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Women's Education Level, Maternal Health Facilities, Abortion Legislation and Maternal Deaths: A Natural Experiment in Chile from 1957 to 2007

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Abstract

Background: The aim of this study was to assess the main factors related to maternal mortality reduction in large time series available in Chile in context of the United Nations' Millennium Development Goals (MDGs).

Methods: Time series of maternal mortality ratio (MMR) from official data (National Institute of Statistics, 1957–2007) along with parallel time series of education years, income per capita, fertility rate (TFR), birth order, clean water, sanitary sewer, and delivery by skilled attendants were analysed using autoregressive models (ARIMA). Historical changes on the mortality trend including the effect of different educational and maternal health policies implemented in 1965, and legislation that prohibited abortion in 1989 were assessed utilizing segmented regression techniques.

Results: During the 50-year study period, the MMR decreased from 293.7 to 18.2/100,000 live births, a decrease of 93.8%. Women's education level modulated the effects of TFR, birth order, delivery by skilled attendants, clean water, and sanitary sewer access. In the fully adjusted model, for every additional year of maternal education there was a corresponding decrease in the MMR of 29.3/100,000 live births. A rapid phase of decline between 1965 and 1981 (−13.29/100,000 live births each year) and a slow phase between 1981 and 2007 (−1.59/100,000 live births each year) were identified. After abortion was prohibited, the MMR decreased from 41.3 to 12.7 per 100,000 live births (−69.2%). The slope of the MMR did not appear to be altered by the change in abortion law.

Conclusion: Increasing education level appears to favourably impact the downward trend in the MMR, modulating other key factors such as access and utilization of maternal health facilities, changes in women's reproductive behaviour and improvements of the sanitary system. Consequently, different MDGs can act synergistically to improve maternal health. The reduction in the MMR is not related to the legal status of abortion.

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Introduction

The fifth Millennium Development Goal (MDG) put forward by the United Nations (MDG-5) proposes to reduce the world's maternal mortality ratio by 75%, by 2015 [1]. Many pregnancy-related deaths are preventable, and maternal mortality remains high in Latin America [2]. Nevertheless, according to a recent independent study of 181 countries by Hogan *et al.* [3], and contrary to previous reports that showed very little decrease in the maternal mortality ratio (MMR, the number of maternal deaths related to childbearing divided by the number of live births) over decades [4–6], the global MMR declined from 422 to 251 per 100,000 live births between 1980 and 2008. In particular, low-income Latin American developing countries, such as El Salvador, Guatemala, Nicaragua, Ecuador, and Bolivia, have made substantial progress in reducing the MMR [3].

Factors such as fertility rate [3,5–9] (a proxy for reproductive behaviour), per capita income [10] (an indicator of material resources in adult life), educational attainment of the female population [3,11–15] (an indicator of early life experiences, acquired knowledge and skills [16]), access to adequate maternal health facilities and personnel (*e.g.* skilled attendants) are all thought to be important determinants of maternal health [17–21]. Additionally, it has been suggested that abortion prohibition may contribute to high maternal mortality rates [22–26]. Finally, although the influence of other development process indicators such as clean water supply and sanitary sewer access on maternal

mortality is virtually unknown, these factors likely influence population health by decreasing epidemics and mortality from diarrhoeal infectious diseases [27,28].

Chile offers an opportunity to investigate the influence of these determinants on maternal mortality trends. Not only are large time series of vital and socioeconomic data available for this country that are of similar quality to those of developed countries [2,29], but legislation prohibiting therapeutic abortion was passed in 1989. As a result, data from Chile provide a rare and unique natural experiment to evaluate the influence of population factors, the legal status of abortion and other historical policies on maternal mortality trends since data are available before and after interventions were implemented.

Interestingly, research has consistently observed an inverse correlation between women's education level and maternal mortality in the developing world [11,12,14,15,30]. Recent Chilean prospective studies have corroborated the finding that educational attainment is a strong independent predictor of all-cause mortality having simultaneously a modulating effect on other factors [16,31]. Although it has been suggested that increasing women's education level contributes to the modulation of other variables known to influence maternal health such as the reproductive behaviour (*e.g.* fertility rate, birth order, delayed marriage and motherhood, family size, contraceptive use, etc.) and access to maternal health facilities (*e.g.* access to prenatal and postnatal care, and delivery by skilled attendants) [3,7,11–15,30], this effect on the MMR decline has yet to be demonstrated mathematically; however, this may be severely limited by the paucity of large and continuous parallel time series in developing countries [7,20,32,33].

