Evolution of infant mortality in Chile and how it has been reflected in scientific publications between 1980 and 2019

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ABSTRACT

Introduction. One of the Millennium Development Goals is to reduce the child mortality rate (CMR), an indicator still present in the Sustainable Development Goals (2015-2030). At the same time, scientific investigations and reports were necessary to assess the behavior of the infant mortality rate (IMR) and the effectiveness of interventions to approach it.

Objective. To describe IMR behavior in Chile and how it has been reflected in the scientific publications made in the 1980-2019 period.

Material and methods. Implementation of the multivariate adaptive regression spline (MARS) method in relation to IMR between 1980 and 2016, and search for related articles published between 1980 and 2019 in SciELO, Lilacs, PubMed, Cochrane Library, and Embase. The analysis included IMR behavior and its reflection in the publications made in that period.

Results. IMR decreased from 28 % to 7.2 % per 1000 live births between 1980 and 2016 (-74 %) and 82 publications were identified in this period. Two types of studies about IMR were reported as of the cutoff point of 1996. In the first period, studies focused on preventable diseases and interventions, while IMR showed a slowing down in its reduction. After the cutoff point, studies focused on non-preventable diseases and factors related to inequalities and inequities.

Conclusions. IMR prevails as a synthetic indicator of health conditions. Changes in its evolution and causes have been reflected in publications, which have shifted their focus and areas of interest in accordance with the changes in this indicator.

Key words: *infant mortality, epidemiological studies, scientific and technical publications, regression analysis.*

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INTRODUCTION

The Millennium Development Goals (MDGs) proposed different goals for 2015, including the reduction of the child mortality rate by two thirds between 1990 and 2015. This international initiative set the stage for the development of social public policies. Public health, with its multidisciplinary nature, together with political epidemiology became tools that helped to enlarge the scientific knowledge in the setting of these proposals.[1]

Between 2014 and 2015, the Sustainable Development Goals (SDGs) were proposed as part of a new agenda establishing new goals for 2030. It comprises 17 goals, including SDG 3 in relation to health and well-being. Regarding child mortality, the goal for 2030 was to reduce global neonatal mortality to 12 per 1000 live births and under-five mortality to 25 per 1000 live births.[2]

In this context, it is not possible to analyze the reduction in infant mortality without referring to the ground-breaking and critical work by Erica Taucher based on the concept and classification of avoidable mortality. Although death is an unavoidable event, based on this approach, some causes are preventable and it is possible to assess their relation to socioeconomic conditions, as reflected in the differences observed in socioeconomic level and mortality causes among countries and regions. This way, the analysis of causes of death becomes a tool to both plan interventions and assess them, and is an essential resource for the management of public policies.[3] Such proposal has served as the basis for planning actions aimed

at reducing infant mortality in different Latin American countries, including Argentina,[4,5] Uruguay,[6] and Colombia,[7] among others.

Chile started working with the MDGs with a low infant mortality rate (IMR). It is worth noting that, between 1980 and 1990, the reduction slowed down due to the decrease in financial resources assigned to the public health sector.[8] Between 1990 and 2011, the IMR decreased by 51.8 %, from 16 to 7.66 per 1000 live births. During 2011, 70 % of deaths among infants younger than 1 year occurred in the neonatal period, linked to a very low birth weight and congenital and chromosomal anomalies. It has been stated that the target established by the MDGs for 2015 was difficult to achieve because almost half of infant mortality cases were related to extreme prematurity and 35 %, to congenital malformations and chromosomal abnormalities.[9,10]

The current strategy in relation to mother and child health considers a life cycle approach, the establishment of multidisciplinary health care teams, research actions taken together with public health services and universities, and the assessment of programs and instruments. The foregoing is complemented by an ongoing improvement in the quality and reliability of epidemiological data.[11,12]

For this reason, health plans should be based on epidemiological, clinical or experimental good-quality research. Without such scientific support, any plan or intervention would be both ineffective and inefficient and would have an impact on the sector's financial resources. Mother and child health plans are based on good-quality investigations, which are not always conducted in the country. Although this may be sufficient in many cases, in others, the particular characteristics of health determinants make it necessary to be based on a specific reality.[13]

Years back, the behavior of the IMR in Chile and the publications related to this indicator were analyzed, and, at that time, the use of time series analysis strategies through non-linear models was discussed.[14] Based on this, the objective of this study was to describe the behavior of the IMR and related published studies in the 1980-2019 period.

