

Forecasted trends in vaccination coverage and correlations with socioeconomic factors: a global time-series analysis over 30 years



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Summary

Background Incomplete immunisation coverage causes preventable illness and death in both developing and developed countries. Identification of factors that might modulate coverage could inform effective immunisation programmes and policies. We constructed a performance indicator that could quantitatively approximate measures of the susceptibility of immunisation programmes to coverage losses, with an aim to identify correlations between trends in vaccine coverage and socioeconomic factors.

Methods We undertook a data-driven time-series analysis to examine trends in coverage of diphtheria, tetanus, and pertussis (DTP) vaccination across 190 countries over the past 30 years. We grouped countries into six world regions according to WHO classifications. We used Gaussian process regression to forecast future coverage rates and provide a vaccine performance index: a summary measure of the strength of immunisation coverage in a country.

Findings Overall vaccine coverage increased in all six world regions between 1980 and 2010, with variation in volatility and trends. Our vaccine performance index identified that 53 countries had more than a 50% chance of missing the Global Vaccine Action Plan (GVAP) target of 90% worldwide coverage with three doses of DTP (DTP3) by 2015. These countries were mostly in sub-Saharan Africa and south Asia, but Austria and Ukraine also featured. Factors associated with DTP3 immunisation coverage varied by world region: personal income (Spearman's $\rho=0.66$, $p=0.0011$) and government health spending (0.66 , $p<0.0001$) were informative of immunisation coverage in the Eastern Mediterranean between 1980 and 2010, whereas primary school completion was informative of coverage in Africa (0.56 , $p<0.0001$) over the same period. The proportion of births attended by skilled health staff correlated significantly with immunisation coverage across many world regions.

Interpretation Our vaccine performance index highlighted countries at risk of failing to achieve the GVAP target of 90% coverage by 2015, and could aid policy makers' assessments of the strength and resilience of immunisation programmes. Weakening correlations with socioeconomic factors show a need to tackle vaccine confidence, whereas strengthening correlations point to clear factors to address.

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Introduction

Rates of vaccine-preventable diseases have decreased in many parts of the world in the past few decades, but many children remain unvaccinated. In 2013, UNICEF reported that 21.8 million children younger than 1 year had not completed the diphtheria, tetanus, and pertussis (DTP) immunisation series, with a similar number not receiving a single measles vaccination.¹ Although access to vaccinations is the main barrier in many settings, growing numbers of parents do not immunise their children based on their own personal attitudes.^{2,3}

Both socioeconomic and attitudinal barriers to vaccination coverage have been identified in several countries. A set of recurring socioeconomic and demographic correlates of coverage have been reported, with parental education level,⁴⁻⁸ age,^{6,9,10} employment status and workplace,^{4,6,7} religion,¹¹ ethnic origin,¹² gender of the child,¹³ poverty,¹⁴⁻¹⁸ and distance to health-care facilities^{4,6,11,14,17,18} all linked to

vaccine uptake, although marked differences often exist between countries.¹¹ Repeating themes have likewise been identified in examination of personal reasons for vaccine acceptance or delay, which range from perceived risks about potential adverse events, to religious or political beliefs that are external to, albeit influential in, vaccination.^{9,19-27} Trust in health-care professionals^{19,20,23,24} and the government^{19,23,26} also features highly.

Recommendations to address gaps in vaccine coverage are context dependent. Targeting of mothers with low education,²⁸ low health literacy,²⁹ and dissemination of more information to communicate vaccine benefits and risks transparently² have been suggested to aid in improvement of vaccine hesitancy, as has the customisation of messages and engagement efforts for specific groups.³⁰ Efficient identification of clusters of non-vaccinators through monitoring of local immunisation rates has been identified as a key public

