

Socioeconomic inequalities in child vaccination in low/middle-income countries: what accounts for the differences?

Mohammad Hajizadeh

► Additional material is published online only. To view please visit the journal online (<http://dx.doi.org/10.1136/jech-2017-210296>).

School of Health Administration, Faculty of Health, Dalhousie University, Halifax, Nova Scotia, Canada

Correspondence to

Dr Mohammad Hajizadeh, School of Health Administration, Faculty of Health, Dalhousie University, Halifax, NS B3H 4R2, Canada; m.hajizadeh@dal.ca

Received 28 November 2017
Revised 14 March 2018
Accepted 15 March 2018
Published Online First
26 March 2018

ABSTRACT

Background Socioeconomic inequalities in child vaccination continue to be a global public health concern. This study aimed to measure and identify factors associated with socioeconomic inequalities in full immunisation coverage against the four core vaccine-preventable diseases (ie, bacille Calmette-Guérin, diphtheria-tetanus-pertussis (three doses), polio (three doses) and measles vaccines) in 46 low/middle-income countries.

Methods The most recent nationally representative samples of children (aged 10–59 months, n=372 499) collected through the Demographic Health Surveys were used to measure vaccination rates. The concentration index (C) was used to quantify socioeconomic inequalities in vaccination coverage. Furthermore, meta-regression analyses were used to determine factors affecting socioeconomic inequalities in vaccination coverage across countries.

Results Results suggested that immunisation coverage was pro-rich in most countries (median C=0.161, IQR 0.131). Gambia (C=−0.146, 95% CI −0.223 to −0.069), Namibia (C=−0.093, 95% CI −0.145 to −0.041) and Kyrgyz Republic (C=−0.227, 95% CI −0.304 to −0.15) were the only countries where children who belong to higher socioeconomic status group were less likely to receive all the four core vaccines than their lower socioeconomic status counterparts. Meta-regression analyses suggested that, across countries, the concentration of antenatal care visits among wealthier mothers was positively associated with the concentration of vaccination coverage among wealthier children (coefficient=0.606, 95% CI 0.301 to 0.911).

Conclusions Pro-rich distribution of child vaccination in most low/middle-income countries remains an important public health policy concern. Policies aimed to improve antenatal care visits among mothers in lower socioeconomic groups may mitigate socioeconomic inequalities in vaccination coverage in low/middle-income countries.

INTRODUCTION

In spite of the remarkable global improvement in routine vaccination coverage worldwide, the overall improvement is not equally distributed among the countries.¹ Furthermore, a growing body of evidence suggests that there exists a social gradient in child vaccination within countries. For example, children whose parents are well-educated, wealthy or living in urban areas have a higher probability to be immunised against vaccine-preventable

diseases.^{2,3} Social inequalities in vaccination uptake can potentially hinder the global efforts to reduce the burden of disease in low/middle-income countries because children from socioeconomically disadvantaged backgrounds are generally at increased risk of contracting infectious diseases.⁴

Incomplete or complete lack of vaccination remains the cause of millions of preventable child deaths each year in low/middle-income countries; there is, therefore, a considerable amount of literature devoted to factors that impact vaccination uptake. Although several studies (eg, refs 5–9) suggest that socioeconomic inequalities are still a major barrier to child immunisation in low/middle-income countries, few studies (eg, ref 10) aimed to quantify socioeconomic inequalities in vaccination coverage using a summary measure of inequality such as the concentration index. Measuring and monitoring of socioeconomic-related inequalities in child vaccination in low/middle-income countries play a major role in evaluating progress towards the targets made by national and international programmes to improve child vaccination coverage. Identifying factors that explain the concentration of incomplete child vaccination among lower socioeconomic status (SES) children can also provide valuable information to introduce effective strategies and policies to address such inequalities.

Using the most recent nationally representative samples of children collected through the Demographic Health Surveys (DHS) and the concentration index approach (which accounts for inequality across the whole socioeconomic distribution), this study aimed to measure socioeconomic inequalities in full immunisation coverage against the four core vaccine-preventable diseases (ie, bacille Calmette-Guérin (BCG), diphtheria-tetanus-pertussis (DTP, three doses), polio (three doses) and measles vaccines, see online supplementary table 1) in 46 low/middle-income countries. Additionally, meta-regression analyses were performed to examine whether inequalities in proximate determinants of child vaccination were associated with the extent of socioeconomic inequality in vaccination across countries.

METHODS

Data

The data for this study were obtained from the Standard DHS from 46 low/middle-income countries collected through the MEASURE DHS project over the period between 2010 and 2015. The DHS



To cite: Hajizadeh M. *J Epidemiol Community Health* 2018;**72**:719–725.

