for healthy development of societies. Children are the most vulnerable to malnutrition and infectious diseases, many of which are either preventable or treatable. The world made significant progress in reducing child mortality in the past few decades. Globally, the under-five mortality rate has dropped from 93 deaths per 1,000 live births in 1990 to 41 in 2016. An accelerated reduction in child mortality was witnessed during the period 2000–2016, as compared to the 1990's, globally. The annual rate of reduction in the under-five mortality rate had increased from 1.9 percent in 1990–2000 to 4.0 percent during the period 2000–2016 (UNICEF, 2017) [34]. According to WHO, nearly 5.6 million children died before their fifth birthday and among them 2.6 million (46 percent) died in their first month of life. It is admissible that 15,000 children die every day, mostly from preventable causes and treatable diseases, even though the knowledge and technologies for life-saving interventions are available (WHO, 2017) [44].

Measles is a highly contagious viral disease which remains a major cause of death and disability among young children globally, despite the availability of a safe, effective and affordable vaccine. It is among the major causes of death among children which can be prevented by a vaccine. An acceleration of the immunization activities has had a major impact on reducing deaths caused by measles. During 2000–2016, measles vaccination prevented an estimated 20.4 million deaths (SAGE, 2016) [29]. Measles can be transmitted through the droplets from the nose, mouth or throat of an infected person. It weakens the immune system and leads to secondary health issues, such as pneumonia, blindness, diarrhoea, and encephalitis. These debilitating effects are most visible in children under five and adults over twenty. Even if a child recovers from measles, s/he can be left with permanent disabilities. Measles is life-threatening in less developed and developing countries where children have limited or no access to medical treatment and are often malnourished. In India, MMR vaccine is given against measles, mumps and rubella. The first dose of vaccine is generally given to children within 9 to 15 months of age, with a second dose at 15 months to 6 years of age, with at least 4 weeks between the doses. After two doses, 97% of people are protected against measles. According to the World Health Organization, India reported 30168 measles cases during the year 2015. Despite the immunization interventions carried out by government and non-government organizations, NFHS-4 assessed measles vaccination coverage as 81.1% which is low compared to the 95% level of coverage required for elimination.

Even though the aggregate level of immunization coverage in India is increasing slowly, India's commitment to the attainment of full immunization with all available vaccines for children up to two years of age and pregnant women is still a question of doubt. Socio-economic inequalities are a major concern in India. Therefore, major economic and social concerns revolve around the vulnerable sections of the population. The socio-economic inequalities, which include gender inequality, rural-urban divide; rich-poor gap, social inequality, demographic and regional inequality, etc., seem to rather increase than decrease, with development. While efforts to reduce socio-economic disparities are in place, achievements are disproportionately low. Recently, there has been increasing interest in the socio-economic inequalities in health outcomes among researchers and policymakers (Mohanty and Pathak, 2009). Evidence has shown the pervasiveness of socio-economic inequalities in healthcare both between and within countries at any stage of development. There are various government programs and schemes to address the vaccination coverage in India, e.g. Mission Indradhanush aims to increase full immunization coverage in India, to at least 90% children, by December 2018. However, there is a need to examine these in terms of their outcomes to ensure greater focus on the child through improvements in existing schemes and suggest new holistic interventions.

The government has initiated several programs to improve the child health conditions in various parts of the country and yet the northeastern region has been far away in terms of progress in many of these programs. The northeastern states of India includes eight small states namely Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. The region is physically isolated from the rest of the country due to mountain terrains, poor infrastructure, being inhabited by numerous tribal and ethnic groups and also has diverse socio-cultural practices. The lack of basic amenities and diverse socio-cultural practices is directly or indirectly responsible for child health in northeast region which affects the coverage of immunization interventions in the region. This is predominately because of its geographical location and its cultural and religious behaviour which contributes significantly to the coverage of vaccinations among the children of northeastern states (Dinachandra *et al*., 2015) [4]. These indigenous people live mostly in rural areas and mountainous terrain with traditional thatched-roof huts without basic amenities. The geographical variations in child health can reveal, to an extent, inequities between and within states. In northeastern states, immunization coverage is very poor. (Kh. Jitenkumar Singh *et al*., 2017) [18]. The Measles vaccination coverage in northeasttern states is 68.3% which falls far behind the national average.

Some of the existing studies have examined the effects of socio-economic status on child health and mortality using cross-sectional data. Few of them have extended their findings to characterize levels of inequality using either rate ratios or more sophisticated measures of inequality (Doherty, E., Walsh, B. and O'Neill, C. 2014, Lauridsen, J., & Pradhan, J. 2011; Gwatkin *et al*. 2003) [5, 1, 11]. However, to the best of our knowledge, none of the studies have looked into the quantification of determinants of measles vaccination coverage in northeastern states of India. Measuring and explaining socio-economic inequalities in health and health care are critical for planning and implementation of health intervention strategies and achieve equity in health care. The aim of this study is to explore the current trends, determinants, and spatial pattern of measles vaccination coverage across different geographical areas (districts) in northeastern states, India. Also, to identify areas with statistically significant clustering of high values (hotspots) or low values (cold-spots), as well as spatial outliers. This study also attempts to identify certain socio-economic factors and to quantify their contributions in generating inequalities in measles vaccination coverage in northeastern states of India.

Methods and Data

The data used in this study has been taken from National Family Health Survey-4 (2015-2016). The National Family Health Survey (NFHS) is a large-scale, multi-round survey conducted on a representative sample of households throughout India and provide information on population, health and nutrition for India and each state and union territory. All four NFHS surveys have been conducted under the stewardship of the Ministry of Health and Family Welfare (MoHFW), Government of India. MoHFW designated the International Institute for Population Sciences (IIPS), Mumbai, as the nodal agency for all of the surveys.

