Infant mortality in Venezuela: a humanitarian crisis under way

ABSTRACT

Background: Since the 1950's Venezuelan infant mortality had shown one of the most significant improvements in Latin America. Full-blown economic meltdown alongside upsurge infectious and parasitic diseases such as malaria, measles and diphtheria may be changing previous patterns. Because no official updated mortality statistics have been published since 2013, the effect of recent events has been impossible to assess accurately. We estimated infant mortality rates from 1985 to 2016 and report the impact of the crisis.

Methods We used direct and indirect methods on all available data sources (census, surveys, mortality yearbooks, vital statistics and notifiable diseases bulletins) to produce infant mortality rates (IMR). We shaped yearly estimations using a semi-parametric regression model, specifically a P-Spline model with a cubic thin plate base.

Findings: Around 2009, the long-term decline in IMR stopped and a new pattern of increase is observed. The IMR reached 20·3 per thousand live births in 2016. This level represents a huge setback on previous achievements in reducing infant mortality; it takes the country back to the IMR level observed in the end-1990s, wiping out 17 years of expected progress in IMR reduction.

Interpretation: Even our conservative estimation indicates that Venezuela is in the throes of a humanitarian crisis. IMR in 2016 is 1·3 times what it was in 2008 (15·2 deaths per thousand live births) and far from achieving the target of 9 per thousand stated by the Venezuelan government in the UN Millennium Development Goals framework.

Key words: Mortality shock, socio-economic crisis, infectious diseases outbreak, p-spline model

Research in context

Evidence before this study

Since 2013, national and international non-government organizations have been confronted by the strict secrecy policy ruling Venezuelan public institutions. By publishing unofficial complaints and journalists' reports they aim to uncover the true impact of the combined political crisis and socio-economic meltdown on ordinary Venezuelans' health. However, no published academic studies quantify the changes in mortality trends for the most recent years. We took advantage of the release of the 2014 to 2016 notifiable diseases bulletins (Boletín epidemiológico) and the recent household and living conditions survey ENCOVI-2016 to produce infant mortality estimations.

Added value of this study

This study may be the only attempt to robustly estimate infant mortality rates (IMR) for the most recent years in Venezuela. In this sense, two added values may be identified: 1) the estimation of long-term updated IMR trends and 2) to determine IMR during crisis times and absent data.

Implications of the available evidence

International IMR estimates for Venezuela do not reflect the recent deterioration. On the contrary, they involuntarily conceal the humanitarian crisis when modeling a continuous decreasing trend in infant mortality. Venezuela's case could be an obvious exception due to a relatively unexpected shift in mortality patterns. However, monitoring in countries should be guided (when possible) by sound empirical data adjusted for known biases, rather than by modeling assumptions.

INTRODUCTION

Accelerated economic and social transformations led to improve living standards in Venezuela during the second half of the 20th century. [1] An increase in life expectancy driven by a reduction of infant mortality – from 108·0 per thousand live births in 1950 to 18·2 in 2000 – was observed during this period. [2] As in most Latin American countries, this progress was linked to macroeconomic development e.g.: sanitary controls, mass vaccination campaigns, elimination of disease vectors and antibiotic distribution. [3] Initial improvements were attributable to a reduction of infectious and parasitic diseases such as gastroenteritis, malaria and tuberculosis. [1]

Recent socio-economic and political events have led to a collapse in living standards along with a breakdown of the health system. [4] The dimension that best describes Venezuela's current situation is that of economic collapse. Gross Domestic Product (GDP) per capita contracted by almost 30% in 2016 and 14% in 2017. [5] Cumulative inflation reached 1,672% in 2016 and 1,087% in 2017, and the fiscal deficit was over 13%.[5] At individual level, already the 2014 consumer survey report signaled declining consumption of foods that provide a significant amount of essential micronutrients, such as milk (-45%), and beef (-12%) compared with previous years. [6] By 2017, 61·2% of the population was in extreme poverty; [7] 89·4% of households reported not having enough money to buy food, and 61·9% of the adult population had gone to bed hungry at least once during the last 3 months. [8]