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Research in context

Evidence before this study

We searched Google Scholar between Jan 1, 1980, and Jan 1, 2016, for studies assessing socioeconomic correlates of vaccine coverage. Our search terms included the words “socio-economic”, “demographic”, “correlates”, and “vaccine coverage”, with variations in each individual term allowed. For example, “vaccine” could be with “vaccination” or “immunise” with “immunisation”, in addition to specific names of vaccine-preventable diseases such as “DTP” and “MMR”; alternative spellings, such as “immunize”, were also allowed. For attitudinal correlates of vaccine coverage, we used search terms such as “vaccine hesitancy”, “vaccine acceptance”, and “vaccine delay”. We identified few publications that examined differences in both attitudinal and socioeconomic correlates between countries, although we found some recent reviews that assessed differing attitudes towards vaccination uptake across Europe, and differing socioeconomic correlates in east African countries. Both attitudinal and socioeconomic surveys reported various correlates of vaccine uptake. Attitudes range from personal, religious, and political beliefs, to trust in health care and the government. Socioeconomic correlates vary between countries, but education level, religion, ethnic origin, and distance to health-care facilities are all recurring themes.

Added value of this study

We studied correlations between 190 socioeconomic factors and immunisation coverage in 190 countries, and report variations in the strength of socioeconomic correlates between world regions and across time. To our knowledge, this work

represents the broadest analysis of socioeconomic links to vaccine coverage yet available, allowing insights into how socioeconomic correlates modulate coverage and how these correlates vary by world region. Forecasting of vaccine coverage time series enabled us to summarise the recent trend and variability in uptake rates and construct a vaccine performance index, which is, as far as we know, the first quantitatively derived marker of vaccine performance. Our predictive performance index represents a distinctive, interpretable measure to assess likely future vaccine coverage behaviour and resilience of immunisation programmes to volatile changes triggered by external shocks, whether driven by political rumour or natural disaster.

Implications of all the available evidence

By use of a probabilistic forecast of future vaccination levels, we have provided a world map of a vaccine performance index that is informative of both the likelihood of stagnated or substandard coverage levels and the chance coverage levels will decline. These forecasts can easily identify countries that are likely to fail to achieve the Global Vaccine Action Plan target of 90% coverage of diphtheria, tetanus, and pertussis vaccine by 2015. We speculate that regions with strong socioeconomic ties to vaccination coverage can be interpreted as targets for intervention (because socioeconomic factors present barriers to vaccination), but that some regions (namely, Europe and the Americas), with low ties to socioeconomic factors, have increased attitudinal barriers to vaccination.

health challenge for the prevention of outbreaks when local groups adopt a non-vaccination status (as was the case in the 2014–15 measles outbreak at Disneyland, Anaheim, CA, USA).³¹ Monitoring of trust in immunisation programmes through various indices has also been proposed as a way to better understand the circumstances in which vaccine hesitancy might arise.^{32,33}

To build on the current literature, we constructed a vaccine performance index: a summary measure of the strength of immunisation coverage in a country. This index could be used to describe the variability in vaccine coverage induced by confidence and access issues, allowing for an intercountry analysis of trends. We interpreted the coverage values in view of the Global Vaccine Action Plan (GVAP)’s target of attaining 90% vaccination coverage in all countries by 2015.³⁴ We discuss the implications of both the correlative study and the performance index on immunisation strategies. We undertook a large-scale, worldwide correlative analysis to investigate the association between a range of socioeconomic factors and vaccine coverage, and to identify temporal trends and differences between WHO world regions.

Methods

Data

We examined a broad range of quantitative data for 190 descriptive socioeconomic factors for 190 countries from 1980 to 2010. Factors spanned economics, health care, industry, demographics, communications, infrastructure, physical geography, trade, and education. This breadth of socioeconomic factors was used to expose, in an unbiased way, which indicators might be related to immunisation coverage. Countries were grouped into six world regions according to WHO classifications: Africa, the Americas, the Eastern Mediterranean, Europe, South-East Asia, and the Western Pacific.³⁵ We obtained data from the Gapminder website, which draws from sources including the World Bank, the International Labour Organization, and WHO. A data curation approach was used to filter and impute missing data (appendix).

Data for vaccine coverage (the proportion of a target group immunised) were obtained for BCG tuberculosis vaccine, DTP1 and DTP3 (representing the first and third doses, respectively, and typically scheduled for 6 months after birth), measles-containing vaccine (MCV), and polio (POL3, representing the third dose of the polio vaccination

For Gapminder see www.gapminder.org

See Online for appendix

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