The NFHS-4 sampling was done through a stratified two-stage sampling method. The 2011 census served as the sampling frame for the selection of PSUs. PSUs were villages in rural areas and Census Enumeration Blocks (CEBs) in urban areas. Within each rural stratum, villages were selected from the sampling frame with probability proportional to size (PPS). In each stratum, six approximately equal substrata were created by crossing three substrata, each created based on the estimated number of households in each village with two substrata, each created based on the percentage of the population belonging to scheduled castes and scheduled tribes (SCs/STs). Within each explicit sampling stratum, PSUs were sorted according to the literacy rate of women age 6+ years. The final sample PSU's were selected through the PPS sampling method. In urban areas, CEB information was obtained from the Office of the Registrar General and Census Commissioner, New Delhi. CEBs were sorted according to the percentage of the SC/ST population in each CEB, and sample CEBs were selected with PPS sampling. Selected PSUs with an estimated number of at least 300 households were segmented into segments of approximately 100-150 households. Two of the segments were randomly selected for the survey using systematic sampling with probability proportional to segment size. Therefore, an NFHS-4 cluster is either a PSU or a segment of a PSU. In the second stage, in every selected rural and urban cluster, 22 households were randomly selected with systematic sampling. Due to the non-proportional allocation of the sample to the different survey domains and to their urban and rural areas, sampling weights were used to ensure the actual representativeness of the survey results. Since the NFHS-4 sample is a two-stage stratified cluster sample, sampling weights were calculated based on sampling probabilities separately for each sampling stage and for each cluster (IIPS and ICF. 2017). A sample of 7254 children aged 12-23 months belonging to northeastern states were selected and after removing the missing observations a sample 7174 sample was used for analysis.

Variables Description

Outcome Variable

In NFHS-4 the information on vaccination coverage was collected from the child's health card and direct reporting from the mother. In this paper the uptake of measles vaccination is taken as the outcome variable. It is taken as a categorical variable, *i.e.,* 0 represents children who have not receive measles vaccination at any time of the survey and 1 represents children who have received measles vaccination.

Predictor Variables

Numerous studies have examined the determinants of immunization coverage in the Indian context. These studies suggest that paternal education (Rammohan, A *et al*. 2012; Ghosh, Arun 1991) [28, 9], social status, religion (Shrivastwa, N. *et al*. 2015) [31], birth order of the child (Patra, Nilanjan, 2006), place of residence (Pebley *et al*, 1996; Padhi, 2001) [27, 25] and economic status (Arokiasamy P, Pradhan J. 2011; Mathew, JL.2012) [1, 20] were important factors that influenced the immunization coverage. Researchers have noted that existing health inequities in India are related to a lack of attention to social determinants of health, including education, employment, and the failure of the health care system to deliver to those in need (Singh, PK *et al*. 2014) [32]. Based on this perspective, we have selected the predicator variables as sex of the child, birth order, place of residence, mother's education, religion, social status, sex of the household head, and wealth index for this study. The selected variables were further categorized. Birth order was classified into first order, second order, third order, four and above. Social groups were classified into Scheduled Castes (SCs), Scheduled Tribes (STs), Other Backward Classes (OBC), and others. Religion was classified as Hindu, Muslim, Christian, and others. Educational status of mother included no education, primary, secondary and higher education.

Wealth index was calculated based on the number and kinds of consumer goods each household owns, ranging from a television to a bicycle or car, and housing facilities such as source of drinking water, toilet facilities, and flooring materials. These scores are derived using the principal component analysis. National wealth quintiles were compiled by assigning the household score to each usual household member, ranking each person in the household population by their score and then dividing the distribution into five equal categories, each with 20 percent of the population (IIPS and ICF, 2017) [14].

Statistical Analysis

In the first stage of statistical analyses, socio-economic determinants of measles vaccination coverage among children of northeastern states were assessed. In the second stage, Odds Ratio [OR] and Prevalence Ratio [PR] with 95% CI were estimated by applying binary logistic regression and log-binomial regression. ORs and PRs [RRs] were estimated in multivariate models by including all independent variables. In the third stage, the concentration indices were estimated to measure the magnitude of inequality. And finally, the concentration indices were decomposed to explain the contribution of different socio-economic predicators to the total inequality in measles vaccination coverage. All our analyses were appropriately weighted. Decomposition of concentration index and other estimates were computed using STATA version 13 with DASP version 2.3 (Distributive Analysis Stata Package) and for spatial analysis, GeoDa version-1.12.1.59 software was used.

The prevalence ratio is defined as the prevalence exposed population divided by the prevalence in non-exposed, while odds ratio is the odds of disease or condition among exposed individuals divided by odds of the disease or condition among non-exposed. In this sense, in cross-sectional designs, where the dependent variable is dichotomous, we usually obtain the prevalence in the descriptive analysis and therefore, PR is more intuitive and easier to understand than OR. Traditionally, the logistic regression is used to estimate OR (Barros, A.J., & Hirakata, V.N. 2003) [2]. Although OR is a good estimator of PR when the prevalence is low, it is known that OR overestimates PR when the prevalence is moderate or high (e.g. prevalence rates above 10%) (Skolt, M., Nieto, F.J. 2014) [33].

Logistic regression is highly used in cross-sectional studies to estimate associations between variables. It is possible and easy to use other models in the analysis of cross-sectional data with binary dependent variables, which yield PR. One of the important advantages of these alternative methods is that PR, as a measure of association, is easier to interpret and communicate, especially to non-epidemiologists (Barros, A.J., & Hirakata, V.N. 2003) [2].

Logistic regression model and log-binomial model

In a logistic regression model, the function is written as:

$$Log\left(\frac{p}{1-p}\right) = Log\left(\frac{a}{b}\right) = \beta_0 + \beta_1 x_1 \; \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. + \; \beta_k x_k$$

where p is the probability of interested outcome and x is the explanatory variable and a/b is the odds of success and the OR estimated of a given covariate X_i is $e^{\beta i}$.

In a binomial regression model with k covariates, the function is written as:

$$Log\left[\frac{a}{a+b}\right] = \beta_0 + \beta_1 X_1 + \cdots \ldots\ldots\ldots\ldots\ldots.. + \beta_k X_k$$

where, a is the number of cases and b is the number of non-cases, and X_i the covariates. Thus, ($a/a+b$) is the probability of success, and the risk ratio (or prevalence ratio) estimated of a given covariate X_i is $e^{\beta i}$.

The new logistic function could be written as:

$$Log\left(\frac{a}{y}\right) = \beta_0 + \beta_1 x_1 \; \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. + \; \beta_k x_k$$

where, y includes non-cases as well as cases. Further, a logistic regression procedure was performed, the ORs obtained were considered direct estimations of RRs [PRs] because β_i defined the relationship between X_i and the Log [a/(y)], which in this model would be mathematically similar to Log [a/(a+b)] of the log-binomial model. For each outcome, a provisional database was prepared for analysis.

The log-binomial model is similar to the logistic regression in assuming that the outcome follows a binomial distribution.

