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Social inequalities in vaccination uptake among children aged 0–59 months living in Madagascar: An analysis of Demographic and Health Survey data from 2008 to 2009

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ABSTRACT

Background: Socioeconomic inequalities in vaccination can reduce the ability and efficiency of global efforts to reduce the burden of disease. Vaccination is particularly critical because the poorest children are often at the greatest risk of contracting preventable infectious diseases, and unvaccinated children may be clustered geographically, jeopardizing herd immunity. Without herd immunity, these children are at even greater risk of contracting disease and social inequalities in associated morbidity and mortality are amplified.

Methods: Data on vaccination for children under five came from the most recent Demographic and Health Survey in Madagascar (2008–2009). Vaccination status was available for diptheria, pertussis, tetanus, hepatitis B, measles, tuberculosis, poliomyelitis, and H. influenza type-B. Multilevel logistic regression was used to analyze childhood vaccination by parental socioeconomic status while accounting for shared district, cluster, and household variation. Maps were created to serve as a roadmap for efforts to increase vaccination.

Findings: Geographic variation in vaccination rates was substantial. Districts that were less covered were near other districts with limited coverage. Most districts lacked herd immunity for diphtheria, pertussis, poliomyelitis and measles. Full herd immunity was reached in a small number of districts clustered near the capital. While within-district variation in coverage was substantial; parental education and wealth were independently associated with vaccination.

Interpretation: Socioeconomic inequalities in vaccination reduce herd immunity and perpetuate inequalities by allowing infectious diseases to disproportionately affect the most vulnerable populations. Findings indicated that most districts had low immunization coverage rates and unvaccinated children were geographically clustered. The result was inequalities in vaccination and reduced herd immunity. To further improve coverage, interventions must take a multilevel approach that focuses on both supply- and demand-side barriers to delivering vaccination to underserved regions, and to the poorest children in those regions.

1. Background

1.1. Social inequalities in vaccination

There have been improvements in childhood immunization in recent years: the World Health Organization (WHO) estimates routine vaccinations now avert between two and three million deaths annually [1]. However gains have not been equally distributed: immunization coverage in developed countries far outpaces that in less developed countries (96–81%, respectively) [2]. Research also suggests that even among countries showing marked improvement, national averages may mask differences or increasing inequalities within a country [3,4]. For example, children whose

Abbreviations: SES, socioeconomic status; GVAP, global vaccination action plan; EPI, World Health Organization's expanded program on immunization; DPT, quadrivalent diphtheriatetanus,pertussis and hepatitis B vaccine; HiB, haemophilus influenza type-B vaccine; MLLM, multi-level logistic modeling.

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parents are richer, more educated, or who live in urban areas often are more likely to be fully immunized [5]. The resulting morbidity and mortality contribute to a cycle of persistent health inequalities.

The Global Vaccine Action Plan (GVAP) explicitly highlights equity [5], framing equity as both the fulfillment of basic human rights and a strategy to maximize public health impact. Poor children typically have greater exposure and susceptibility to disease and as such, vaccination programs can substantially improve coverage by targeting underserved populations. Moreover, ensuring adequate, and uniform, coverage can create herd immunity, which amplifies impact by protecting individuals who are not themselves vaccinated [6]. Of particular concern, pockets of disease may thrive when unvaccinated individuals are residentially segregated from those who are vaccinated [7].

GVAP suggests two equity indicators: monitor districts and ensure diphtheria, pertussis, and tetanus coverage does not fall below 80%, and monitor gaps between lowest and highest wealth quintiles [5]. Gaps in geographic equity can indicate supply-side barriers, such as a lack of health care facilities, providers, or vaccines. Indeed, proximity to clinics and roads plays a large role in determining vaccination coverage [8].

The second recommendation reflects increasing recognition that social factors influence medical interventions including vaccination [9,10]. Demand-side barriers may include time constraints, financial constraints (e.g., user fees or transportation costs), and even broader issues such as women's autonomy and ability to use resources to vaccinate children [11]. Theory suggests that individuals with more resources, including money, knowledge, power, prestige, and beneficial social connections, will access vaccination more, more rapidly, and more effectively to influence survival [9,10]; and a growing body of empirical work highlights such associations between socioeconomic status (SES) and vaccination [8,11–13].

