Estimating the effect of the comprehensive smoke-free legislation on neonatal and infant mortality in middle-income countries using a synthetic control method

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ABSTRACT

BACKGROUND: Increasing evidence supports the positive effects of smoke-free legislation on infant health. However, such studies are almost entirely restricted to high-income countries. We estimated the impact of the comprehensive smoke-free legislation on neonatal and infant mortality in middle-income countries.

METHODS: We obtained country-level panel data from the World Bank and Penn World datasets covering the 2001-2017 period. We used the synthetic control method, which reduces the probability of biased estimations. For each country with smoke-free legislation, we constructed a synthetic control country that was the combination of 'control' middle-income countries without smoke-free legislation but with similar temporal trends in the outcome and confounding variables in the pre-legislation period. The legislation effects for the post-legislation periods were derived from the difference between temporal outcome patterns of countries with smoke-free legislation and that of their synthetic control country. We compared the legislation effects to the placebo effects obtained by fictitiously assuming that smoke-free legislation occurred at random in the observed countries. We aggregated the country-specific effects to estimate the average legislation effect.

FINDINGS: Neonatal and infant mortality rates decreased substantively following smoke-free legislation in a number of countries relative to their synthetic control country.

INTERPRETATION: Implementation of comprehensive smoke-free legislation was associated with reductions in infant mortality in some middle-income countries. Expanding smoke-free policies to middle-income countries along with addressing the local barriers and facilitators of this legislation could avert substantial numbers of early-life deaths. The synthetic control method is a promising approach to assessing policies in population health research.

Keywords: smoke-free legislation, child health, synthetic control method, tobacco control policy, infant mortality, neonatal mortality

INTRODUCTION

Neonatal and infant exposure to second- and third-hand tobacco smoke and maternal smoking during pregnancy are associated with adverse health outcomes. Tobacco smoke exposure at perinatal or early life stages increases the risk of preterm birth, low weight birth, and eventually neonatal or infant mortality rates.[1-3] Annually approximately 166,000 avoidable deaths and 6.6 million healthy life-years lost among children can be attributed to second-hand smoke exposure worldwide.[2 4] Thus, the protection of children from the harm of tobacco smoke exposure has been identified as a vital tool to achieve the Sustainable Development Goal 3 aimed at improving healthy lives and wellbeing across the life-course introduced by United Nations.[5]

Smoke-free policies have the potential to reduce tobacco smoke exposure during pregnancy and infancy and to improve adverse health outcomes.[6-8] Based on a recent systematic review and meta-analysis, implementation of smoke-free legislation covering enclosed public places was followed by an average 3.8% (95% CI -6.4 to -1.2) decrease in preterm birth rates, a 9.8% (-16.6 to -3.0) decrease in rates of hospital attendance for asthma exacerbations, and an 18.5% (-32.8 to -4.2) decrease in rates of hospital attendance for lower respiratory tract infections.[6] Furthermore, evidence from England suggested that smoke-free legislation reduces neonatal mortality rate by 7.6% (-11.7 to -3.4) and infant mortality by 6.3% (-9.6 to -2.9).[7]

However, this evidence is almost entirely derived from high-income countries (HICs) which cannot easily be generalised to middle-income countries (MICs). Exceptionally large outdoor and household air pollution in MICs may reduce the effectiveness of smoke-free policies. More specifically, (1) household tobacco smoke exposure, (2) outdoor air pollution, (3) indoor air pollution due to solid fuel used for cooking and heating, and (4) tobacco smoke exposure among pregnant women are significantly higher, whereas (5) awareness of tobacco-related harms is significantly lower in MICs than in HICs.[8-11] Moreover, pregnancy outcomes are poorer in MICs due to insufficient antenatal care capacities.[12] Despite these difference between HICs and MICs, limited evidence suggests that smoke-free legislation might also protect children in MICs. However, so far only one study derived evidence on the effects of smoke-free legislation on infant health from an upper-middle-income country. Based on this study, the implementation of comprehensive smoke-free laws across Brazil was estimated to have prevented 15,068 infant deaths across 6 years .[13]