However, in logistic regression, the link function is the logarithm of the odds, which is the ratio between cases and non-cases. While in binomial regression, the link function is the logarithm of the proportion, i.e., the ratio between cases and cases plus non-cases. Overestimations of OR with respect to PR for each variable were calculated, using the following formula: [Overestimation= (OR-PR)/ (OR-1)] (Brotman, 2006; Espelt *et al*., 2013; Shishehbor, Litaker, Lauer, 2006) [3, 6, 30]. The degree of overestimation depends on the prevalence of measles vaccination coverage among different socio-economic groups.

Concentration Index

Generally, concentration curves are used to identify the socio-economic inequality in health sector variables. However, a concentration curves does not give a measure of the magnitude of inequalities that can be used for comparison across different time periods, socio-economic groups, countries and regions. The concentration index (Kakwani 1977, 1980) [17, 18] measures the degree of socio-economic related inequality in a health variable (Wagstaff, van Doorslaer, and Paci 1989) [38]. It has been used to measure and to compare the degree of socio-economic-related inequality in child mortality (Wagstaff, 2000) [40], child immunization (Doherty, E., Walsh, B. and O'Neill, C. 2014; Lauridsen, J., & Pradhan, J. 2011; Gwatkin *et al*. 2003) [5, 1, 11], adult health (van Doorslaer *et al*. 1997) [17], child malnutrition (Wagstaff, van Doorslaer, and Watanabe 2003) [42], utilization of full antenatal care (Gupta A, Kumar P and Dorcas O. A. 2016) [10], health subsidies (O'Donnell *et al*. 2007) [24], and health care utilization (van Doorslaer *et al*. 2006) [26]. In this paper, the concentration index is used to measure the degree of socio-economic inequality in the utilization of measles vaccination coverage among the children of northeastern states.

The concentration index is defined as twice the area between the line of equality and the concentration curve. So, in the case in which there is no socio-economic related inequality, the concentration index is zero. The convention is that the index is negative when the curve lies above the line of equality, indicating disproportionate concentration of the measles vaccination coverage among the poor and is positive when it lies below the line of equality. A negative value of the concentration index means that low coverage is among the poor. The concentration index can be obtained by using the following formula:

$$C = \frac{2}{N\mu} \sum_{i=1}^{n} h_i r_i - 1 - \frac{1}{N} \qquad (1)$$

where, h_i denotes the health sector variable, μ is its mean and $r_i = 1/N$ is the fractional rank of individual in the economic status with $i = 1$ for the poorest and $i = N$ for the richest. For convenience in computation, the concentration index can be defined in terms of covariance between the health variable and the fractional rank in the economic status (Kakwani, Wagstaff, and Van Doorslaer, 1997; Van Doorslaer and Koolman, 2004) [17, 35].

$$C = \frac{2}{\mu} cov_w(h_i, r_i) \qquad (2)$$

where h_i and r_i are respectively the health status of the i^{th} individual and the fractional rank of the i^{th} individual regarding the index of economic status; μ is the mean of the health variable in the sample and cov_w denotes the covariance.

Decomposition of the concentration index

The concentration index gives the measure of socio-economic related inequality in health or health care. It can be further decomposed to estimate how determinants proportionally contribute to inequality in a health variable. The method proposed by Wagstaff, van Doorslaer, and Watanabe (2003) [42] is used in this paper to decompose the socio-economic inequality in measles vaccination coverage among the children of northeastern states of India. A decomposition method is usually preferred over regression models in studying socio-economic related inequality, as it gives estimates on the relative contribution of factors to inequality in health variable. For any linear additive regression model; the measles vaccination uptake variable Y_i, can be presented as

$$Y_i = \alpha + \sum_k \beta_k X_{ki} + \varepsilon_i \qquad (3)$$

where, β_k are coefficients and ε_i is the error term. We assume that everyone in the selected sample or subsample, irrespective of their socioeconomic charcteristics, faces the same coefficient vector β_k**.** Interpersonal variations in Y_i are thus assumed to derive from systematic variations across income groups in the determinants of y, i.e. X_{ki}. The equation of concentration index for Y_i, C, can be written as

$$C = \sum_k \left(\frac{\beta_k \overline{X}_k}{\mu}\right) C_k + \frac{GC_\varepsilon}{\mu} \qquad (4)$$

where, μ the mean of is Y_i, $\overline{X}_k$ is the mean of X_k, C_k is the concentration index forX_k. And In the last term $\frac{GC_\varepsilon}{\mu}$ (residual), GC_ε is the generalized concentration index for ε_i . Equation (4) has two components. The first is the deterministic or 'explained' component. This is equal to a weighted sum of the concentration indices of the regressors where the weights are the elasticities. Elasticity is defined as a unit-free measure of partial association, i.e. the percentage change in the health variable associated with a percentage change in the explanatory variable. $\frac{\beta_k \overline{X}_k}{\mu}$ of Y_i with respect to each X_k. The second is a residual, or 'unexplained', component. This reflects the inequality in health that cannot be explained by systematic variations in the X_k across different socio-economic groups. That is the unexplained component reflects the inequality in measles vaccination coverage across socio-economic groups which cannot be explained by the selected predicators.

Spatial Analysis

Spatial analysis is defined as the general ability to manipulate spatial data into different forms and extract additional meaning from the result. Specifically, the spatial analysis comprises a body of techniques requiring access to both the locations and the attributes of objects. Spatial statistics quantify geographic variation in geographic variables, and it can identify violations of assumptions of independence required by many epidemiological statistics; and measure how populations, their characteristics, covariates and risk factors vary in geographic space (Goodchild, M.F 1992) [8]. In the past decades, spatial analysis techniques have been widely used in infectious disease surveillance and outbreak investigation (Fosgate G, *et al*. 2002; Naish S, *et al*. 2018) [7, 23]. It is used to visualize epidemiological data, detect and evaluate hotspots or clusters to improve surveillance and introduce efficient vector control programmes.

Spatial Autocorrelation

Spatial autocorrelation measures the correlation of a variable with itself in space. Spatial autocorrelation analysis is applied to summarize the extent to which persons with a similar health status tend to occur next to each other i.e., form spatial clusters. Spatial autocorrelation can be positive or negative. Positive spatial autocorrelation occurs when similar values occur near one another (high or low values for a random variable tend to cluster in space). Negative spatial autocorrelation occurs when dissimilar values occur near one another (location tends to be surrounded by neighbours with very dissimilar values). We used a binary weight matrix to assign weights to the neighbours. This binary weight matrix assigns a weight of unity for neighbours and zero for non-neighbours. The spatial patterns were explored with global measures that allowed for spatial clustering tests. The present study has used exploratory spatial data analysis (ESDA) techniques to measure the spatial autocorrelation among districts that are spatially contiguous. The first measure used in this study is global Moran's *I*, which gives an indication of the overall spatial autocorrelation of a dataset. The second measure is a local indicator of spatial association (LISA) measure of local Moran's *I*, which indicates the "presence or absence of significant spatial clusters or outliers for each location" in a dataset. For ESDA, northeastern states shapefile were extracted from India shapefile after downloading through Diva GIS.