Research report

surveys are nationally representative cross-sectional household surveys with large sample sizes, typically between 5000 and 30 000 households.¹¹ Using a multistage sampling procedure,¹² the DHS collects reliable and comparable information on a variety of health-related topics¹³ such as vaccination status of children in the household. High response rates and national coverage are key advantages of the DHS.¹⁴ To facilitate comparability of surveys across time and countries a similar set of questions is used.¹³ Data collection methods, validation and reliability assessment are described elsewhere.¹³ Immunisation records of children aged 59 months and younger were drawn from the DHS surveys. To allow each child a follow-up period to receive all the four routinely recommended core vaccines: BCG, DTP (three doses), polio (three doses) and measles vaccines (10 months as per the WHO¹⁵ recommended immunisation schedules for the four routine vaccines, see online supplementary table 1), 82 694 live births that occurred less than 10 months before the survey interview were excluded from the analysis. The final sample contained 372 499 live births aged 10–59 months in 46 low/middle-income countries between 2010 and 2015. Online supplementary table 2 presents the survey years, sample size and gross national income (GNI) per capita (current US\$) for the sampled countries.

Measures

The outcome variable in this study is binary variable indicating whether a child received all the four routinely recommended core vaccines. Immunisation status of children was collected using vaccination record cards provided by mothers or caregivers during the survey interview. In the absence of vaccination cards, mothers' or caregiver's verbal reports of children's immunisation coverage were used. Maternal reports may suffer from recall bias; however, previous studies (eg, ref 16) showed that maternal recall reports are valid when we compare child vaccination coverage across populations. Socioeconomic inequalities in vaccination coverage among children were measured using a constructed wealth index (WI) for each household in the DHS surveys as a measure of child SES. Using a principal components analysis (PCA) technique the DHS uses information on selected household's assets to construct the WI.¹⁷ Based on the extant literature (eg, refs 5–6), the effects of inequalities in income and other proximate determinants of vaccination uptake (which have been consistently collected in all DHS surveys) on socioeconomic inequalities in vaccination coverage were assessed. This included socioeconomic inequalities in mother's education, mother's age 19 and below, higher number of children under 5 in the household (3 and above) and antenatal care (ANC) coverage (a minimum of four prenatal care visits), and income inequality as measured by Gini index. As the DHS does not collect information on expenditure or income, the World Bank's World Development Indicators and Global Development Finance data set¹⁸ was used to obtain Gini index for each country in the study.

Statistical analysis

The statistical analysis involved two steps: (1) calculating socioeconomic inequalities in vaccination coverage and (2) performing meta-regression analyses to determine factors affecting socioeconomic inequalities in vaccination coverage.

Measuring socioeconomic inequalities

Socioeconomic inequality in vaccination coverage in each country was measured using the (relative) concentration (C) index. The C index is measured regarding the (relative) concentration curve,

which plots the cumulative share of vaccination coverage, on its y-axis, against the cumulative share of the children, ranked in ascending order of SES (WI), on its x-axis. If all children, ranked by WI, received an equal proportion of vaccination coverage, the curve would coincide with the 45° line (ie, the line of 'perfect equality'). The C index is described as twice the area between the 45° line and the concentration curve. The C index ranges from –1 to +1, with zero representing 'perfect equality'.¹⁹ If a health variable is concentrated among the rich, multiplying the C index by 75 will give us the fraction of health variable that needs to be transferred from the wealthier half to the poorer half to achieve 'perfect equality'.²⁰

The C index can be computed using the 'convenient regression' approach as follows²¹:

$$2\sigma_r^2 \left(\frac{y_i}{\mu} \right) = \alpha + \beta r_i + \varepsilon_i, \quad (1)$$

where y_i is child i 's vaccination coverage status, μ is the mean of vaccination coverage for the total sample, $r_i = i/n$ is the fractional rank of child i in the distribution ($i = 1$ and n for the poorest and wealthiest child, correspondingly), and σ_r^2 indicates the variance of fractional rank. The ordinary least squares (OLS) estimate of β represents the C index and its SE provides the SE for the C index.²² As the outcome variable in this study is binary, the C index was normalised²³ to summarise wealth-related inequalities in vaccination coverage by multiplying by $1/1 - \mu$. To obtain estimates that are representative of children (aged 10–59 months) living in each country sampling weights were applied in the calculation of the C index. 95% CIs were used to assess statistical significance of the C index. A method suggested by Altman and Bland²⁴ was used to examine the significance of differences in the C at 95% CI.

Meta-regression analyses

Univariate and multivariate meta-regression analyses were performed to assess the determinants of socioeconomic inequalities in vaccination coverage. The C index in vaccination coverage for each country was used as the dependent variable and socioeconomic inequalities in proximate determinants of vaccination uptake (measured by the C index) and income inequality (measured by the Gini index) were used as explanatory variables. The number of covariates in the model satisfies the 'rule of thumb' of having at least 5–10 observations per predictor in multivariable regression analysis.²⁵ The random effects models were used in the meta-regression analyses. This is because fixed effects meta-regression assumes that the covariates included in the model can explain all the heterogeneity in the outcome variable and thus is not often recommended.²⁶ The inverse variances of the C index for vaccination coverage were used as weights in all univariate and multivariate meta-regression analyses. All analyses were performed in V.13 of the STATA software package (StataCorp, College Station, Texas).