In parallel, the Venezuelan public health system has been gradually starved of funds since 2007. [9] Patient-doctor ratios have fallen from 1·7 to 1·2 per thousand [10] while hospital beds have fallen from 1·3 to 0·73 per thousand.[11] Vaccination campaigns have also been slashed. Between 2007 and 2009, for example, the Ministry of Health did not provide polio, pentavalent and viral trivalent vaccines to children under 5 years old and in 2010 did not vaccinate nearly 20% of children. [12] In addition, shortages of basic medicines, surgical supplies and infant formula raised health-care costs, [13] making it unaffordable for most of the population. Contrary to official governmental rhetoric, public health spending has never exceeded private one since 1990. Household spending accounted for 64% of total health expenditures in 2014, one of the highest percentages in Latin America. [11]

Medical and humanitarian non-government organizations have been reporting increasing morbidity and mortality due to infectious and parasitic diseases. Diseases that had been already controlled or eradicated in past decades are reappearing. Most of them are associated with a lack of access to basic sanitation, malnutrition and missing vaccination campaigns. During the last two years, the Pan-American Health Organization has issued several epidemiological alerts reporting malaria, [14] measles [15] and diphtheria [16] outbreaks.

Critical warnings are given out not just to the Venezuelan government but also to neighboring countries affected by the spread of these diseases. [17]

A strict secrecy policy has ruled public institutions, especially since 2013. Official health and mortality data are hard to come by. [4] Data sources are no longer updated or have simply disappeared from public access. The Government's constant denial of the crisis has made it even more difficult to properly assess its extent. At international level, United Nation Economic Commission for Latin America and the Caribbean (ECLAC) collected, systematized and published statistical information including infant mortality estimations. [18] Their estimations were built on the basis of life tables implicit in the population projections. Likewise, the United Nations Inter-Agency Group for estimating infant mortality (IGME) [19] produces an annual report on trends in neonatal, infant and under-five mortality for all United Nations members. In Venezuela's case, the latest available estimates are based on data reported by the National Institute of Statistics in 2013. IGME's updated 2017 estimations as well as ECLAC's updated 2016 rely on the assumption of a continuous decrease in infant mortality. As a consequence they cannot reflect the impact of the recent socio-economic deterioration.

In order to overcome the information gap, we took up the challenge of producing the most accurate infant mortality rate (IMR) estimation possible. We decided to focus on IMR because its trends are very sensitive to malnutrition, environmental risks and dysfunctional health services, [20] all of which are combined in the current Venezuelan context. Our hypothesis is that the historical downward trend in infant mortality has been reversed and that the economic breakdown has led to a humanitarian crisis in the country. Our aim is three-fold: 1) to estimate IMR trends, 2) to reveal the current situation of infant mortality in the absence of official estimations, and 3) to report the humanitarian emergency under way through IMR analysis. To carry out our analysis, we considered all data sources available in the country since 1985: Notifiable Diseases Bulletins "Boletín epidemiológico" [21], Mortality Yearbooks, [22] vital statistics, surveys and population censuses.

DATA AND METHODS

Infant mortality analysis requires computing death counts in the population under one-year old as well as live births during the same period. Information related to both events are covered and published by a vital statistics system. The Venezuelan vital statistics system has better data quality and coverage than most Latin American countries. [23] For our analysis we decided to take death counts published by the Ministry of Health in its mortality yearbooks from 1985 to 2013[19] and reported by the World Health Organization (WHO). These yearbooks include all deaths for which a medical certification was issued, regardless of its civil or legal registration [24] (appendix, p 2). To complete our rates, we took long-term births series estimated by ECLAC [18] and those held as reference by the Venezuelan Ministry of Health for its official IMR estimations.