Results

The district-wise measles vaccination coverage (in percentage) among children age 12-23 months in northeastern states is depicted in *Figure-1*. The green colour stands for the highest percentage and red colour stand for the lowest percentage of measles vaccination coverage. The lowest percentage was observed in East Kmeng-17.45% (Arunachal Pradesh), Kurung Kumey-28.16% (Arunachal Pradesh) Mon-30.96% (Nagaland) Longleng-37.90% (Nagaland) Dhubri-38.46% (Assam) and the highest in North (100%) and south (100%) districts of Sikkim. The univariate LISA cluster map for district-wise measles vaccination coverage among children aged between 12-23 months is shown in *Figure-2*. It can be seen that measles vaccination coverage has high-high spatial association among one district of Sikkim and two districts of Assam. Whereas a low-low spatial association was observed in one district of Arunachal Pradesh and Nagaland. The measles vaccination coverage status, adjusted odds ratio adjusted prevalence ratio and over estimation of odds ratio by background characteristics among children aged 12-23 months at any time before the survey is given in *Table-1*. From the sample of 7174 children, 1564 belonged to urban areas and 5610 belonged to rural areas. There is almost an equal distribution of male and female children observed in the sample. From the given sample, it was inferred that 19.6% mothers never went to school, 17.2 percent had attained primary education, 56.6 percent had secondary education and 6.7 percent had attained higher levels of education. About 39.7 percent of the children had a birth order of 1, 29.7 percent of the children of 2, 15.5 percent of the children of 3 and 15.1 percent of the children had a birth order of four or higher. Around 11.9 percent of the children belonged to female-headed households and 88.2 percent of the children belonged to male-headed households. 8.9 percent of the children belonged to scheduled caste, 28.7 percent to the scheduled tribe, 18.7 percent belonged to OBC category and 43.7 percent from general and other categories. Within the sample, it was observed that 24.03 percent of the children belonged to the poorest families while 20.48 percent belonged to the middle-income families and 15.59 percent of the children belonged to the richest families. It was observed that the value was significant for all background characteristics except for sex of the child. The uptake of measles vaccination is slightly lower (69.5%) among female children as compared to that of male children (70.9%). On considering the place of residence, it was observed that the urban areas had a higher coverage of measles vaccination than rural areas. The percentage of children receiving measles vaccination in accordance with their birth order was negatively related i.e. the prevalence of measles vaccination is highest (76.1%) among children of birth order 1, 72.9% for children of birth order 2, 62.9% for children of birth order 3 and lowest 57.3% among children of birth order 4 or higher. The uptake percentage of measles vaccination increased with an increase in mother's education. The highest was among those children whose mothers had a higher education of 10 or more years (83.7 %) and lowest among the children whose mothers had never attended school (56.3 %). The measles vaccination coverage is higher (75.7%) among those children of female-headed households as compared to those male-headed households (69.5%). The uptake of measles vaccination according to social status is highest (80.4%) among children who belonged to Scheduled caste and lowest (67.0%) among children who belonged to Scheduled tribe. On observing religious affiliation, it was found that Hindus had the highest level of vaccination of 78.4% and lowest were observed among the Muslim children (61.1%). The measles vaccination coverage was found the lowest (57.9%) among the children of the poorest families and the percentage rises with an increase in family income i.e. 71.6% coverage among children belonging to middle-class families and 84.0% coverage among children belonging to richest families.

The binary logistic regression analysis of association between background characteristics and measles vaccination coverage indicate that the coverage of measles vaccination is respectively 1.71 times, 1.53 times and 1.36 times higher among children whose mothers have attained higher education (OR= 1.71, CI: [1.02, 2.87]), secondary education (OR= 1.53, CI: [1.19, 1.97]) and primary education (OR=1.36, CI: [1.04, 1.79]) as compared to the children of mothers without any education. In the northeastern region, female children has relatively lower odds (OR= 0.94, CI: [0.79, 1.11]) of getting a measles vaccination as compared to male children. Further, on observing the religious affiliation, it was found that Muslim children are 57 percent less likely to get measles vaccination as compared to Hindu children. The odd of measles vaccination is 1.23 times higher among children who belonged to female-headed households (OR= 1.23, CI: [0.92, 1.63]) as compared to those children who belong to male-headed households. On observing social status, it was inferred that scheduled tribe children are 44 percent and OBC children are 22 percent less likely to receive measles vaccination as compared to those children who belonged to other social classes. The probability of children receiving measles vaccination in accordance with the birth order was negatively related i.e. odds were 30 percent for children of birth order four and higher, 29 percent for children of birth order three, and 4 percent for children of birth order second, as compared to those children of birth order one. Children who belong to the richest and middle-class families are 2.14 times (OR= 2.14, CI: [1.24, 3.69]) and 1.76 times (OR= 1.76, CI: [1.32, 2.35]) more likely to receive measles vaccination as compared to the children of poorest families. The χ^2 value is significant for all background characteristics except for sex of the child.

The results of log binomial regression shows that measles vaccination prevalence is respectively 1.16 times, 1.32 times and 1.48 times higher among children whose mothers have attained higher education (OR= 1.16, CI: [1.05,1.29]), secondary education (OR= 1.32, CI: [1.21,1.45]) and primary education (OR= 1.48, CI: [1.33,1.65]) as compared to the children of mothers without any education. In the North Eastern region, female children has relatively lower prevalence (PR=0.97, CI: [0.89, 1.01]) of getting a measles vaccination as compared to male children. Further, on observing the religious affiliation, it was found that Muslim children are 19 percent less likely to get measles vaccination as compared to Hindu children. The prevalence of measles vaccination is 1.08 times higher among children who belonged to female-headed households (PR= 1.08, CI: [1.01, 1.16]) as compared to those children who belong to male-headed households. The probability of children receiving measles vaccination in accordance with the birth order was negatively related i.e. were 20 percent for children of birth order four and higher, 14 percent for children of birth order three, and 3 percent for children of birth order second less likely to receives as compared to those children of birth order one. Children who belong to the richest and middle-class families are 1.44 times (OR= 1.44, CI: [1.32, 1.55]) and 1.39 times (OR= 1.39, CI: [1.23, 1.45]) more likely to receive measles vaccination as compared to the children of poorest families. The overestimation of odds ratio was observed across all socio-economic groups in the study. The overestimation was found to be high in social status and comparatively low in birth order.