RESULTS

Child vaccination coverage

Online supplementary table 3 and figure 1 present the percentage of children (aged 10–59 months) who received all the four core vaccines in 46 low/middle-income countries. Overall, 55.5% of children in the sampled countries were immunised against the diseases. There was a significant difference across the countries in the vaccination uptake; for example, in Nepal, Honduras and Armenia more than 85% of children received all the four vaccines, whereas this figure was less than 35% in Mali, Nigeria and Ethiopia. As reported in online supplementary table 3, up to

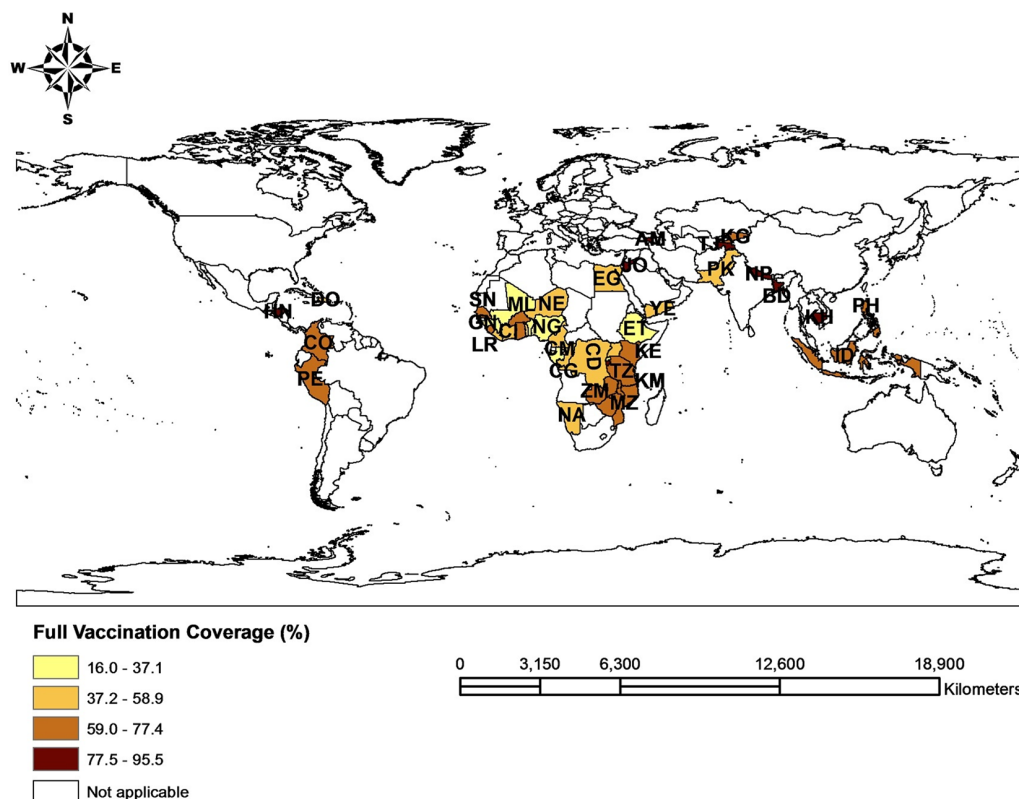


Figure 1 Child vaccination coverage (%) against the four core vaccine-preventable diseases in 46 low/middle-income countries.

58.3% of children in low-income countries completed immunisation for the four main diseases; these figures were 52.9% and 68% in the sampled lower middle-income and upper middle-income countries, respectively.

As reported in online supplementary table 3, the vaccination rates were generally similar for males and females in all countries, except Gambia, Tanzania, Honduras and Gabon, where vaccination uptakes were slightly higher among men compared with women. The results also indicated that child vaccination was higher in urban areas compared with rural areas in most countries. The vaccination rates were significantly higher in rural than urban areas in Gambia, Namibia, Kyrgyz Republic, Malawi and Honduras.

Socioeconomic inequalities in child vaccination coverage

Table 1 reports the magnitude of socioeconomic inequalities in immunisation coverage in 46 low/middle-income countries. The results suggested that immunisation coverage is pro-rich in the majority of countries (median $C=0.161$, IQR 0.131). Gambia ($C=-0.146$, 95% CI -0.223 to -0.069), Namibia ($C=-0.093$, 95% CI -0.145 to -0.041) and Kyrgyz Republic ($C=-0.227$, 95% CI -0.304 to -0.15) were the only countries where children who belong to higher SES were less immunised compared with lower SES counterparts. As shown in figure 2, socioeconomic inequalities in vaccination coverage were higher in countries such as Nigeria, Pakistan, Yemen, Cambodia, Cameroon and Indonesia compared with the other countries. The results did not suggest any association between socioeconomic inequalities in immunisation coverage and (log) GNI per capita ($r(44)=-0.020$, $p=0.89$).

The C index indicated persistent pro-rich inequalities in vaccination coverage in urban (median $C=0.154$, IQR 0.141) and rural areas (median $C=0.163$, IQR 0.171) in most of the

sampled countries. Peru and Togo were the two countries with the pro-poor distribution of child immunisation in rural areas. While in countries such as Nigeria, Pakistan, Gabon and Jordan socioeconomic inequalities were significantly higher in rural compared with urban areas, in countries such as Ethiopia, Togo, Peru and Nepal socioeconomic inequalities in vaccination uptake were greater in urban compared with rural areas.