MATERIAL AND METHODS

This was a time series study about the IMR in the 1980-2016 period based on data available as of 2020 provided by the Health Statistics and Information Department (Dirección de Estadística e Información en Salud, DEIS) of the Ministry of Health of Chile. At the same time, publications about infant mortality in Chile made in the 1980-2019 period were analyzed.

To identify the studies published about infant mortality in Chile, a search was done in the following databases: SciELO, Lilacs, PubMed, Cochrane Library, and Embase. Terms were looked for using thesauruses, such as the Medical Subject Headings (MeSH) of the National Library of Medicine and Health Sciences Descriptors (Descriptores en Ciencias de la Salud, DeCS), developed by BIREME. However, no descriptors for more specific concepts were found. Therefore, the search strategy was extended to include the terms "mortality" AND "infant" AND "Chile," with the following unique selection criteria: 1980-2019 period; Chilean infant mortality studies (children younger than 1 year); and in English, Portuguese or Spanish language. Then, each study was analyzed and classified by journal, study design, variables, and statistics used. The review was conducted by an investigator based on the search and selection developed in advance by researchers that belonged to the same team.[14]

The 1980-2016 time series of the IMR was analyzed using the multivariate adaptive regression spline (MARS) method, a technique recommended for this type of data.[15] This is a non-linear regression model based on spline basis function, a generalization of recursive partitioning regression, which divides the space of the predictor variable into different sub-regions and attempts a local approximation in each of them. The complexity of the resulting model is controlled by the maximum number of regions (Mmax) into which the input space is divided. The model selection is based on generalized cross-validation (GCV) criteria, a measure of data adjustment. The model is validated with the information from the year following the year of the generated model. That is to say, if the model was generated for 2006 with data from the series for the 1980-2005 period, the predictive power was assessed based on data from the following year, thus achieving data independence. From the series of 37 data, the last 3 years were subtracted to establish a training sample and a validation sample; the latter was made up of observed and predicted values. The assumption is that these values are as similar as possible, i.e., acceptable estimates. Lastly, the MARS generates cutoff points (knots) for the variables; in this case, year and IMR. The knot is represented between 2 basis

functions, which indicates the end of a region and the beginning of another region, thus allowing to identify relevant changes in the time series. This then allows to connect periods of higher or lower concentration of scientific publications before and after the cutoff point.

For publication description, descriptive studies were defined as those that only reviewed the evolution, trend and/or causes related to infant mortality. Association studies were defined as those that explored the relation among the variables that addressed specific aspects of infant mortality in general or by component. The identification of the analysis strategy used took into account the study of trends, frequency distribution, risk estimation, Spearman's or Pearson's correlation and/or modeling (Poisson, logistic), and the comparison between groups using statistical inference based on Student's *t* test.

RESULTS

IMR decreased from 28 per 1000 live births in 1980 to 7.2 per 1000 live births in 2016 (-74 %). In turn, 1996 was established as a cutoff point (*Figure 1*) using the MARS method, suggesting a change in the reduction rate of IMR as of this point. The equation accounts for both data regions and the cutoff year:

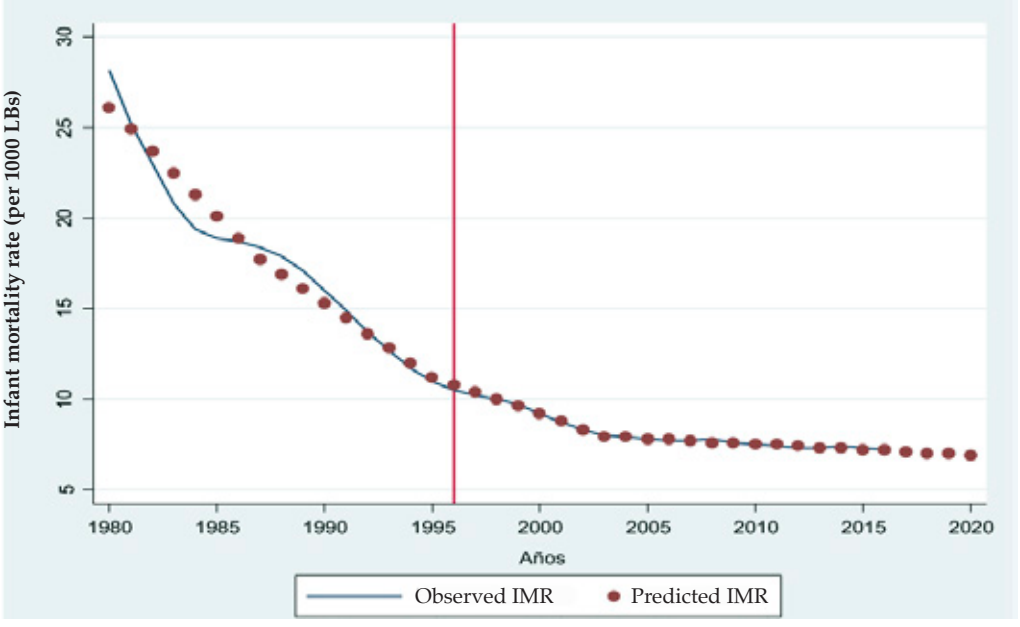
$$Y = 9.72691 - 0.152248 \times \max(0, \text{year}-1996) + 0.974091 \times \max(0, 1996-\text{year}).$$

In the same manner, based on this equation, predicted rates were estimated until 2019. The assessment of estimations considered 2 statistics: GCV = 0.97516, which accounts for a measure of data adjustment, and the penalty due to the model complexity resulting from an increase in variance (*Figure 2*).

In relation to publications made in the 1980-2019 period, 82 articles related to infant mortality in Chile were registered. The highest number of articles was published in the 2000-2009 period (n = 30), mostly in *Revista Chilena de Obstetricia y Ginecología*, *Revista Chilena de Pediatría*, and *Revista Médica de Chile* (*Table 1*).

In addition, the number of publications increased in the early 1980s along an IMR of 28 per 1000 live births. After this period, the decline in the rate was sustained. However, as of the cutoff point (1996), a new increase in published studies was observed, coincident with the change in the rate of reduction and a lower