Table 1: Measles vaccination coverage status, adjusted odds ratio adjusted prevalence ratio and over estimation of odds ratio by background characteristics among children aged 12-23 months in North Eastern states, India, 2015-16

Background characteristics	Sample (%)	Received measles vaccination		χ^2, p-value	Adjusted Odds ratio	Adjusted Prevalence ratio	Over estimate@
		No (%)	Yes (%)				
Sex							
Male	3662 (51.8)	29.1	70.9	1.67	1.00	1.00	
Female	3512 (48.2)	30.5	69.5	p=0.419	0.94 [0.79, 1.11]	0.97[0. 89, 1.01]	50 %
Birth order							
First	2609 (39.7)	24.0	76.1	169.21	1.00	1.00	
Second	2038 (29.7)	27.1	72.9	p<0.001	0.96 [0.77, 1.19]	0.97 [0. 92, 1.01]	25 %
Third	1100 (15.5)	37.2	62.9		0.71 [0.55, 0.92]	0.86 [0.79, 0.94]	52 %
Fourth and more	1427 (15.1)	42.7	57.3		0.70 [0. 55, 0.90]	0. 80 [0. 74, 0. 87]	33 %
Residence							
Urban	1564 (14.8)	20.3	79.7	53.34	1.00	1.00	
Rural	5610 (85.2)	31.4	68.6	p<0.001	0.98 [0.74, 1.29]	0.99 [0.89, 1.07]	50 %
Mother's education							
No education	1276 (19.6)	43.7	56.3	225.06	1.00	1.00	
Primary	1230 (17.2)	34.4	65.6	p<0.001	1.36 [1.04, 1.79]	1.16 [1.05, 1.29]	56 %
Secondary	4158 (56.6)	25.2	74.9		1.53 [1.19, 1.97]	1.32 [1.21, 1.45]	40 %
Higher	510 (6.6)	16.3	83.7		1.71 [1.02, 2.87]	1.48 [1.33, 1.65]	32 %
Religion							
Hindu	2105 (46.4)	21.7	78.4	217.12	1.00	1.00	
Muslim	1014 (32.8)	38.9	61.1	p<0.001	0.43 [0.31, 0,59]	0.81 [0.76, 0.88]	67 %
Christian	3509 (18.2)	34.8	65.2		0.73 [0.56, 0.95]	0.87 [0.83,0.92]	52 %
Others	546 (2.6)	24.6	75.4		1.07 [0.76, 1.51]	1.01 [0.79, 1.47]	86 %
Caste/Tribe							
Scheduled caste	406 (8.9)	19.7	80.3	79.92	0.83 [0.61, 1.13]	1.06 [1.10, 1.12]	143 %
Scheduled tribe	4290 (28.7)	33.0	67.0	p<0.001	0.56 [0.40, 0.80]	0.99 [0.93, 1.06]	98 %
OBC	779 (18.7)	23.3	76.7		0.78 [0.56, 1.10]	1.03 [0.95, 1.13]	114 %
Others	1699 (43.7)	32.5	67.5		1.00	1.00	
Sex of household head							
Male	6306 (88.2)	30.5	69.5	13.78	1.00	1.00	
Female	868 (11.8)	24.3	75.7	p<0.05	1.23 [0.92,1.63]	1.08 [1.01,1.16]	65 %
Wealth index							
Poorest	1918 (24.0)	42.1	57.9	244.62	1.00	1.00	
Poorer	1586 (21.1)	34.3	65.7	p<0.001	1.35 [1.06,1.71]	1.13 [1.03, 1.23]	63 %
Middle	1421 (20.5)	28.4	71.6		1.76 [1.32, 2.35]	1.23 [1.12, 1.34]	70 %
Richer	1270 (18.8)	21.9	78.1		2.01 [1.38, 2.93]	1.39 [1.23, 1.45]	61 %
Richest	979 (15.6)	16.0	84.0		2.14 [1.24, 3.69]	1.44 [1.32, 1.55]	61 %
Total	7174(100.0)	29.8	70.2				

Note: @Overestimation of odds ratio with respect to prevalence ratio was calculated using the formula: [Overestimation = (OR-PR)/(OR-1)]

Table 2: Decomposition analysis of concentration index of measles vaccination coverage among children age 12-23 months in North Eastern states, India 2015-16

Background characteristics	Mean	Elasticity	concentration Index (CI)	Contribution to CI	Percentage contribution
Sex					
Male	0.5179	0.0000	0.0071	0.0000	0.07
Female	0.4821	-0.0070	-0.0076	0.0001	
Birth order					
First	0.3952	0.0445	0.1138	0.0051	8.50
Second	0.2975	0.0304	0.0428	0.0013	
Third	0.1556	0.0010	-0.0799	-0.0001	
Fourth and more	0.1516	0.0000	-0.2986	0.0000	
Residence					
Urban	0.1481	0.0068	0.5535	0.0037	5.05
Rural	0.8519	0.0000	-0.0962	0.0000	
Mother's education					
No education	0.1959	0.0000	-0.4531	0.0000	17.62
Primary	0.1727	0.0159	-0.2887	-0.0046	
Secondary	0.5648	0.0723	0.1586	0.0115	
Higher	0.0666	0.0084	0.7364	0.0062	
Religion					
Hindu	0.4641	0.1051	0.0929	0.0098	21.60
Muslim	0.3283	0.0000	-0.2086	0.0000	
Christian	0.1824	0.0426	0.1205	0.0051	
Others	0.0253	0.0081	0.1337	0.0011	
Caste/Tribe					
Scheduled caste	0.0892	0.0000	0.0759	0.0000	3.10
Scheduled tribe	0.2865	-0.032	0.0514	-0.0016	
OBC	0.1868	-0.0115	0.0646	-0.0007	
Others	0.4375	-0.0012	-0.0767	0.0001	
Sex of household head					
Male	0.8815	-0.0277	-0.0149	0.0004	0.56
Female	0.1185	0.0000	0.1106	0.0000	
Wealth index					
Poorest	0.2404	-0.0413	-0.7260	0.0300	50.82
Poorer	0.2119	-0.019	-0.2817	0.0053	
Middle	0.2039	-0.0105	0.0908	-0.001	
Richer	0.1877	0.0000	0.4627	0.0000	
Richest	0.1561	0.0039	0.8253	0.0032	
Residual				-0.06557	