Factors affecting socioeconomic inequalities in child vaccination coverage

Table 2 reports the meta-regression analysis results. According to the univariate meta-regression results, the concentration of mother's educational level (coefficient=0.361, 95% CI 0.091 to 0.63) and ANC coverage (coefficient=0.505, 95% CI 0.248 to 0.762) among wealthier children was positively associated with socioeconomic inequalities in vaccination coverage. In multivariate analysis, only the concentration of ANC use among wealthier women was associated with socioeconomic inequalities in vaccination coverage; a 10% increase in the magnitude of the C index for ANC use was associated with a 6% increase in the value of the C index for vaccination coverage. Figure 3 demonstrates bubble plots of the correlations between the C index for mother's ANC use and the C index for vaccination coverage.

DISCUSSION AND CONCLUSIONS

This study, similar to previous studies in low/middle-income countries (eg, refs 5–8), found pro-rich inequalities in immunisation rate in most countries under study. Gambia, Namibia and Kyrgyz Republic were the only countries where children who belong to higher SES households were less likely to be fully immunised against the four diseases than their lower SES counterparts. Lower vaccination coverage among higher

Table 1 Socioeconomic inequalities in child vaccination coverage in 46 low/middle-income countries

		The Concentration index			
Country	Code	Total	Urban	Rural	Urban-rural
Low-income countries (LIC)					
Bangladesh	BD	0.248 (0.179 to 0.318)	0.209 (0.118 to 0.3)	0.262 (0.185 to 0.34)	−0.054 (−0.174 to 0.066)
Benin	BJ	0.091 (0.052 to 0.131)	0.082 (0.021 to 0.144)	0.08 (0.033 to 0.126)	0.003 (−0.075 to 0.08)
Burkina Faso	BF	0.134 (0.084 to 0.184)	0.05 (−0.032 to 0.132)	0.149 (0.097 to 0.201)	−0.099 (−0.196 to −0.001)
Burundi	BI	0.031 (−0.02 to 0.083)	0.048 (−0.173 to 0.269)	0.027 (−0.027 to 0.081)	0.021 (−0.206 to 0.248)
Cambodia	KH	0.296 (0.236 to 0.357)	0.304 (0.163 to 0.444)	0.264 (0.198 to 0.33)	0.04 (−0.115 to 0.195)
Comoros	KM	0.232 (0.158 to 0.306)	0.111 (−0.013 to 0.236)	0.28 (0.195 to 0.365)	−0.169 (−0.319 to −0.018)
Congo Democratic Republic	CD	0.19 (0.147 to 0.234)	0.238 (0.172 to 0.304)	0.153 (0.1 to 0.205)	0.085 (0.001 to 0.169)
Ethiopia	ET	0.22 (0.159 to 0.281)	0.41 (0.316 to 0.505)	0.115 (0.053 to 0.178)	0.295 (0.181 to 0.408)
Gambia	GM	−0.146 (−0.223 to −0.069)	−0.071 (−0.166 to 0.024)	0.087 (0.021 to 0.153)	−0.158 (−0.273 to −0.043)
Guinea	GN	0.122 (0.063 to 0.181)	0.041 (−0.055 to 0.137)	0.104 (0.047 to 0.161)	−0.063 (−0.175 to 0.049)
Haiti	HT	0.046 (−0.008 to 0.099)	0.069 (−0.003 to 0.14)	0.076 (0.009 to 0.142)	−0.007 (−0.105 to 0.091)
Liberia	LR	0.191 (0.126 to 0.256)	0.127 (0.045 to 0.209)	0.21 (0.156 to 0.263)	−0.082 (−0.18 to 0.015)
Malawi	MW	0.029 (−0.011 to 0.068)	−0.004 (−0.088 to 0.081)	0.086 (0.051 to 0.121)	−0.09 (−0.182 to 0.001)
Mali	ML	0.129 (0.076 to 0.181)	0.039 (−0.032 to 0.109)	0.112 (0.049 to 0.174)	−0.073 (−0.168 to 0.021)
Mozambique	MZ	0.197 (0.147 to 0.246)	0.018 (−0.077 to 0.113)	0.197 (0.145 to 0.25)	−0.179 (−0.288 to −0.071)
Nepal	NP	0.227 (0.116 to 0.338)	0.359 (0.221 to 0.498)	0.219 (0.094 to 0.343)	0.141 (−0.046 to 0.327)
Niger	NE	0.253 (0.217 to 0.288)	0.094 (0.021 to 0.168)	0.212 (0.174 to 0.25)	−0.117 (−0.2 to −0.034)