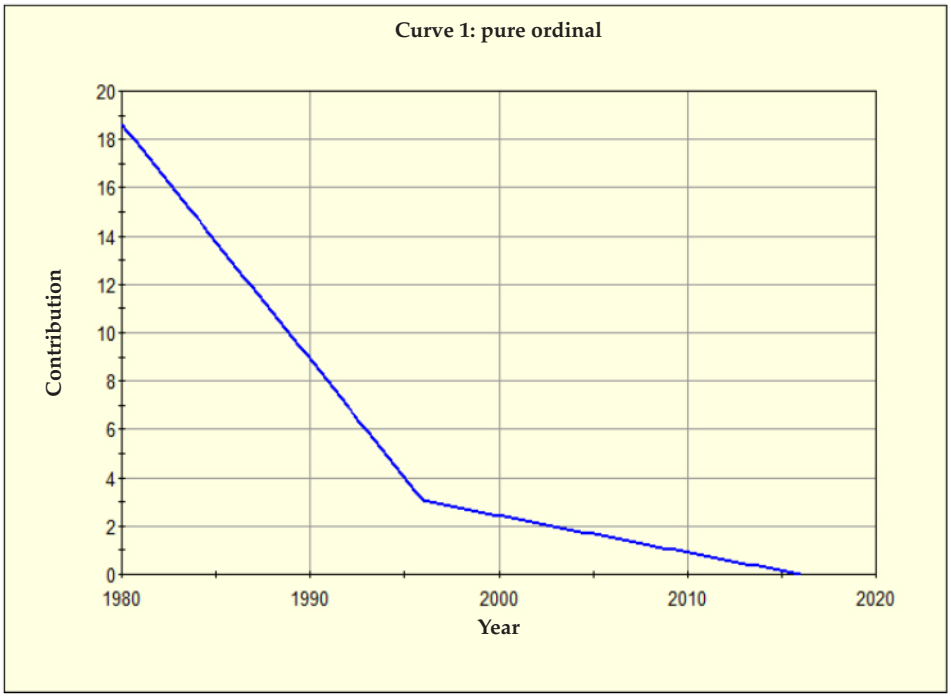
FIGURE 1. *Evolution of observed and predicted infant mortality rates with a cutoff point at 1996, based on a multivariate adaptive regression spline method*



Y = 9.72691 - 0.152248 x max (0, year-1996) + 0.974091 x max (0, 1996-year).

IMR: infant mortality rate.

FIGURE 2. *Cutoff point estimated based on the year and infant mortality rate variables*



BF1 = max (0, year-1996)
BF2 = max (0, 1996-year)

$$Y = 9.72691 - 0.152248 \times BF1 + 0.974091 \times BF2$$

$$Y = 9.72691 - 0.152248 \times \max(0, \text{year}-1996) + 0.974091 \times \max(0, 1996-\text{year})$$

BF: basis function.

TABLE 1. *Number of publications about infant mortality in Chile and journals. Chile, 1980-2019*

Journal (N = 23)	Period				
	1980-1989	1990-1999	2000-2009	2010-2019	Total
Am J Public Health	1	0	1	0	2
An Pediatr	0	0	1	0	1
Appl Econ	0	1	0	0	1
Bol Epidem Chile	2	0	0	0	2
Rev Panam Salud Publica	3	0	2	3	8
Bol Hosp San Juan de Dios	1	0	0	0	1
Cuad Med Soc (Chile)	0	1	1	0	2
Environ Health Perspect	0	0	1	0	1
J Pediatr	0	0	0	1	1
J Perinat Med	1	0	0	0	1
Medwave	0	0	0	1	1
Papeles de Población	0	0	0	1	1
Pediatría (Santiago)	1	1	0	0	2
Pediatría al Día	0	0	1	0	1
Rev Chil Obst Ginecol	2	3	7	0	12
Rev Chil Pediatr	7	7	8	2	24
Rev Chil Salud Publica	0	0	1	0	1
Rev Med Chile	2	3	5	4	14
Rev Med del Maule	0	0	1	0	1
Rev Chil Enferm Respir	0	2	0	0	2
Rev Hosp Clín U de Chile	0	1	1	0	2
World Development	0	0	0	1	1
Total	**20**	**19**	**30**	**13**	**82**

IMR (*Figure 3*). Between 1980 and 1996, the IMR decreased from 28.2 to 10.5 per 1000 live births, showing a reduction of 62.8 %. In the same period, 31 scientific studies were developed and published. Between 1980 and 1983, 12 studies were published; 1982 was the year with the greatest production: 8 published studies. Between 1984 and 1996 (the latter was the cutoff year), 19 articles were published. Out of all studies, 61 (74.4 %) implemented a descriptive design (cross-sectional and ecological) and 21 (25.6 %) corresponded to association studies (cohort, association, and spatial analyses) (*Table 2*). The main assessments conducted in selected studies (*Table 3*) showed that those classified as descriptive included absolute frequency, stratification, and variation analyses (n = 18). In the case of association studies, analyses were mainly bivariate in order to look for factor association, and Pearson's and Spearman's correlation and risk and regression analyses were used (n = 73). A third group of studies, which implemented prediction analysis, used spatial and economic analyses and simulation models (n = 3).

