Test file: Impact of National Vaccination Policies on Measles Elimination: An Interrupted Time Series Analysis of 35 Countries

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Abstract

This interrupted time series analysis evaluated the impact of national vaccination policies on measles elimination progress across 35 countries from 2000 to 2023. Using longitudinal data from WHO and national surveillance systems, we found that countries implementing mandatory vaccination laws combined with robust catch-up campaigns achieved significantly greater reductions in measles incidence. Policy interventions were associated with an immediate 45% reduction in measles cases and an additional 6% annual decline post-implementation. The effectiveness varied by policy stringency, implementation timing, and healthcare system capacity, providing crucial evidence for optimizing vaccination strategies in measles elimination efforts.

Keywords: Measles Elimination; Vaccination Policy; Interrupted Time Series; Immunization Programs; Public Health Policy; Infectious Disease Epidemiology

1. Introduction

Measles remains a significant global health threat despite the availability of an effective vaccine for over five decades. The World Health Organization has established regional measles elimination goals, yet progress has been uneven across countries. National vaccination policies represent critical interventions for achieving and maintaining measles elimination, but their effectiveness varies substantially. While numerous studies have examined individual vaccination interventions, comprehensive analyses of policy packages across diverse national contexts are limited. This study employs interrupted time series analysis to evaluate the population-level impact of national vaccination policies on measles transmission dynamics, examining both immediate and sustained effects across 35 countries with varying epidemiological contexts and healthcare systems.

2. Methods

2.1 Study Design and Data Sources

We conducted a longitudinal analysis of measles surveillance data from 35 countries spanning 2000-2023. Countries were selected based on data completeness and policy implementation timing. Monthly measles case notifications were obtained from WHO centralized data systems and national surveillance databases. Vaccination coverage data were extracted from WHO/UNICEF estimates of national immunization coverage. Policy implementation dates and characteristics were documented through systematic review of national legislation and policy databases.

2.2 Policy Classification and Measures

Vaccination policies were categorized into four domains: 1) Mandatory vaccination requirements

for school entry; 2) Catch-up vaccination campaigns targeting specific age cohorts; 3) Supplemental immunization activities; 4) Vaccine exemption restrictions. Policy strength was graded using a validated scoring system accounting for enforcement mechanisms, coverage targets, and monitoring systems. The primary outcome was monthly measles incidence per 100,000 population, with secondary outcomes including outbreak frequency and duration.

2.3 Statistical Analysis

Segmented regression analysis of interrupted time series was used to estimate policy impacts. Models included terms for baseline trend, immediate level change post-policy, and trend change post-policy. We controlled for confounding by including covariates for healthcare access, educational attainment, and previous measles incidence. Country-level random effects accounted for clustering. Sensitivity analyses tested different lag structures and model specifications.

3. Results

3.1 Policy Implementation Patterns

Among the 35 study countries, 28 implemented significant vaccination policy changes during the study period. Policy packages typically combined multiple interventions, with school-entry requirements being the most common. Considerable variation existed in policy timing, with some countries implementing comprehensive packages early in the study period while others adopted gradual approaches.

3.2 Impact on Measles Transmission

Countries implementing comprehensive policy packages demonstrated significant reductions in measles incidence. The immediate post-policy effect showed a 45% reduction in monthly measles cases, followed by an additional 6% annual decline in incidence. Policy effectiveness was modified by several factors: earlier implementation relative to elimination goals, higher policy stringency scores, and integration with existing healthcare infrastructure all enhanced effectiveness. School-entry requirements combined with restricted exemption policies showed the strongest independent effects.

3.3 Heterogeneity and Effect Modifiers

Policy impacts varied substantially across countries. Nations with stronger primary healthcare systems and higher pre-policy vaccination coverage achieved more rapid and sustained reductions. The effectiveness of catch-up campaigns was particularly dependent on target age selection and campaign quality. Countries experiencing political instability or vaccine hesitancy movements showed attenuated policy effects, highlighting the importance of social and political context.

4. Discussion

4.1 Interpretation of Findings

This comprehensive analysis demonstrates that well-designed vaccination policy packages can significantly accelerate measles elimination efforts. The substantial immediate reductions suggest that policies effectively reach previously undervaccinated populations, while the sustained declines indicate successful integration into routine immunization systems. The variation in policy effectiveness underscores the importance of contextual factors and implementation quality.

4.2 Policy Implications

The findings support WHO recommendations for comprehensive vaccination policies while highlighting the need for country-specific adaptations. School-entry requirements emerge as

particularly effective, but their success depends on adequate enforcement and limited exemptions. Catch-up campaigns require careful targeting to address specific immunity gaps. Policy makers should consider these findings when designing elimination strategies, particularly in countries nearing elimination thresholds.

4.3 Limitations and Research Needs

Study limitations include potential misclassification of policy implementation dates and incomplete capture of all relevant policy dimensions. The ecological design prevents causal inference at the individual level, and residual confounding remains possible despite extensive covariate adjustment. Future research should examine cost-effectiveness and long-term sustainability of different policy approaches.

5. Conclusion

National vaccination policies significantly impact measles transmission dynamics, with comprehensive packages yielding the greatest benefits. Successful elimination requires tailored approaches considering local epidemiology, healthcare infrastructure, and social context. These findings provide robust evidence to guide policy decisions in measles elimination efforts and highlight the importance of monitoring and evaluation to optimize implementation. Continued investment in vaccination policies remains essential for achieving and maintaining measles elimination globally.

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