Rwanda	RW	0.167 (0.103 to 0.23)	0.147 (−0.036 to 0.331)	0.107 (0.042 to 0.172)	0.041 (−0.154 to 0.235)
Sierra Leone	SL	0.167 (0.103 to 0.23)	0.147 (−0.036 to 0.331)	0.107 (0.042 to 0.172)	0.041 (−0.154 to 0.235)
Tajikistan	TJ	0.167 (0.103 to 0.23)	0.147 (−0.036 to 0.331)	0.107 (0.042 to 0.172)	0.041 (−0.154 to 0.235)
Tanzania	TZ	0.167 (0.103 to 0.23)	0.147 (−0.036 to 0.331)	0.107 (0.042 to 0.172)	0.041 (−0.154 to 0.235)
Togo	TG	0.023 (−0.037 to 0.082)	0.156 (0.082 to 0.23)	−0.07 (−0.132 to −0.008)	0.226 (0.129 to 0.323)
Uganda	UG	0.066 (0.02 to 0.112)	0.031 (−0.072 to 0.134)	0.034 (−0.016 to 0.083)	−0.003 (−0.117 to 0.112)
Zimbabwe	ZW	0.171 (0.116 to 0.226)	0.134 (0.05 to 0.218)	0.15 (0.088 to 0.212)	−0.016 (−0.12 to 0.088)
Lower middle-income countries (IMIC)					
Armenia	AM	−0.017 (−0.144 to 0.11)	−0.009 (−0.171 to 0.153)	−0.129 (−0.288 to 0.031)	0.12 (−0.108 to 0.347)
Cameroon	CM	0.273 (0.217 to 0.329)	0.156 (0.096 to 0.216)	0.26 (0.188 to 0.331)	−0.103 (−0.197 to −0.01)
Congo Brazzaville	CG	0.146 (0.088 to 0.204)	0.036 (−0.045 to 0.118)	0.147 (0.081 to 0.213)	−0.111 (−0.215 to −0.006)
Cote d'Ivoire	CI	0.154 (0.094 to 0.214)	0.158 (0.076 to 0.24)	0.038 (−0.031 to 0.107)	0.12 (0.012 to 0.227)
Egypt	EG	0.096 (0.03 to 0.163)	0.079 (0.001 to 0.156)	0.218 (0.084 to 0.351)	−0.139 (−0.293 to 0.015)
Ghana	GH	0.122 (0.063 to 0.181)	0.041 (−0.055 to 0.137)	0.104 (0.047 to 0.161)	−0.063 (−0.175 to 0.049)
Honduras	HN	−0.026 (−0.08 to 0.027)	0.078 (−0.011 to 0.166)	0.013 (−0.06 to 0.085)	0.065 (−0.05 to 0.18)
Indonesia	ID	0.263 (0.23 to 0.296)	0.182 (0.135 to 0.229)	0.282 (0.238 to 0.325)	−0.1 (−0.163 to −0.036)
Kenya	KE	0.191 (0.126 to 0.256)	0.127 (0.045 to 0.209)	0.21 (0.156 to 0.263)	−0.082 (−0.18 to 0.015)
Kyrgyz Republic	KG	−0.227 (−0.304 to −0.15)	−0.239 (−0.357 to −0.121)	−0.167 (−0.264 to −0.07)	−0.072 (−0.225 to 0.081)
Nigeria	NG	0.547 (0.517 to 0.577)	0.295 (0.244 to 0.346)	0.564 (0.507 to 0.62)	−0.269 (−0.345 to −0.193)
Pakistan	PK	0.384 (0.326 to 0.442)	0.207 (0.127 to 0.288)	0.431 (0.368 to 0.494)	−0.223 (−0.326 to −0.121)
Philippines	PH	0.167 (0.103 to 0.23)	0.147 (−0.036 to 0.331)	0.107 (0.042 to 0.172)	0.041 (−0.154 to 0.235)
Senegal	SN	0.167 (0.103 to 0.23)	0.147 (−0.036 to 0.331)	0.107 (0.042 to 0.172)	0.041 (−0.154 to 0.235)
Yemen	YE	0.34 (0.299 to 0.381)	0.192 (0.126 to 0.259)	0.245 (0.19 to 0.3)	−0.053 (−0.14 to 0.033)
Zambia	ZM	0.15 (0.113 to 0.187)	0.175 (0.112 to 0.237)	0.088 (0.048 to 0.128)	0.087 (0.013 to 0.161)
Upper middle-income countries (uMIC)					
Colombia	CO	0.036 (0.005 to 0.067)	0.015 (−0.021 to 0.052)	0.12 (0.069 to 0.172)	−0.105 (−0.168 to −0.042)
Dominican Republic	DO	0.096 (0.03 to 0.163)	0.079 (0.001 to 0.156)	0.218 (0.084 to 0.351)	−0.139 (−0.293 to 0.015)
Gabon	GA	0.024 (−0.049 to 0.097)	0.009 (−0.074 to 0.092)	0.215 (0.08 to 0.35)	−0.206 (−0.364 to −0.047)
Jordan	JO	0.148 (−0.023 to 0.32)	0.097 (−0.115 to 0.308)	0.3 (0.098 to 0.502)	−0.204 (−0.496 to 0.089)
Namibia	NA	−0.093 (−0.145 to −0.041)	−0.029 (−0.102 to 0.044)	0.033 (−0.03 to 0.096)	−0.062 (−0.159 to 0.035)
Peru	PE	−0.009 (−0.053 to 0.035)	0.021 (−0.028 to 0.07)	−0.121 (−0.209 to −0.034)	0.142 (0.042 to 0.243)
Median (IQR)		0.161 (0.131; 0.066 to 0.197)	0.154 (0.141; 0.056 to 0.197)	0.163 (0.171; 0.027 to 0.198)	0.004 (0.049; −0.023 to 0.026)

95% CIs in parentheses.

