



Impact of measles supplementary immunization activities on reaching children missed by routine programs



Allison Portnoy^a, Mark Jit^{b,c}, Stéphane Helleringer^d, Stéphane Verguet^{a,*}

^a Department of Global Health and Population, Harvard T.H. Chan School of Public Health, Boston, MA, USA

^b Department of Infectious Disease Epidemiology, London School of Hygiene and Tropical Medicine, London, United Kingdom

^c Modelling and Economics Unit, Public Health England, London, United Kingdom

^d Department of Population, Family and Reproductive Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

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ABSTRACT

Background: Measles supplementary immunization activities (SIAs) are vaccination campaigns that supplement routine vaccination programs with a recommended second dose opportunity to children of different ages regardless of their previous history of measles vaccination. They are conducted every 2–4 years and over a few weeks in many low- and middle-income countries. While SIAs have high vaccination coverage, it is unclear whether they reach the children who miss their routine measles vaccine dose. Determining who is reached by SIAs is vital to understanding their effectiveness, as well as measure progress towards measles control.

Methods: We examined SIAs in low- and middle-income countries from 2000 to 2014 using data from the Demographic and Health Surveys. Conditional on a child's routine measles vaccination status, we examined whether children participated in the most recent measles SIA.

Results: The average proportion of zero-dose children (no previous routine measles vaccination defined as no vaccination date before the SIA) reached by SIAs across 14 countries was 66%, ranging from 28% in São Tomé and Príncipe to 91% in Nigeria. However, when also including all children with routine measles vaccination data, this proportion decreased to 12% and to 58% when imputing data for children with vaccination reported by the mother and vaccination marks on the vaccination card across countries. Overall, the proportions of zero-dose children reached by SIAs declined with increasing household wealth.

Conclusions: Some countries appeared to reach a higher proportion of zero-dose children using SIAs than others, with proportions reached varying according to the definition of measles vaccination (e.g., vaccination dates on the vaccination card, vaccination marks on the vaccination card, and/or self-reported data). This suggests that some countries could improve their targeting of SIAs to children who miss other measles vaccine opportunities. Across all countries, SIAs played an important role in reaching children from poor households.

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1. Introduction

At the turn of the 21st century, measles was the leading cause of vaccine-preventable child mortality, with an estimated global mortality burden of 535,000 deaths in the year 2000 [1]; it was then a leading cause of death among post-neonates, causing 4–5% of deaths in this age group [2]. While substantial progress to reduce measles mortality has been made in recent years, measles still caused an estimated 115,000 deaths globally in 2014 [3]. Despite the availability of a safe and effective vaccine, routine vaccination programs worldwide only reached approximately 85% of children

under the age of one with the first dose of the measles vaccine in 2014 [3]. This coverage also varies by region, ranging from a low average of 83% in the World Health Organization (WHO) African Region to a high average of 93% in the Americas Region [4]. Routine measles vaccination coverage decreases further with the recommended second dose to approximately 35% for children under two and 53% at older ages globally [3,5]. WHO recommends that all countries include a second routine dose of measles-containing vaccine (MCV) [6]. However, in practice, the second dose of MCV is offered through routine vaccination programs, supplementary immunization activities (SIAs), or both. The administration of the second dose of measles vaccine can vary by type of delivery and recommended age of vaccination according to health system infrastructure and measles endemicity. Countries with high levels

* Corresponding author.

E-mail address: verguet@hsph.harvard.edu (S. Verguet).

of vaccination coverage, typically due to strong health systems, rely on routine services for delivery, whereas countries with low levels of coverage use SIAs to close the gaps in target coverage from the routine program [6]. In order to supplement those routine vaccination efforts, organizations such as the Measles & Rubella Initiative (partners including the American Red Cross, the United Nations Foundation, the U.S. Centers for Disease Control and Prevention, UNICEF and the WHO) and Gavi, the Vaccine Alliance, currently provide support and co-financing for measles SIAs every two to four years in low- and middle-income countries. SIAs are mass campaigns lasting up to three weeks during which health workers provide vaccinations directly to targeted children, regardless of their history of vaccination [7–9]. However, despite this widespread support, many countries have still not achieved the WHO target of a 95% reduction in measles mortality between 2000 and 2015 [3].

In order to achieve the current goal of eliminating measles in at least five of the six WHO regions by 2020 [10], efforts must focus both on strengthening the routine vaccination program and addressing missed measles vaccination opportunities in the routine program through SIAs to achieve the necessary very high levels of measles vaccination coverage required for population immunity [11]. Achieving high levels of vaccination coverage necessitates effective implementation of SIAs in countries that continue to experience high measles burden, with the success of these campaigns contingent upon high coverage of target populations likely to be missed by the routine vaccination program [12].