As said before, neither mortality yearbooks nor any other official mortality estimates have been published since 2013. However, weekly Notifiable Diseases Bulletins (NDB) [21] from 2013 to 2016 were briefly available during the year 2017 on the Ministry of Health's official website.[4] While the main aim of these bulletins is not to report death counts; they do dedicate a section to reporting weekly hospital deaths of the population under one-year-old. The NDB annual deaths summary has historically underestimated mortality yearbook counts. This underestimation is readily summarized into a linear model (appendix, pp 2-3). We created adjusted death counts for the years 2013 to 2016 corrected with a linear extrapolated underestimation ratio. Births counts for the years 2003 to 2016 came from summaries of registered births corrected by the National Institute of Statistics. [25] We generated a proportional factor to assess late-registration pattern. Later on, we used it to disentangle occurrence and registration (appendix, p 3). For estimating this set of IMRs, we assumed late-registration patterns and proportion of hospital deaths from among overall all deaths remained with the same historical pattern.

Another important source of information existing in the country is censuses and survey data. On the period of our analysis the National Institute of Statistic has undertaken three population and household censuses in 1990, 2001 and 2011. Censuses data remains available and through it is possible to gleaned information about number of children ever born and children dead by women's age. More recently a National Survey of Living Conditions of Venezuelan Population (ENCOVI) is being carried out annually by three of the most important universities in the country. On its 2016's wage ENCOVI survey included questions regarding number of children ever born and still alive. This information known as Summary Birth Histories (SBH) is commonly used by demographers to applied model-based methods to estimate IMR. Here, we use Brass' method on Trussell's variant (appendix, p 4). This variant calculated multipliers to transform proportions of dead children into cohort–specific probabilities of dying through regression approach.

In short, we used estimations based on direct and indirect methods to produce three sets of data. One) 1985 to 2013: IMR using a direct method on death counts from the mortality yearbooks and birth records published by ECLAC and the Ministry of Health. Two) IMR from 2003 to 2016 using direct methods on adjusted deaths and births. Finally, three) a group of IMR estimations obtained through indirect methods based on census data and a recent living conditions survey ENCOVI-2016. All previous IMR estimations were synthetized and smoothed in a P-Splines model. This model allows us to eliminate irregularities in the data produce by combining several data sources and methods of adjustment, each affected by different types of errors, [26] without losing possible changes in the pattern.

The P-spline method of this research has a cubic thin plate base and the smoothing parameter λ is estimated using maximum restricted likelihood [27] (appendix, p 5). We used maximum restricted likelihood to set probable historical patterns. We presented here not necessary the most exact IMR estimations but for sure the most probable ones due to the available estimations in the country.

RESULTS

Our estimation shows that the trend in IMR has changed with respect to previous decades (Figure 1), confirming our hypothesis. Trends in IMR from previous decades started changing from 2009 onward. IMR stopped declining and a new stage of increase is now observed. The steepest rise is seen after 2011, following the entrenchment of economic and politic meltdown. Gains achieved during the first decade of the 21th century have been completely cancelled out over the last seven years. By 2016, IMR (20·3 deaths per thousand live births) had fallen back to the level observed in the end-nineties.

Comparing our results with IGME (2017 revision) we noticed that the IMR figures before 2011 were very similar (Figure 2). As said before, IGME's most recent data for estimating IMR come from the 2013 vital registration system. These data certainly cannot account for the effects of the recent deterioration in living conditions in Venezuela. It should give clues about increasing mortality rates before 2013, however. Differences between our estimations and IGMEs exceed 10% in 2012 and 14% in 2013 (appendix, pp 6-7). We found the same discrepancy when observing World Health Organization (WHO) estimations 2017's revision. [28] Digging deeper into the data is possible to see differences come from births estimations. Birth figures contemplate by WHO are considerably higher when comparing with ours but also in comparison with ECLAC's latest estimations. [18] There has been a reduction in the births rate that is possible to capture through 2011's census data and when following adjusted births in vital registration for the recent years.