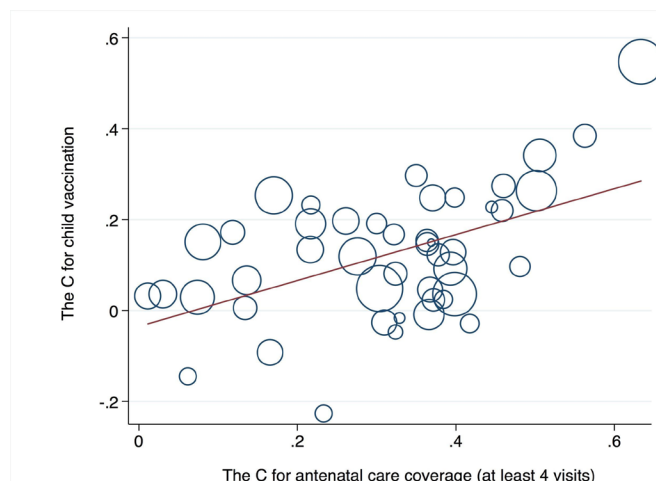


Figure 3 Bubble plot of the association between the C indices for child vaccination and antenatal care coverage (at least four visits). The size of the bubbles in the figure is proportional to the weight of each observation in the meta-regression analysis.

education on inequality in child vaccination uptake can be explained through human, social, cultural and empowerment routes. The human capital advantage of maternal education in higher compared with lower SES households can lead to greater receptivity to public health messages aimed at boosting child immunisation rates among higher SES household because highly educated mothers have a greater understanding about the benefits of immunisation.³⁰ Educated mothers also have larger social networks (social capital) which provide good health behaviour-related information and where to find available healthcare services. The social capital of well-educated mothers can result in higher concentration of immunisation rates among children from wealthier households. Moreover, well-educated mothers generally have socially valued general skills that provide them with a higher social status. This cultural capital can result in better communications between mothers and medical providers and thus enables wealthier households to use more healthcare such as immunisation services.³¹ Higher educational attainment (as a means for empowering women) among wealthier mothers also assists them to play an active role in public and in their households which enables them to

Explanatory variables	The C for child vaccination				
	Univariate meta-regression			Multivariate meta-regression	
	Coefficient	P values	Adjusted R ² (%)	Coefficient	P values
Gini index	−0.299 (−0.778 to 0.18)	0.215	1.64	0.153 (−0.326 to 0.631)	0.523
The C for mother's educational level (year)	0.361 (0.091 to 0.63)	0.01	12.95	0.19 (−0.074 to 0.453)	0.154
The C for mother's age at birth—less than 19	0.078 (−0.377 to 0.534)	0.731	−1.52	0.231 (−0.194 to 0.656)	0.279
The C for number of children (less than 5 years old) 3 and above	0.129 (−0.306 to 0.564)	0.553	−2.21	0.3 (−0.157 to 0.757)	0.192
The C for antenatal care coverage (at least four visits)	0.505 (0.248 to 0.762)	0.000	26.06	0.606 (0.301 to 0.911)	0.000
Adjusted R ² (%)				33.72	
n	46				

Hajjzadeh M. *J Epidemiol Community Health* 2018;**72**:719–725. doi:10.1136/jech-2017-210296

Research report

insist on better healthcare (eg, vaccination coverage) for their newborn babies.³²

Results of both univariate and multivariate meta-regression analyses suggested that, across countries, the concentration of ANC among wealthier mothers was statistically significantly positively associated with the concentration of vaccination coverage among wealthier children. Previous studies (eg, refs 33–34) have documented the positive impact of ANC visits on child vaccination coverage. The positive impacts of pro-rich inequalities in ANC visits on the concentration of child vaccination coverage can be attributed to the fact that higher compared with lower SES mothers have more opportunities to receive messages about the benefits of child vaccination that encourage them to use vaccination services for their newborns because they use more ANC services. ANC visits establish communication and build trust between healthcare providers and mothers, which, in turn, may affect mothers' immunisation-seeking behaviours.³⁵ By increasing the interaction between health personnel and mother, ANC care visits can address some of the reasons behind low rate of vaccine uptake, including lack of information about immunisation benefits, fear of side effects and unfamiliarity with place and time of immunisation.³⁶

Methodological overviews of measuring and monitoring inequalities in health recommend reporting both absolute and relative measures to ensure appropriate tracking of health inequalities.³⁷ Thus, a modified absolute (generalised) concentration (AC) index³⁸ was used to compute and identify key determinants of absolute socioeconomic inequalities in

vaccination coverage across the sampled countries. More information about the AC index can be found elsewhere.^{38–39} The results were qualitatively very similar to those obtained using the C index to measure socioeconomic inequalities (see online supplementary tables 4 and 5 and supplementary figures 1 and 2). The results of multivariate meta-regression analysis using the AC index suggested that, across countries, the concentration of ANC and educational attainment among wealthier mothers was statistically significantly positively associated with the concentration of vaccination coverage among wealthier children. Furthermore, similar to the results obtained from multivariate meta-regression analysis using the C index, the concentration of the presence of three or more siblings (aged <5 years) in the household among the poor households had a positive effect on absolute socioeconomic inequality in immunisation coverage. This latter result can be explained by the fact that the concentration of larger numbers of children in poor households encompasses a greater competing demand for mothers' limited time and resources resulting in lower rates of immunisation among the poor children.⁴⁰