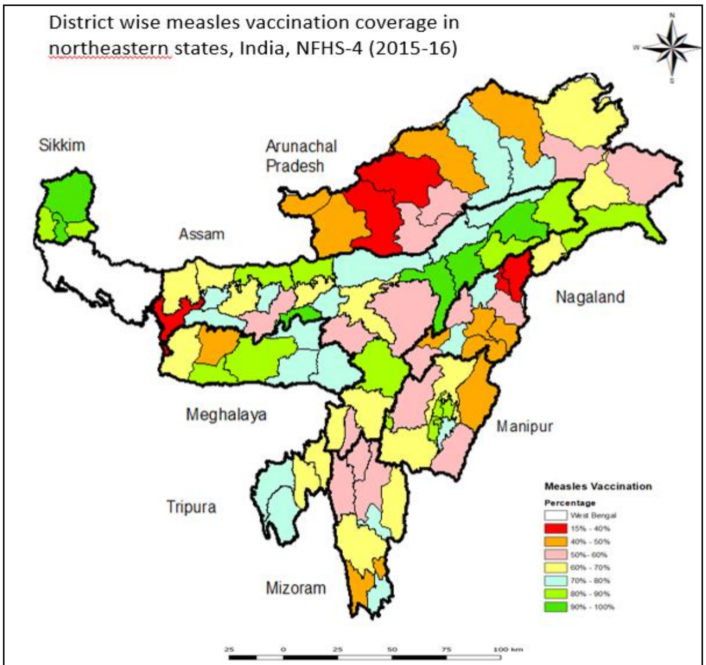

Figure:1

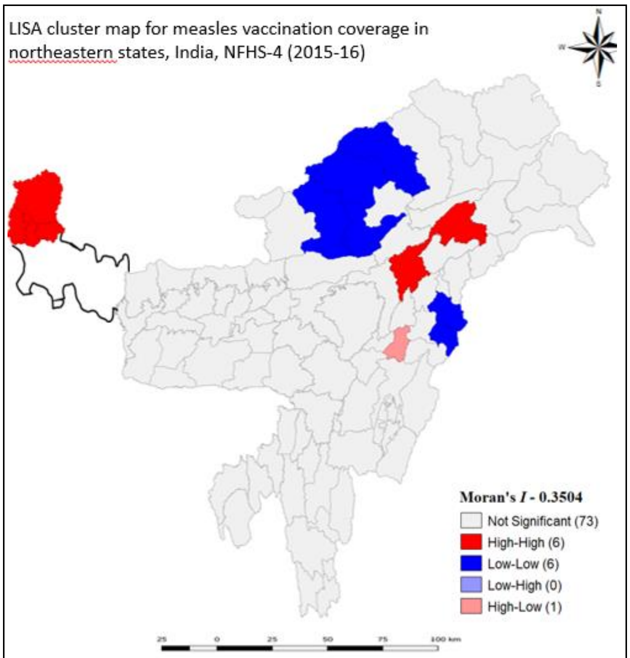

Figure:2

The results of decomposition analysis of concentration index for measles vaccination coverage among the north eastern states is presented in Table-2. The table depicts the coefficients of regressors, the concentration indices, absolute contribution as well as percentage contributions of explanatory variables. Decomposition analysis shows that the estimated value of relative contribution is negative for factors such as poorest wealth index (Concentration Index: -0.7260), Muslim religion (Concentration Index: -0.2086), residence in rural area (Concentration Index: -0.0962), mother's with no education (Concentration Index: -0.4531) and birth order 4+ (Concentration Index: -0.2986). Therefore, it is reflected that the weaker socio-economic groups in northeastern states are more disadvantaged in terms of immunization interventions. The decomposition analysis indicates that the inequality in measles vaccination coverage is highest among the poorest classes of the society (50.8%). Religion (21.6%), mother's education (17.6%) and birth order (8.5%) were inferred to make important contributions to inequality. The residual value (-0.065) depicts the portion of inequality in measles vaccination coverage which are not determined by the systematic variations among the chosen explanatory variables. Hence the analysis results suggest that inequality in measles vaccination coverage is more concentrated among the vulnerable sections of the society.

Discussion

Despite significant progress achieved in reducing child mortality through vaccination, India's commitment to the attainment of full immunization, with all available vaccines for children up to two years of age and pregnant women is still a question of doubt. Besides, there are concerns of socio-economic inequalities persistent in India and some of the major burdens are borne by the vulnerable sections of the society. The Rapid Survey on Children 2013-2014 conducted by UNICEF and the Ministry of Health and Family Welfare, GoI, India, reveals the deprived status of children in the Country. The SRS bulletin 2019 shows that northeastern states such as Assam, Arunachal Pradesh, and Meghalaya have infant mortality rates (IMR) higher than the national average of 33 deaths per 1000 live births.

It is quite evident that low socio-economic status is significantly associated with child immunization and other health care utilization but the inequalities caused by social and economic factors are poorly quantified. Therefore, this paper is an attempt to move in this direction to identify the socio-economic factors and to quantify their contributions in generating inequalities in measles vaccination coverage in northeastern states of India, which makes a solid contribution to the existing literature on health disparity determination in India. The results would help identify vulnerable populations and bridge the socio-economic gaps. Recent estimates on measles vaccination coverage improved in India where 81.1% of children received measles vaccination in 2015–2016 as against 58.8 % in 2005–06 (NFHS-4, NFHS-3). However, it is worth noting that the northeastern states are still far behind measles vaccination coverage even though there is a significant improvement during the last decade from 51.5% in 2005-06 to 68.3% in 2015-16.

The result from this paper suggests that wealth factor indirectly made the largest contribution to socio-economic inequality in measles vaccination coverage. Since measles vaccination is given to children free of cost through immunization interventions, the underlying factors such as accessibility, vaccine hesitancy and awareness through education play a vital role in accessing measles vaccination among weaker economic sections. The proportion of people sceptical of getting vaccinated is increasing tremendously because of anti-vaccine groups gaining traction in the political sphere. As a result, the confidence in vaccines is declining mainly in the weaker sections of the society. Factors such as religion, mother's education, birth order and place of residence proved further important contributions to inequality. These findings are consistent with other contemporary studies that have identified socio-economic and regional factors related to childhood Immunization (Doherty, E., Walsh, B. and O'Neill, C. 2014; Lauridsen, J., & Pradhan, J. 2011; Gwatkin *et al*. 2003) [5, 1, 11]. Therefore, it is reflected that weaker socio-economic groups in northeastern states are more disadvantaged in immunization interventions. The residual value (-0.065) depicts the portion of inequality in measles vaccination coverage which is not determined by the systematic variations among the chosen explanatory variables. Hence the result of analysis suggests that inequality in measles vaccination coverage is more concentrated among the vulnerable sections of the society.