Putting our results in an analytical framework, according to Reed *et al* (1998), several stages of alerts based on mortality rates can be used as thresholds to formally declare a humanitarian emergency. These thresholds can be either fixed or assigned according to a baseline. [29] One way to see it, is to link stages to specific proportional increases. Thus, an initial phase of a crisis is determined by the time in which the rate doubles its value, while the height of the crisis will be the phase between the doubling and its maximum increase. In Venezuela, IMR during the year 2016 (20·3) was 1·33 times 2008's IMR (15·2). This means that the country is on the way to entering the second stage of a humanitarian crisis.

Future prospects do not seem encouraging. To put this in context, 2017 2018 WHO report indicated that during the first decade of the 21st century malaria prevalence stabilized at around 1·5 per thousand inhabitants, with lethality at under 0·05% of the reported cases (appendix, pp 8-9). By 2016, incidence had increased fivefold to 7·5 per thousand inhabitants and continued increasing up to 10·1 during the year 2017. [14] Up to now, Malaria outbreaks have been mostly geographical concentrated in the southern area, where uncontrolled mining activity has substantially increased. However, WHO most recent reports started to allocate cases all over the country.

Likewise, measles cases have tripled since 2013. While in the past, there were rarely more than 300 cases per year, 727 cases were reported in 2017 and 904 cases in the first quarter of 2018. The age group most affected among the confirmed cases is children under 5 years of age. [15] Diphtheria, a diseases eradicate in Venezuela since the nineties, has reappeared. Diphtheria outbreaks continues spreading, in total 1602 cases have been reported since 2016 (324: 2016, 1040:2017, and 352:January-April 2018). So far, cumulative diphtheria lethality exceeds 14% of reported cases [16] when it does not normally exceed 10%. [30] Medicine shortage, elevated cost of antibiotics cost and deficit of tetanus-diphtheria booster impair the situation.

In addition to the alarming malaria, measles and diphtheria outbreaks, reported diseases in the 2014-2016's Notifiable Diseases Bulletins (NDB) [21] showed constant increases in cases of diarrhea (34·6%) and acute bronchitis (almost 40%), as well as an upsurge in already high maternal mortality. 65·79% more deaths were associated to complications during childbirth in 2016 than in previous years. Deterioration of health system and less access to monthly pregnancies control contributed to this increase.

DISCUSSION

Different methods have been used in this work to produce accurate infant mortality estimations, from simple linear regression adjustment to more sophisticated techniques such as splines. We believe we have provided robust estimations and fill the gap of national statistics for the most recent years. Our assumptions have indeed been based on the most conservative scenarios in which, despite the deep crisis, late-registration patterns and proportions of hospital deaths with respect to overall deaths remained stable. Even so, the results are shocking.

The United Nations Millennium Development Goals (MDGs) and the Sustainable Development Goals (SDGs or Global Goals) of the 2030 Agenda consider child mortality as a key indicator of health, social and environmental conditions. In this framework, and as a member of the United Nations, Venezuela assumed the legal commitment to reduce infant mortality to 9 or less per thousand live births by the year 2015. This commitment has not been reached. During the 2000s, Venezuela has created policies aimed at the most vulnerable population, such as health missions. But those efforts are not reflected in the Venezuelan children avoidable deaths. As the concluding year of the MDGs, Venezuela resumed its international engagement to SDGs to eradicate preventable infant deaths. Regrettably, far from succeeding, the country is showing for the first time a deterioration of child survival. Venezuela is the only country in South America that has fallen back to the levels of the 1990s.

During deep crisis the most common causes of death are the same as those reported in countries with the highest child mortality rates: diarrhoeal diseases, acute respiratory infections, measles, malaria, and severe malnutrition. [20] As it showed all these elements are already presented in Venezuela and certainly adversely affect future IMR trends. Organizations such as the Venezuelan Health Observatory, [31] International Amnesty [32] and recently the United Nations Refugee Agency [33] have acknowledged the state of humanitarian crisis existing in Venezuela. In 2016, the Venezuelan National Assembly declared a humanitarian crisis in the country and requested international humanitarian aid to facilitate the importation of medical supplies and medicines into the country [4]. This and all other attempts have been vetoed by the government.