Our paper extends the scope of research to all middle-income countries that implemented comprehensive smoke-free legislation according to the World Health Organization Report on the Global Tobacco Epidemic 2019.[2] For this purpose, we apply the synthetic control method.[14] This approach has never been applied before to estimate the effects of tobacco control legislation on infant health, despite its potential to reduce the probability of biased estimation. It has been already used to analyse the effects of tobacco control policies on adult health and the number of tobacco users,[14-16] and other interventions (such as liberalisation or democratisation) on child health.[17 18]

ANALYTICAL STRATEGY

We used a synthetic control method to estimate the effects of comprehensive smoke-free legislation on neonatal and infant mortality in middle-income countries. At first, we estimated how neonatal and infant mortality statistics would have progressed in countries which introduced comprehensive smoke-free legislation if they had not implemented this legislation. Thus, for each country that introduced smoke-free legislation, we constructed a synthetic control country as a weighted average of multiple control countries (i.e. countries that never

introduced comprehensive smoke-free legislation).[14 19] Second, we estimated the impact of the smoke-free legislation as the difference in outcomes between each country with smoke-free legislation and its synthetic control country. Thereafter, we assessed whether these estimated legislation effects are indeed a response to the legislation or it could be merely the result of other random processes. For this purpose, we used the placebo test that compares each legislation effect to the placebo effects that were obtained by fictitiously assuming that the smoke-free legislation was introduced in the control countries at the same times as in the given country that has actually introduced this legislation. Finally, we aggregated the country-specific effects to calculate the average effect of smoke-free legislation. The advantage of this method is that the combination of control countries instead of using a single control country provides a better counterfactual scenario and eventually leads to less biased estimation.[14 19 20]

DATA SOURCES

We used the Word Bank's Country Classification System to categorize countries according to their income level (i.e. HICs and MICs) and the WHO Report on the Global Tobacco Epidemic 2019 to identify the countries that have implemented smoke-free legislation (e.g. Thailand). The outcome variables – national-level neonatal and infant mortality– were extracted from the World Bank Database.[21] We selected predictor variables based on previous literature demonstrating their effects on the development of the outcomes. [17 20] Thus, we included as a predictor gross domestic product (GDP) per capita, current health expenditure per capita, number of hospital beds (per 1,000 people), openness to trade, the proportion of the rural population, females' primary education completion, access to clean fuels and technologies for cooking, the level of CO_2 emissions, and total fertility rate. Additionally, we also used as predictors the pre-legislation values of the outcome variables. Predictors were collected for the pre-legislation periods from the World Bank Dataset, except for openness to trade which was obtained from the Penn World Dataset.[22]

PRELIMINARY RESULTS

Preliminary results suggest that comprehensive smoke-free policies were successful in reducing neonatal and infant mortality in a number of middle-income countries. One of the most successful practices was found in Thailand where the comprehensive smoke-free legislation was followed by a 7.3% decrease in neonatal mortality and an 8.1% decrease in infant mortality two years after the law was implemented. This smoke-free legislation effect is comparable to ones that were found in high-income countries.[7]

Our research indicates that the smoke-free legislation could potentially avert a substantive number of neonatal and infant deaths even in middle-income countries. An in-depth assessment of local barriers and facilitators is required to explore variation in effectiveness across countries and identify the potential factors that facilitate successful smoke-free legislation in middle-income countries. Further future studies should also extend the scope of the research to low-income countries (in which countries other types of predictor variables might also be important than in this study) and other types of tobacco control policies.

A limitation of our study is that, similarly to every observational study, it might not have been successful in ruling out all possible confounding variables and co-exposures. We applied the state-of-the-art synthetic control method to address these issues.

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