The lowest percentage was observed in East Kmeng-17.45% (Arunachal Pradesh), Kurung Kumey-28.16% (Arunachal Pradesh) Mon-30.96% (Nagaland) Longleng-37.90% (Nagaland) Dhubri-38.46% (Assam) and the highest in North (100%) and south (100%) districts of Sikkim. The Moran's I value (0.3504) showed a non-significant positive spatial auto-correlation in measles vaccination coverage at the district level. The East Kmeng, Kurung Kumey, Papumpare, Upper Subanisiri districts of Arunachal Pradesh and Tuensang, Kiphire districts of Nagaland which showed a low-low spatial association requires special attention on measles vaccination interventions as these were identified as the poor performing districts in the region. The rugged mountain terrain of these districts makes transport and communication extremely difficult. There are few surface roads which remain cut off during monsoon seasons due to flood and landslide which makes them physically isolated from the rest of the country. These districts are mainly inhabited by numerous tribal and ethnic groups, hardly explored by outsiders. The lack of basic amenities and diverse socio-cultural practices is directly or indirectly responsible for less vaccination coverage. To improve vaccination coverage and to reduce the socio-economic inequalities in these districts, focus should be channelled on the development of infrastructure and health intervention strategies aiming at reducing poverty and illiteracy in particular.

There are social, economic, cultural and spatial impediments which restrain the immunization coverage. The results of our study depict that the children who reside in the urban area are more likely to receive measles vaccination compared to those children belong to rural areas. There are not much visible variations in vaccination coverage due to gender differentials. The measles vaccination coverage according to social status is highest among children who belonged to Scheduled caste and lowest among children who belong to Scheduled tribe. The vaccination percentage is proportional to mother's education i.e. the percentage is highest among the children whose mothers had the higher education of 10 or more years and lowest among the children whose mothers were illiterate. It is clearly visible that the place of residence also has an impact on measles vaccination coverage. The measles vaccination coverage is lowest among the children of poorest families and percentage rises with the increase in the family income. Socio-economic inequalities are the result of dispossession of some segments of population historically, politically, economically and socially. However, the tragic impact of these inequalities is denying certain sub-groups their right to be healthy.

Conclusion

Some of the existing studies have examined the effects of socio-economic status on child health or mortality using cross-sectional data. However, few of them have extended their findings to characterize levels of inequality, using either rate ratios or, especially, more sophisticated measures of inequality (Doherty, E., Walsh, B. and O'Neill, C. 2014, Lauridsen, J., & Pradhan, J. 2011; Gwatkin *et al*. 2003) [5, 1, 11]. However, to the best of our knowledge, none of the studies have looked into the quantification of determinants of measles vaccination coverage in northeastern states of India. In this context, this paper offers several insights to explain the dynamics behind the variation in vaccination coverage across various socio-economic groups using a decomposition method.

The findings inferred through this paper suggest that inequalities can be minimized by focusing on vulnerable sections of the society and regions where the effects of health programs hardly reach. The poor households need to be uplifted through income-generating programs and policies. Knowledge and awareness about the importance of childhood vaccination need to be disseminated among the vulnerable sections, and more work needs to be done to generate their interest in the government health programs. The public policies should be targeted and implemented well in deprived communities where the concentration of uneducated and poor is high. Also, there should be more focus on those areas which have clearly demonstrated the lower vaccination coverage. Targeting the health programs to the deprived sections and regions not only reduces inequalities but also helps the country to achieve full immunization with all available vaccines for children up to two years. Therefore, programs and policymakers should shift their concern from achieving 'average' lower vaccination coverage to 'distribution' of the schemes among the neediest groups. The findings of the paper are also relevant in other geographical locations of India such as Empowered Action Group (EAG) states (Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Orissa, Rajasthan, Uttarakhand and Uttar Pradesh) which constitute of a large number of vulnerable populations living in rural areas and are characterized by low level of health access. Finally, we recommend that future studies must use the decomposition analysis in the health sector so that policies and programs can be targeted on the root causes of inequalities. In short, we hope that our study results have done justice to shed some light on possible causes of inequalities in measles vaccination coverage in northeastern states of India.

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Ethics Statement

The study was performed using secondary data which is readily available on the public domain, so no ethical approval was required.

Author's Contributions

Kh. Jitenkumar Singh and Vinod Joseph K J designed the paper. JK, VJKJ, SG, SS and JY analyse the data and wrote the manuscript, Both the author's JK and VJKJ read and approved the final manuscript.

Competing Interest and Funding

The authors declare that they have no competing interests. Also, no funding was received by the authors to conduct the study. This study is a part of summer internship programme at ICMR-NIMS, New Delhi during June-July, 2018.

References

1. Arokiasamy P, Pradhan J. Measuring wealth-based health inequality among Indian children: the importance of equity vs efficiency. Health policy and planning. 2011; 26 (5):429-440.
2. Barros AJ, Hirakata VN. Alternatives for logistic regression in cross-sectional studies: an empirical comparison of models that directly estimate the prevalence ratio. BMC Medical Research Methodology. 2003; 3:21-21.
3. Brotman DJ. Mediators of the association between mortality risk and socioeconomic status. JAMA: The journal of the American Medical Association. 2006; 296:763–764.
4. Dinachandra Konsam, Alagarajan Manoj, Ladusingh Laishram. What Explains Child Malnutrition of Indigenous People of North Eastern India? PloS one. 2015; 10:0130567.
5. Doherty E, Walsh B, O'Neill C. Decomposing socio-economic inequality in child vaccination: Results from Ireland. Vaccine. 2014; 32(27):3438-3444.
6. Espelt A, Borrell C, Palència L, Goday A, Spadea T, Gnavi R *et al*. Socioeconomic inequalities in the incidence and prevalence of type 2 diabetes mellitus in Europe. Gaceta Sanitaria. 2013; 27:494-501.
7. Fosgate G, Carpenter T, Chomel B, Case J, DeBess E *et al*. Time-space clustering of human Brucellosis, California, 1973–1992. Emerg Infect Dis. 2002; 8:672-678.
8. Goodchild MF. Geographic data modelling. Computers and Geosciences. 1992: 18(4):401-408.
9. Ghosh Arun. Eighth Plan: Challenges and Opportunities—XII, Health, Maternity and Child Care: Key to Restraining population Growth', Economic and Political Weekly. 1991; 20:1017-22.
10. Gupta A, Kumar P, Dorcas OA. Decomposing the socio-economic inequalities in utilization of full antenatal care in Jharkhand State, India. International Journal of Population Studies. 2016; 2(2):92-106.
11. Gwatkin DR, S Rustein K, Johnson R, Pande, A Wagstaff. Initial Country-Level Information about Socio-Economic Differentials in Health, Nutrition and Population, Volumes I and II. Washington, DC: World Bank Health, Population and Nutrition, 2003.
12. International Institute for Population Sciences (IIPS) and Macro International. National Family Health Survey (NFHS-3), 2005–06: India: Volume I. Mumbai: IIPS, 2007.
13. International Institute for Population Sciences (IIPS) and