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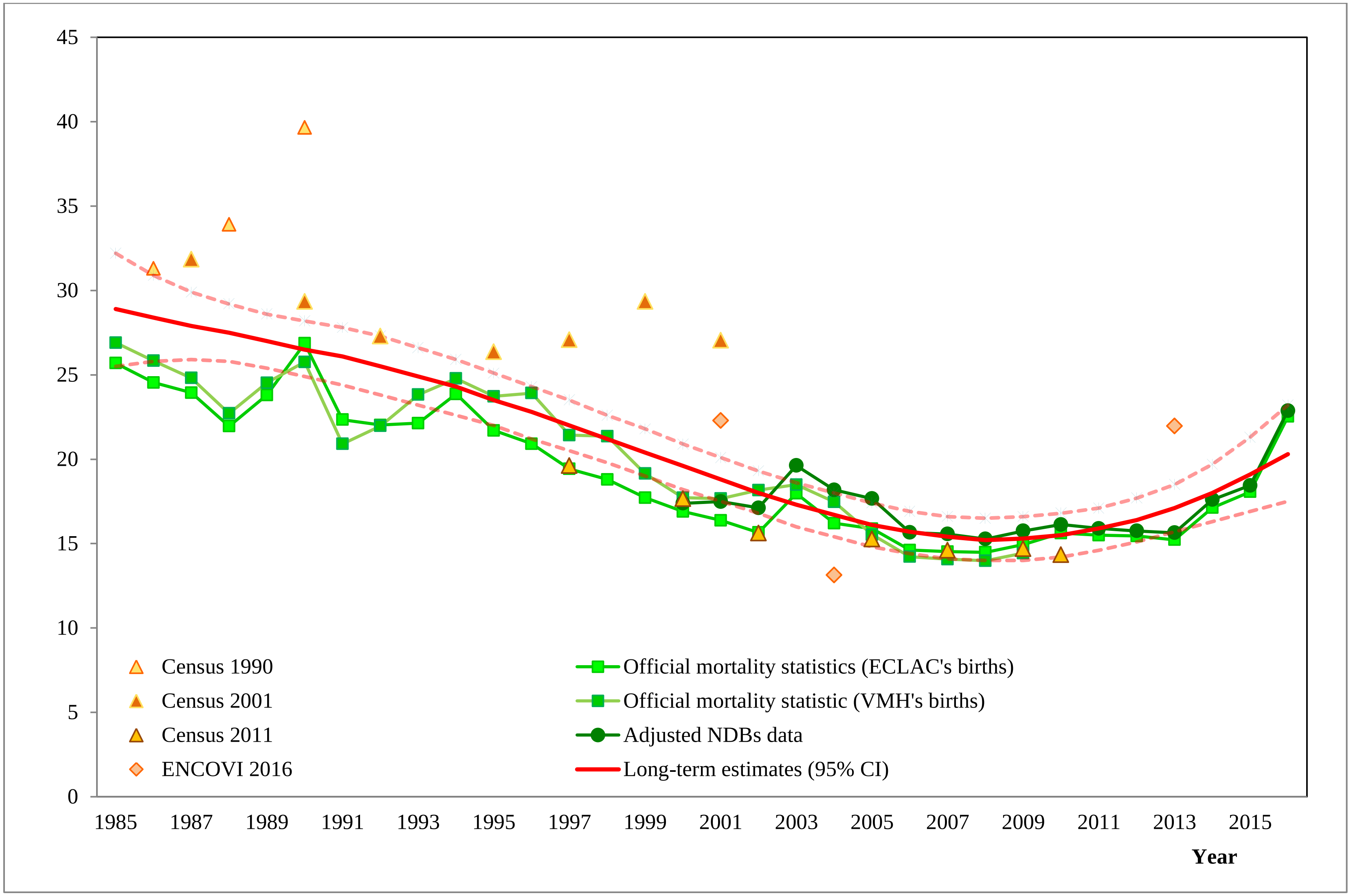

Figure 1: Venezuelan infant mortality estimations, 1985-2016.