The degree of inequality and the characteristics it attaches to (e.g., geography, mother's education) vary by country, and have clear implications for strategic planning. Results from 28 African countries suggested that "the contribution of wealth-related inequality to the child and maternal health service coverage gap differs by both country and type of health service, warranting case-specific interventions" [14]. In that study, socioeconomic inequality accounted for 56% of the health service gap in Madagascar – more than any of the other countries included – suggesting that Madagascar could benefit from further study of health inequalities. In this study, we examine vaccination coverage equity in relation to both household SES and geographic factors in Madagascar. Details about the extent of inequality can inform the choice between investments in universal immunization campaigns or more targeted approaches; data on the most salient predictors of inequality can help refine such approaches.

1.2. Vaccination in Madagascar

To date, no research has examined the role of socioeconomic inequalities within Madagascar, which is among the poorest and least developed countries [2]. An island nation off the east coast of Africa, Madagascar has a population of around 23 million, 2 million of whom live in the capital Antananarivo. More than two fifths of Malagasy live on less than $1.25 per day [2]. The poorest people live in rural areas in the southwestern regions of Madagascar, while wealth and services are concentrated around the capital. Only 4.1% of gross domestic product (~$18/person) is spent on health care. In rural areas, many do not have ready access to health services: only 60% of the population lives within 5 km of a health center [15].

The child mortality rate is high (58/1000 live births in 2012) and ranks at 146th out of 192 countries in the world, though doing better than the rest of Africa (87/1000 live births) [2]. In 2010, 79% of child mortality was due to infectious disease: 25% from respiratory infections (such as pneumonia, influenza, and tuberculosis), 16% from diarrheal disease, 9% from malaria, 4% from meningitis/encephalitis, 2% from measles, and 1% from pertussis [16].

Madagascar has implemented the WHO's expanded program on immunization (EPI) since 1976 [15], and increases in coverage have arisen in part from sustained interest at the governmental level, which has increased funding for vaccination. Such efforts have contributed to declines in child mortality (from 97/1000 in 2002 to 58/1000 in 2012) [2]. Despite sustained efforts, health clinics continue to have problems ensuring vaccine supplies. Indeed, districts in Madagascar face critical geographic and socioeconomic barriers to child health services, including lack of refrigeration, gasoline, and transportation for both suppliers and patients [15].

1.3. Study aims

Using nationally representative data from Madagascar, this study (1) examines the role of SES in childhood vaccination while acknowledging that administrative and geographic barriers may contribute to low coverage. Thus, the study also (2) examines geographic disparities in childhood vaccination coverage. By simultaneously modeling SES and geographic variability, this study robustly estimates inequalities in coverage in order to identify gaps and to help inform immunization program decisions.

2. Methods

2.1. Data

Data come from the most recent (2008–2009) Demographic and Health Survey (DHS) in Madagascar. The DHS is a multi-stage stratified sample of 17,375 households randomly situated within 600 clusters encompassing 109 administrative districts [17]; we limited analysis to children aged 0–4 years, leaving a sample size of 5346 children situated within 593 clusters in 108 districts. Vaccination status in these data are valid and provide results that are often less biased than official statistics [18].

2.2. Measures

Children's *vaccination status* was observed for: diphtheria, tetanus, pertussis, and hepatitis B (DPT); tuberculosis (TB); measles; poliomyelitis (polio), given orally; and meningitis, pneumonia, and epiglottis using the haemophilus influenza type-B (HiB) vaccine. Vaccination requirements vary depending on vaccine. For example, DPT (a widely used indicator of coverage) includes three shots at ages 1–2, 3, and 4 months of age, while TB is given as soon as possible after birth. We analyzed compliance for immunizations defined using the national immunization schedule, which follows EPI guidelines. Where multiple rounds of vaccination were indicated (DPT, polio), vaccination indicates children who had received all vaccinations necessary for their age (±1 month). Vaccination was assessed by reviewing a vaccination card (available 80% of the time) or through mothers' report. For a small number of cases (<1%) where mothers responded that they did not know if their child had been vaccinated and health cards were unavailable, we considered the child unvaccinated, though case-wise deletion provides similar results. Districts were considered to have achieved *herd immunity* when coverage was higher than 85% for diphtheria, 92% for measles, and 85% for polio [19].

Different indicators of SES may convey different information and may independently impact vaccination. In general, human capital is usually measured by educational attainment while economic resources are often measured using wealth or income. In these analyses, we used three indicators of SES. *Mother's educational*