This study is subject to some limitations. First, similar to other studies using DHS data sets to determine factors associated with child vaccination,⁶ maternal recall was used to identify the child's vaccination status in the absence of vaccination record card. Although the validity of relying on maternal recall to obtain child's vaccination status has been confirmed,¹⁶ it would be ideal to use a written record to obtain this information to avoid potential recall bias. Second, as the DHS collects vaccination coverage of still living children at the time of the survey interview, this study indicates socioeconomic inequalities in vaccination coverage among children who were alive at the time of the survey. Third, this study examined socioeconomic inequalities in child vaccination at the national level. Since there may be different associations between factors at the subnational level in different countries, the generalisability of the findings should not be extended to population groups within the country. Finally, this study focused only on wealth-related inequalities in child vaccination coverage and did not examine other social inequalities in vaccination coverage (eg, race/ethnic-related inequalities) that may be present in the sampled countries.

Caveat considered, this study suggested that pro-rich distribution of child vaccination in most low/middle-income countries remains an important public health policy concern and policies aimed to improve ANC among mothers in lower socioeconomic groups may mitigate socioeconomic inequalities in vaccination coverage in low/middle-income countries.

Acknowledgements MH gratefully acknowledges MEASURE DHS for their permission to use the Demographic Health Surveys (DHS) data. MH thanks two anonymous reviewers and the associate editor for their helpful comments and suggestions. MH also acknowledges the comments from participants in the Canadian Immunization Research Network and the Canadian Center for Vaccinology (CIRN/CCFV) Education Series at Dalhousie University.

Contributors MH is the single author of the paper.

Funding The author has not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent Detail has been removed from this case description/these case descriptions to ensure anonymity. The editors and reviewers have seen the detailed information available and are satisfied that the information backs up the case the authors are making.

Ethics approval This study was not subject to ethical approval because it did not involve data concerned with human participants. The study used secondary data

What is already known on this subject

- There have been several international initiatives set out to improve child immunisation rates in low/middle-income countries over the last four decades. These initiatives led to a significant increase in child vaccination coverage globally, which, in turn, reduced child mortality and morbidity due to infectious diseases in several countries. Despite the remarkable global improvement in child vaccination coverage, the improvement is not equally distributed among the countries. There is also a growing body of evidence suggesting socioeconomic inequalities in child vaccination within low/middle-income countries.

What this study adds

- Although the current studies indicated socioeconomic gradients in child vaccination in low/middle-income countries, few studies have summarised the magnitude of socioeconomic inequalities across countries. There are even fewer studies that have examined the determinants of socioeconomic inequalities in child vaccination across countries. This study provides a comprehensive analysis of socioeconomic inequalities in vaccination coverage in 46 low/middle-income countries. The results suggested that pro-rich distribution of child vaccination in most low/middle-income countries remains an important public health policy concern. Policies aimed at improving antenatal care among mothers in lower socioeconomic groups may mitigate socioeconomic inequalities in child vaccination in low/middle-income countries.

from Demographic Health Surveys (DHS, <http://www.dhsprogram.com/>). The DHS surveys are fully available upon request without restriction.

Provenance and peer review Not commissioned; externally peer reviewed.

© Article author(s) (or their employer(s) unless otherwise stated in the text of the article) 2018. All rights reserved. No commercial use is permitted unless otherwise expressly granted.