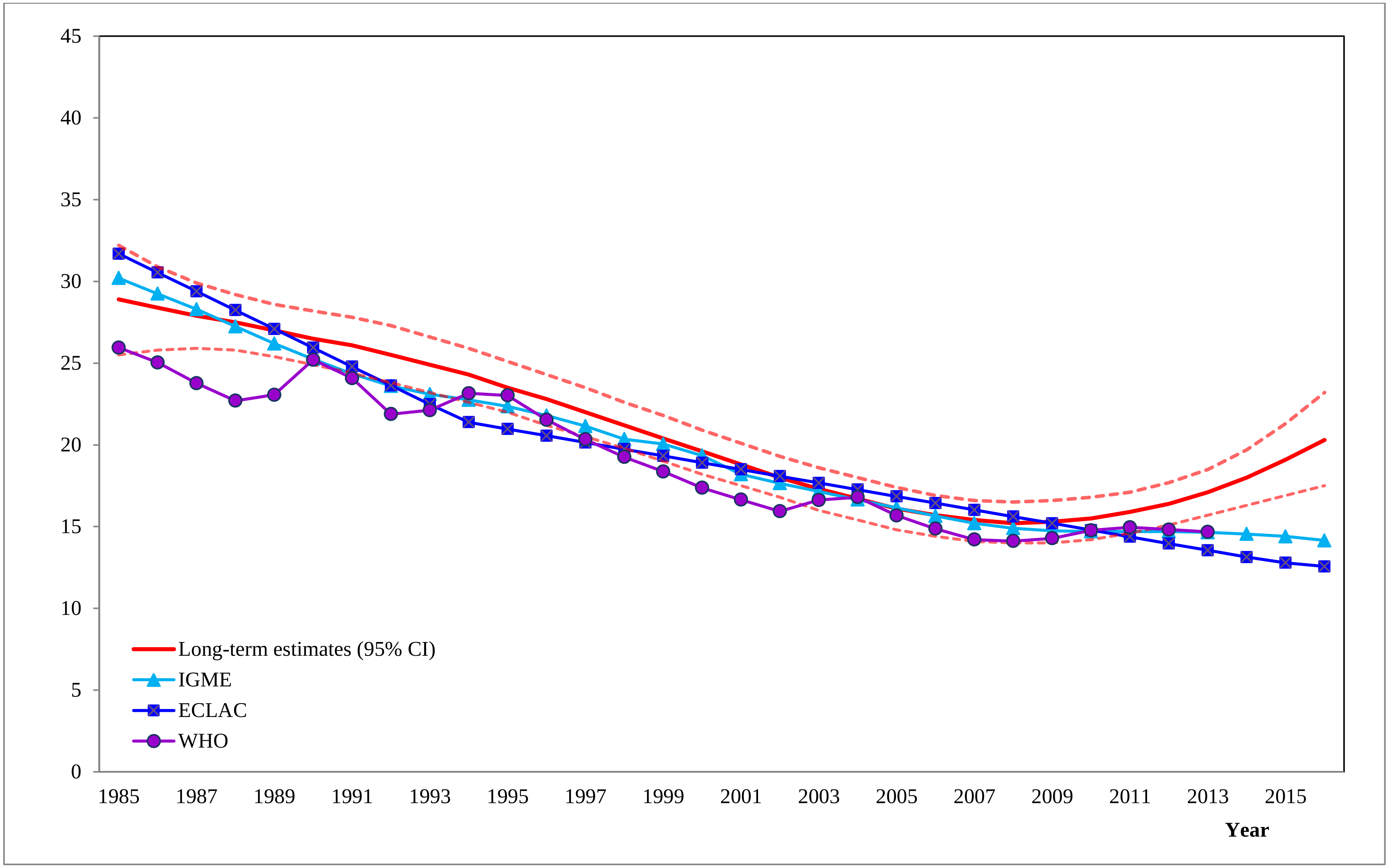

Figure 2: Comparison with international Venezuelan infant mortality estimations, 1985-2016.