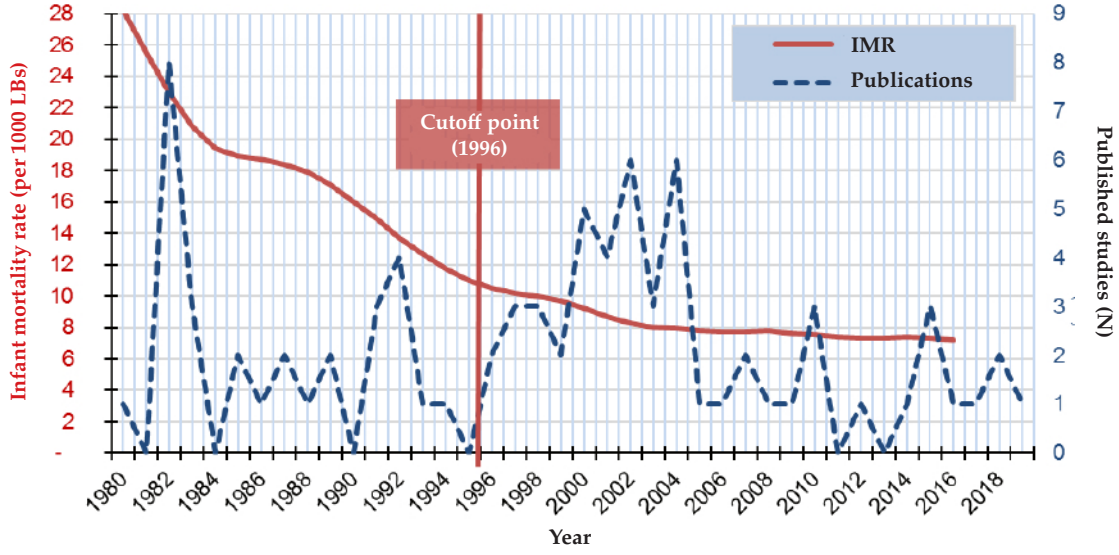
DISCUSSION

This study has allowed to establish the behavior of the IMR in the 1980-2016 period and associated publications. As an overall outcome, IMR decreased by 74 % in the study period, along a total publication production of 82 articles until 2019. In relation to IMR behavior, the reduction rate slowed down as of 1996. In relation to the first data region (1980-1996), it is worth noting that respiratory and perinatal diseases changed their presence as cause of death, with prevalent causes that were harder to prevent, such as

TABLE 2. *Number of publications by methodological design used in infant mortality studies conducted in Chile, 1980-2019*

Period	Association		Descriptive		Total	
	N	%	N	%	N	%
1980-1989	0	0.0	20	24.4	20	24.4
1990-1999	5	6.1	14	17.1	19	23.2
2000-2009	11	13.4	19	23.2	30	36.6
2010-2019	5	6.1	8	9.8	13	15.9
Total	21	25.6	61	74.4	82	100

FIGURE 3. *Evolution of infant mortality rates, number of publications, and cutoff point identified through the MARS method, 1980-2019*



LBs: live births; IMR: infant mortality rate; N: number.

congenital malformations. Similarly, an important number of deaths in infants younger than 1 year were preventable, so it was proposed to maintain the focus on health resources targeted at the care of pregnant women, newborns, and infants at high risk.[16] In Chile, the reverse association between socioeconomic level and infant mortality remained consistent until the 1960s. Once the National Health Service and mother and child programs were established, the economic level stopped being the most relevant determining factor.[17] Precisely, such background was evidenced in the articles published in this period, which used different study designs. In addition to describing the evolution of IMR, these studies expressed associated factors and highlighted the focus on preventable causes of death proposed by Taucher. Thus, death results from multiple conditions, and deaths may be regrouped based on intervention clusters to help with their control. The causes leading to a higher number of deaths and that could be prevented with easily applicable measures included accidents, pneumonia, and early childhood diseases. At the same time, guidance on the analysis of determining factors was provided in the framework of development policies, including infant mortality and other policies grouped as preventable deaths due to mixed measures.[3]