The primary objective of this study is to assess the main factors related to maternal mortality reduction in Chile over the last fifty years, including the implementation of historical policies. A complementary objective is to test the modifying effect of women's education level on other variables identified to influence the mortality trend. Accordingly, we use a parallel time series design combining segmented regression techniques with a pathway modelling approach.

Methods

Ethics statement

The ethical aspects of this study were reviewed and approved by the institutional review board of the Faculty of Medicine of the University of Chile. Since this work was based on historical mortality statistics and did not directly involve any human subjects, this institutional review board explicitly waived the need for informed consent.

Maternal deaths and live births

We systematically searched the Chilean National Institutes of Statistics (INE) for official government data on maternal deaths and live births from 1957 to the present. Vital registration in Chile is virtually complete, and the quality of the data meets the standards of developed countries [29,34,35]. In our analysis of official vital statistic yearbooks that have been published continually from 1957 by the INE, we identified four well-defined periods of registry, during which specific international classification of diseases (ICD) were utilised in Chile. During the first period from 1958 to 1967, causes of maternal mortality were classified according to ICD-7 (7^{th} version). In 1957 the ICD-6 (6^{th} version) was used but obstetric causes were directly homologated with ICD-7. In the second period from 1968 to 1979, maternal deaths were classified using ICD-8 (8^{th} version). From 1980 to 1996, the ICD-9 (9^{th} version) was used, and from 1997 to the present, ICD-10 (10^{th} version) has been used. The detailed description to classify death causes is presented in Appendix S1 and Tables S1, S2, S3, S4 and S5. Regarding live births, between 1957 and 1979 there was an increase in the delay of the inscription of births [36]. Therefore, in this study, the number of live births for every year was corrected using the method of delayed registration (Appendix S1).

Independent variables

Women's education level was assessed with the construction of parallel time series using the average number of schooling years (Appendix S1). First, we used the series published by the Central Bank of Chile [37] and by the Economic History and Cliometrics Laboratory [38]. Second, we used estimates from the Social Characterization Survey conducted by the Chilean Ministry of Planning to calculate the average number of schooling years for economically active female population. Finally, we used the percentage of women with nine or more schooling years at the time of delivery, published by the INE in the annual registry of live births from 1957 to 2007. To obtain a single set of 51 points representing the average number of schooling years, we used a multiple regression method [39], including all of the variables mentioned above. Other independent predictors that were analysed in continuous and parallel times series were income per capita (Gross Domestic Income [GDI] in U.S. dollars), percent of population with clean water supply, percent of population with sanitary sewer access, total fertility rate (TFR), birth order (percent of primiparous women giving birth and percent of primiparous women >29 years giving birth from the total live births each year), and percentage of women who were delivered by skilled attendants (deliveries by medical doctors and/or professional midwifes in hospitals or maternities). The conceptual definitions and the procedures for collecting all parallel time series data are detailed in Appendix S1.

Historical interventions

In our analysis we considered three historical interventions and policies that may have influenced women's health and consequently the MMR (a full description is provided in Appendix S1). First, in 1965, laws were passed implementing free and mandatory education to a minimum of eight years [40]. Second, between 1964 and 1967, an extensive prenatal primary care program with a family planning component was implemented [41]. Finally, in 1989, a legislation prohibiting therapeutic abortion was passed, completing all historical interventions considered.

Statistical analyses

The MMR per 100,000 live births was directly calculated from the official registry of maternal deaths and live births. Additionally, because it was not possible to completely align all ICD codes, we computed the relative importance of various causes of maternal mortality, grouping similar causes of maternal deaths together while attempting to work within the context of the original codification (Table S1, Appendix S1). In particular, ICD-9 and ICD-10 included separate codes for several causes that were not included in the ICD-7 or ICD-8. Therefore, the oldest ICD was used as a reference to construct the various mortality groups and to calculate the relative importance in four five-year periods: 1958–1962, 1971–1975, 1985–1989 and 2003–2007. In exploratory statistical analyses using a spline smoothing procedure for the number of maternal deaths, these four five-year periods were parsimoniously representative of the four ICD codes used in the time series. Additional analysis to identify changes in the trend for the percent of mortality causes included continuous five-year