In this respect, measuring the overlap between routine measles vaccination coverage and measles SIAs is necessary to ensure the accurate estimation of the impact of countries' full vaccination program, which can subsequently help policymakers in the selection between routine and SIA strategies for the second dose of measles vaccine to establish effective measles control. In addition, the lowest measles vaccination coverage and greatest risk of measles mortality are often concentrated in populations that are the most marginalized and disadvantaged economically [13]. Hence ensuring equitable coverage of measles vaccination is a further objective of SIAs.

Despite the widespread implementation of SIAs, marginalized populations that are not vaccinated through routine health services are often missed in vaccination campaigns, requiring additional efforts to serve these hard-to-reach populations [14–16]. A key question regarding coverage of marginalized populations is the degree to which current SIA outreach efforts have proven to be effective. To what extent are the children targeted and covered by measles SIAs previously unvaccinated and what are the characteristics of these children, as compared to those covered by the routine vaccination program? In other words, how many and what children who have not previously received a measles vaccine dose are reached by SIAs? Our analysis aims to address these questions using Demographic and Health Survey (DHS) data.

2. Methods

The analysis focused on low- and middle-income countries (as classified by the World Bank) for which years and dates of SIAs were available from the WHO [17,18]. A full list of all the countries with measles SIAs reviewed is included in the [Supplementary appendix \(Table A\)](#). We relied on DHS data to determine the routine and SIA vaccination status of children. The DHS are nationally representative household-based surveys conducted periodically in more than 90 countries [19]. Each country survey includes a vaccination history for children under 5 years of age at the time of the survey. The interviewing approach of the DHS, which reconstructs the child's history of vaccination according to the child's health

card and/or maternal reports of prior vaccination, is currently the best practice to determine the proportion of children covered by each vaccine at the time of the survey [20]. Specifically, for routine vaccination, if the health card of the child is available, DHS interviewers ask to see the card and transcribe the dates of each vaccination recorded on the card and also ask if the child has obtained other vaccinations that are not recorded. If the card is not available, interviewers ask the mother/guardian whether the child has received doses of each vaccine at any time before the survey, and, if so, how many doses [21].

We first examined the schedule of SIAs in the identified countries from 2000 to 2014 [18]. We then selected available survey years from the DHS that occurred one to two years following measles SIAs [22]. The survey data was inspected for availability of the “vaccinated during campaign” indicator, in order to determine if SIA (campaign) vaccination status was included in addition to routine vaccination status during the administration of the survey. In the included surveys, mothers were asked whether their children participated in a specific SIA (with possible answers being “yes”, “no”, or “don't know”) for which the date of implementation was available [18]. While the mother/guardian is asked if additional doses not included on the vaccination card were received as described above, we do not rely on this question to classify children as vaccinated through routine or SIA, but instead we have only selected surveys where specific questions about SIAs are asked. Data included both routine and SIA vaccination status, child age at time of vaccination, and household wealth quintile. We also estimated the 95% confidence intervals (CIs) using a logit transform for the proportion of children receiving routine measles vaccination for each country in the analysis [23].

In order to estimate the proportion of children reached for each measles vaccination campaign among children with no previous history of vaccination, we first examined these children according to whether or not they were covered by the most recent measles SIA prior to the survey round in the DHS-derived dataset. We then examined the routine vaccination status of the children, according to the child's vaccination card. There are several approaches to defining receipt of routine measles vaccination prior to the SIA with this dataset, including utilizing vaccination card information, either dates or check marks, and self-reported data. Of the children who reported routine measles vaccination coverage (MCV1) in the DHS dataset, approximately 55.6% have vaccination dates on their vaccination card, approximately 43.7% have self-reported vaccination, and 0.7% have marks on the vaccination card. Our preference in this analysis was to identify children with a measles vaccination date marked on the vaccination card prior to the initial date of the measles SIA, i.e. children with a history of measles vaccination prior to the SIA. This approach enabled us to estimate the proportion of SIA doses that reach children with no prior doses of measles vaccine (i.e., “zero-dose children”) before the initial date of the SIA. In order to estimate this proportion, for each scenario, the denominator was the number of children under five years of age reported as receiving a specific SIA measles vaccine. The numerator varied according to the definition of routine measles vaccination prior to the SIA within this dataset in order to find the children who received both measles SIA and routine vaccines, as described above.

The probability of reaching zero-dose children with measles SIAs was subsequently measured by household wealth quintile, according to the DHS wealth index defined as: poorest, poorer, middle, richer, richest [22]. We then tested for “trend” of SIA vaccination status by wealth quintile, relying on Cuzick's nonparametric test for trend across ordered groups in STATA [24]. Additionally, we examined how SIAs might improve population immunity using standardized assumptions for vaccine efficacy: 85% for the first

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