Macro International. National Family Health Survey (NFHS-3), 2005–06: India: Volume II. Mumbai: IIPS, 2007.
14. International Institute for Population Sciences (IIPS) and ICF. National Family Health Survey (NFHS-4), 2015-16: India. Mumbai: IIPS, 2017.
15. Kakwani NC. Measurement of Tax Progressivity: An International Comparison. Economic Journal. 1977; 87(345):71–80.
16. Kakwani NC. Income Inequality and Poverty: Methods of Estimation and Policy Applications. New York: Oxford University Press, 1980.
17. Kakwani N, Wagstaff A, Van Doorslaer E. Socio-economic inequalities in health: Measurement, computation and statistical inference, Journal of Econometrics. 1997; 77(1):87–103.
18. Kh. Jitenkumar Singh, Apoorva Nambiar, Damini Yadav, Swati Kadian, Amandeep Kaur, Kiran Saini *et al*. A Spatial Analysis of Child Health in North-East States, India: Evidence from National Family Health Survey. 4 (2015-16). Int. J. of Adv. Res, 2017, 5.
19. Lauridsen J, Pradhan J. Socio-economic inequality of immunization coverage in India. Health economics review. 2011; 1(1):11.
20. Mathew JL. Inequity in childhood immunization in India: a systematic review. Indian Pediatr. 2012; 49(3):203–223.
21. Ministry of women and child development. Rapid Survey on Children : The government of India. New Delhi, 2013-2014.
22. Morasae EK, Forouzan AS, Majdzadeh R, Asadi-Lari M, Noorbala AA, Hosseinpoor AR. Understanding determinants of socioeconomic inequality in mental health in Iran's capital, Tehran: A concentration index decomposition approach. International journal for equity in health. 2012; 11:18.
23. Naish S, Hu W, Mengersen K, Tong S. Spatio-temporal patterns of Barmah Forest virus disease in Queensland, Australia. PloS One. 2011; 6(10):25688.
24. O'Donnell O, Van Doorslaer E, Wagstaff A *et al*. Analyzing health equity using household survey data: A guide to techniques and their implementation, The International Bank for Reconstruction and Development. Washington DC: The World Bank, 2008.
25. Padhi, Sakti. 'Infant and Child Survival in Orissa: An Analysis with NFHS Data', Economic and Political Weekly. 2001; 25:3316-26.
26. Patra Nilanjan. Universal Immunization Programme in India: The Determinants of Childhood Immunization. 42nd Annual Conference of the Indian Econometric Society (TIES), GND Univ., Amritsar, India, 2006.
27. Pebley AR, Goldman N, Rodriguez G. Prenatal and Delivery Care and Childhood Immunization in Guatemala: Do Family and Community Matter, Demography. 1996; 33(2):231-47.
28. Rammohan A, Awofeso N, Fernandez RC. Paternal education status significantly influences infants' measles vaccination uptake, independent of maternal education status. BMC Public Health. 2012; 12(1):336.
29. SAGE. Midterm review of the global vaccine action plan-2016. New York, 2016.
30. Shishehbor MH, Litaker D, Lauer MS. Mediators of the association between mortality risk and socioeconomic status - Reply. JAMA: The Journal of the American Medical Association. 2006; 296:764–764.
31. Shrivastwa N, Gillespie BW, Kolenic GE, Lepkowski JM, Boulton ML. Predictors of Vaccination in India for Children Aged 12-36 Months. Vaccine. 2015; 33(4):99-105.
32. Singh PK, Kumar C, Rai RK, Singh L. Factors associated with maternal healthcare services utilization in nine high focus states in India: a multilevel analysis based on 14 385 communities in 292 districts. Health Policy Plan. 2014; 29(5):542–559.
33. Szklo M, Nieto FJ. Epidemiology: beyond the basics. 2nd ed. Burlington, Jones & Bartlett Learning, 2014.
34. UNICEF. Levels and Trends in Child Mortality Report-United Nations Children's Fund: New York, 2017.
35. Van Doorslaer E, Koolman X. Explaining the differences in income-related health inequalities across European countries, Health Economics. 2004; 13(7):609–28.
36. Van Doorslaer E, C Masseria, X Koolman. And the OECD Health Equity Research Group. Inequalities in Access to Medical Care by Income in Developed Countries. Canadian Medical Association Journal. 2006; 174:177–83.
37. Wacholder S. Binomial regression in GLIM: estimating risk ratios and risk differences. American Journal of Epidemiology. 1986: 123:174-184.
38. Wagstaff A, E van Doorslaer, P Paci. Equity in the Finance and Delivery of Health Care: Some Tentative Cross-Country Comparisons. Oxford Review of Economic Policy. 1989; 5(1):89-112.
39. Wagstaff A, Paci P, Van Doorslaer E. On the measurement of inequalities in health, Social Science and Medicine, 33(5):545–557.
40. Wagstaff A. Socio-economic Inequalities in Child Mortality: Comparisons across Nine Developing Countries. Bulletin of the World Health Organization. 2000; 78(1):19–29.
41. Wagstaff A, Van Doorslaer E, Watanabe Naoko. On Decomposing the Causes of Health Sector Inequalities with an Application to Malnutrition Inequalities in Vietnam. Policy Research Working Paper; No. 2714. World Bank, Washington, DC, 2001
42. Wagstaff AE, van Doorslaer, N Watanabe. On Decomposing the Causes of Health Sector Inequalities, with an Application to Malnutrition Inequalities in Vietnam. Journal of Econometrics. 2003; 112(1):219–27.
43. Wagstaff A, N Watanabe. What Difference Does the Choice of SES Make in Health Inequality Measurement? Health Economics. 2003; 12(10):885-90.
44. WHO. Global Health Observatory (GHO) data-2017. World Health Organization: Geneva, 2017.