Infant mortality in Venezuela: a humanitarian crisis under way
Supplementary Material

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Content

List of Tables

1. Estimating infant mortality rates

Infant mortality rate requires computing death counts in the population under one-year old as well as live births during the same period. In order to provide long-term infant mortality estimation and to face recent lack of official mortality estimations, three sets of infant mortality rates (IMR) were approximated in this study. Grouping depended on the available mortality database for IMR computation, consequently also the estimation method applied. The first group is IMRs calculated using *Official mortality statistics* corresponding to the period 1985 to 2013. The second group tallies to adjusted death counts published in the *Notifiable Diseases Bulletins* for the years 2003 to 2016. Finally, a third group of estimations obtained through indirect methods on *others demographic databases*. All IMRs were later on synthesized by a P-Splines model into one smoothed long-term dataset.

1.1. Official mortality statistics

IMR were directly calculated through official death counts published by the Venezuelan Ministry of Health (VMH) and reported by the World Health Organization (WHO). Deaths in which a medical certification had been issued are listed in VMH's mortality yearbooks. PDF file versions of these mortality yearbooks from 1985 to 2013 were until recently available online. The Venezuelan vital statistics system has better data quality and coverage than most Latin American countries. [1] In fact, at the beginning of the eighties proportion of under-coverage was already estimated in less than 10% [2] and continuous improvements placed it in 2010 between 4% and 9%. [3)]

Two IMR time series were estimated using official death counts: The first one took birth counts held as reference by VMH for producing its official infant mortality rates. [4] Births counts aforesaid are the result of adjusting registered birth published by the Venezuelan National Institute of Statistics (VNIS). We availed the availability of these adjusted counts to produce IMR from 1985 to 2009. However, some issues came up concerning this data. The assumptions taken for the adjustment could not be found in any technical document published either by VMH or VNIS. In addition to this, still some figures were need for the most recent years (2010-2013).

We calculated a second set of IMR estimations for the period 1985 to 2013. This time, the denominator came from the United Nation Economic Commission for Latin America and the Caribbean (ECLAC) birth records [5] published in 2016. Both sets are displayed in Table 1. ECLAC's estimations cover the period 1950 to 2100. These long–term figures are updating with each household and population census data. Latest census gleaned in 2011 [6] allowed to review recent trends in fertility patterns.

Some differences were found when comparing results. Setting VHM's birth counts as the benchmark to compute the proportional difference, it was possible to evince an over-estimation of ECLAC's figures for most of the period. Exceptionally the years 1990 and 1991 in which VHMs had greater amounts. From 2005 on trend changed and births used by VHM progressively started to be higher than those adjusted by ECLAC according to 2011 census findings. Because the two time series were built with official statistics without strong elements to disregard either of them, they were both considered.

1.2. Notifiable Diseases Bulletins data

We estimate IMR from 2003 to 2016 using direct methods on adjusted deaths and births. Deaths came from adjusted annual summary of the weekly Notifiable Diseases Bulletins (NDB). [7] Since the year 2003, NDB has incorporated under one-year-old-population death counts along with death counts associated with pregnancy, childbirth and the puerperium conditions occurred on the premises of the health system. NDB were not usually available for the general public. Instead, Morbidity yearbook summarized data related to some specific diseases reported on it. On May 2017, weekly NDB corresponding to the years 2002 to 2016 were briefly released on the VHM's official website. [8] We adjusted these figures. For this second set of estimations, we adjusted deaths reported on NDB as well as births counts published by the VNIS to produce the most recent IMR.