REFERENCES

- World Bank. *Health nutrition and population statistics*. Washington, DC, 2018. <https://datacatalog.worldbank.org/dataset/health-nutrition-and-population-statistics>. (accessed 16 Feb 2018).
- Glatman-Freedman A, Nichols K. The effect of social determinants on immunization programs. *Hum Vaccin Immunother* 2012;8:293–301.
- Berkley S, Chan M, Elias C, et al. *Global vaccine action plan 2011–2020*: World Health Organization, Decades of Vaccines Collaboration, 2012.
- World Bank Working Group on Child Poverty. *Better health for poor children: a special report*. Geneva, Switzerland, 2002.
- Shrivastwa N, Gillespie BW, Kolenic GE, et al. Predictors of Vaccination in India for Children Aged 12–36 Months. *Am J Prev Med* 2015;49:S435–44.
- Bondy JN, Thind A, Koval JJ, et al. Identifying the determinants of childhood immunization in the Philippines. *Vaccine* 2009;27:169–75.
- Zere E, Kirigia JM, Duale S, et al. Inequities in maternal and child health outcomes and interventions in Ghana. *BMC Public Health* 2012;12:252.
- Branco FL, Pereira TM, Delfino BM, et al. Socioeconomic inequalities are still a barrier to full child vaccine coverage in the Brazilian Amazon: a cross-sectional study in Assis Brasil, Acre, Brazil. *Int J Equity Health* 2014;13:118.
- Arsenault C, Harper S, Nandi A, et al. Monitoring equity in vaccination coverage: a systematic analysis of demographic and health surveys from 45 Gavi-supported countries. *Vaccine* 2017;35:951–9.
- Lauridsen J, Pradhan J. Socio-economic inequality of immunization coverage in India. *Health Econ Rev* 2011;1:11.
- The DHS Program. DHS Overview. 2016 <http://dhsprogram.com/What-We-Do/Survey-Types/DHS.cfm> (accessed 17 Jan 2016).
- Demographic and Health Survey. *Sampling manual. DHS-III*. Calverton, 1996.
- Rutstein SO, Rojas G. *Guide to DHS Statistics: Demographic and Health Surveys Methodology*. Calverton, NY: U.S. Agency for International Development: ORC Macro, 2006.
- Corsi DJ, Neuman M, Finlay JE, et al. Demographic and health surveys: a profile. *Int J Epidemiol* 2012;41:1602–13.
- World Health Organization. WHO recommendations for routine immunization - summary tables. 2016. http://www.who.int/immunization/policy/immunization_routine_table2.pdf?ua=1 (accessed 8 Sep 2016).
- AbdelSalam HHM, Sokal MM. Accuracy of Parental Reporting of Immunization. *Clin Pediatr* 2004;43:83–5.
- Rutstein SO, Johnson K. The DHS wealth index. DHS Comparative Reports No. 6. ORC Macro, MEASURE DHS 2004.
- World Bank. *World development indicators database and global development finance*. Washington DC, 2016. <http://databank.worldbank.org/data/home.aspx>. (accessed 5 Jul 2016).
- World Bank. *Quantitative techniques for health equity analysis: concentration curve*: World Bank, 2017.
- Koolman X, van Doorslaer E. On the interpretation of a concentration index of inequality. *Health Econ* 2004;13:649–56.
- Kakwani N, Wagstaff A, van Doorslaer E. Socioeconomic inequalities in health: measurement, computation, and statistical inference. *J Econom* 1997;77:87–103.
- O'Donnell O, van Doorslaer E, Wagstaff A, et al. *Analyzing health equity using household survey data - a guide to techniques and their implementation*. Geneva: The World Bank, 2008.
- Wagstaff A. The bounds of the concentration index when the variable of interest is binary, with an application to immunization inequality. *Health Econ* 2005;14:429–32.
- Altman DG, Bland JM. Interaction revisited: the difference between two estimates. *BMJ* 2003;326:219.
- Muller KE, Regression FBA. and ANOVA: an integrated approach using SAS software. *SAS Institute* 2002.
- Thompson SG, Sharp SJ. Explaining heterogeneity in meta-analysis: a comparison of methods. *Stat Med* 1999;18:2693–708.
- Barata RB, Ribeiro MC, de Moraes JC, et al. Socioeconomic inequalities and vaccination coverage: results of an immunisation coverage survey in 27 Brazilian capitals, 2007–2008. *J Epidemiol Community Health* 2012;66:934–41.
- Bardenheier B, Yusuf H, Schwartz B, et al. Are parental vaccine safety concerns associated with receipt of measles-mumps-rubella, diphtheria and tetanus toxoids with acellular pertussis, or hepatitis B vaccines by children? *Arch Pediatr Adolesc Med* 2004;158:569–75.
- Matsumura T, Nakayama T, Okamoto S, et al. Measles vaccine coverage and factors related to uncompleted vaccination among 18-month-old and 36-month-old children in Kyoto, Japan. *BMC Public Health* 2005;5:59.
- Glewwe P. Why does mother's schooling raise child health in developing countries? Evidence from Morocco. *J Hum Resour* 1999;34:124–59.
- Gittelsohn J, Bentley ME, Peltz PJ. *Listening to women talk about their health - Issues and evidences from India*. New Delhi: South Asia Books, 1994.
- Vikram K, Vanneman R, Desai S. Linkages between maternal education and childhood immunization in India. *Soc Sci Med* 2012;75:331–9.
- Konstantyner T, Taddei JA, Rodrigues LC. Risk factors for incomplete vaccination in children less than 18 months of age attending the nurseries of day-care centres in Sao Paulo, Brazil. *Vaccine* 2011;29:9298–302.
- Mohamud AN, Feleke A, Worku W, et al. Immunization coverage of 12–23 months old children and associated factors in Jijiga District, Somali National Regional State, Ethiopia. *BMC Public Health* 2014;14:865.
- Rowe R, Calnan M. Trust relations in health care—the new agenda. *Eur J Public Health* 2006;16:4–6.
- Dixit P, Dwivedi LK, Ram F. Strategies to improve child immunization via antenatal care visits in India: a propensity score matching analysis. *PLoS One* 2013;8:e66175.
- King NB, Harper S, Young ME. Use of relative and absolute effect measures in reporting health inequalities: structured review. *BMJ* 2012;345:e5774.
- Erreygers G. Correcting the concentration index. *J Health Econ* 2009;28:504–15.
- O'Donnell O, O'Neill S, Van Ourti T, et al. conindex: Estimation of concentration indices. *Stata J* 2016;16:112.
- Danis K, Georgakopoulou T, Stavrou T, et al. Socioeconomic factors play a more important role in childhood vaccination coverage than parental perceptions: a cross-sectional study in Greece. *Vaccine* 2010;28:1861–9.