TABLE 3. *Number of publications by analysis strategy used in infant mortality studies conducted in Chile, 1980-2019*

Analysis	Statistical methods	N
Descriptive	Absolute and relative frequencies	1
	Stratification	1
	Differences	11
	Standard deviation	4
	Analysis of variation	1
Associative	Student's t test	3
	Population attributable risk	6
	Commune attributable rate	1
	Inequality	1
	Spearman's correlation	3
	Pearson's correlation	14
	χ^2 test	10
	Fisher's test	2
	Mann-Whitney U test	1
	Odds ratio	7
	Logistic regression	2
	Linear regression	3
	Poisson regression	3
	Time series	10
	Relative risk	7
	Multiple-equation models and simulation	1
	Spatial analysis	1
	Economic analysis	1

According to the bibliography reviewed in the 1980-1998 period, major changes in the causes of infant death were detected, from causes that could be prevented with interventions at the level of the population to harder to prevent causes requiring a greater focus and public policies targeted at vulnerable groups. At this time, the rate of reduction in IMR started to slow down. Chile started this period with a low overall rate and faces the challenge proposed by the MDGs with a different epidemiological profile and established inequality and inequity processes.

When comparing Chile to the rest of the countries in South America in 2003, scientific articles reported a life expectancy of 75.6 years and an IMR of 7.8 per 1000 live births. When compared to more developed countries with adequate health indicators, like Canada, Chile's life expectancy is 3.4 years shorter and IMR, two times higher. Studies published in this period agree that, in the past 30 years, Chilean medicine has successfully reduced the risk of death due to infectious and malnutrition-related diseases.[18]

In the second part of the series reported here, by 2005, IMR decreased to 7.5 per 1000 live births. At this point, publications started focusing on topics related to inequality and inequity processes, and the relation with social determinants of health. Measuring socioeconomic inequalities and the differential risk in infant mortality at a national and regional level in Chile between 1990 and 2005 is a challenge for the proposal of new public policies and the overall commitment with MDGs, which were first implemented in 2000. One of the global goals was to reduce the child mortality rate by two thirds between 1990 and 2015. Although Chile started this period with rates close to those observed in more developed countries, a slowing down was observed at a commune level. Published studies refer to the presence of groups with high socioeconomic inequalities. Others evidence inequalities in vital statistics coverage, as well as problems with the misdefinition of causes of death. Experts have warned that, in households with a low socioeconomic level, newborns may have a higher risk for death in the first 3 months of life. It has been suggested that, to continue reducing infant mortality, public policies focused on populations at risk are required.[19,20]

The MDGs finally redirected strategies, which had an even bigger impact on this indicator. The reduction in the post-neonatal component has allowed to achieve the current levels; however,

neonatal mortality, the main component of this indicator, has gained special interest.[21] This component is determined by different biological, health care, and socioeconomic factors. Likewise, maternal factors associated with neonatal mortality, such as age, a low level of education, and a short birth interval, are relevant. The most important known predictors include preterm births, asphyxia, and infections, like sepsis and pneumonia.[22]

To conclude, it is important to continue assessing the IMR as a synthetic indicator and the contributions made by the scientific community to developments in this field. Two regions were identified in the IMR series analyzed. The first one, with studies that addressed preventable diseases and interventions; afterwards, a slowing down process in the reduction rate of IMR. After the cutoff point, studies evidenced the prevalence of non-preventable diseases, but also emphasized the factors related to inequalities and inequities.

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