Table 1: Infant mortality rates considering official mortality statistics.

Year	Official Death counts	Births		Infant Mortality Rates		% Difference
		ECLAC	VMH	ECLAC's births	VMH	
1985	13517	525983	502329	25.7	26.9	4
1986	13028	530781	504278	24.5	25.8	5
1987	12823	535578	516773	23.9	24.8	4
1988	11867	540376	522392	22.0	22.7	3
1989	12976	545173	529015	23.8	24.5	3
1990	14776	549970	573501	26.9	25.8	-4
1991	12394	554768	592785	22.3	20.9	-7
1992	12327	559565	560994	22.0	22.0	0
1993	12494	564362	524387	22.1	23.8	7
1994	13577	568840	547819	23.9	24.8	4
1995	12352	569165	520584	21.7	23.7	9
1996	11913	569490	497975	20.9	23.9	13
1997	11069	569815	516636	19.4	21.4	9
1998	10721	570139	501808	18.8	21.4	12
1999	10108	570464	527888	17.7	19.1	7
2000	9649	570789	544416	16.9	17.7	5
2001	9353	571114	529552	16.4	17.7	7
2002	8949	571438	492678	15.7	18.2	14
2003	10276	571763	555614	18.0	18.5	3
2004	9272	572088	530565	16.2	17.5	7
2005	9093	572413	585655	15.9	15.5	-2
2006	8371	572738	588500	14.6	14.2	-3
2007	8323	573062	591345	14.5	14.1	-3
2008	8307	573387	594191	14.5	14.0	-4
2009	8577	573712	594300	15.0	14.4	-4
2010	8965	574037		15.6		
2011	8900	574361		15.5		
2012	8881	574686		15.5		
2013	8757	575011		15.2		

1.2.1. Adjusting death counts

Due to the main aim of the NDB is not to report all death counts, but those occurred on the premises of the health system. Its annual summary underestimated mortality yearbook counts. We captured this underestimation into a statistical relation and foreseen deaths for the period 2014 to 2016 assuming continuity on previous pattern. In other words, proportion-of-hospital-death pattern from previous years remained despite the deep crisis. We established a ratio between death count from mortality yearbooks and those in NDB during the years 2003 to 2013. This underestimation ratio was linearly related to time and it was possible to express as: Underestimation ratio=-0.0532year+1.8694. Thus, we corrected under-reported deaths from the NDB counts through a linear prediction of the ratio. Our result in Table 2 pointed up death counts reported in the NDBs represents from 81.2% to 88.9% of the deaths that would have been reported in the mortality yearbook.

1.2.2. Adjusting births counts

Registered births gathered and published by the Venezuelan National Institute of Statistics (VNIS) [9] were adjusted to estimate IMR. VNIS has made available online registered births considering the year of their occurrence. To approximate purely occurred births by year-calendar from registered birth, we followed cumulative time lags in registered birth for a twelve-year period (2000 to 2012). We created a Proportional Factor (PF) for each year. Our results pointed out that it takes six-years-delay to achieve 99% or more of occurred births to be registered.

Base on previous computations, we adjusted occurred births from 2006 to 2012. Adjustment of births occurred in year y (B_y^o) are made taking into account births occurred and registered in the same year B_y^r plus the proportion of unregistered births calculated from the proportional factor

$$B_y^o = B_y^r + \left(B_y^r * \left(1 - PF_{2012-y}\right)\right).$$

Once all known information is complete we established an annual registration-occurrence ratio. The average of the lasts three years-with-information ratio (2009 to 2011) is applied for the last four years in which no information related to year of occurrence is found (2013 to 2016). Results are shown in Table 2. We chose the average of the ratio because there was not statistical significant relation to establish. Disregarding on the year 2012 is based on the consideration of exaggerated late-registration for the year when comparing previous ones.

Table 2: Infant mortality rates considering adjusted birth and death counts.

Year	Deaths				Births					IMR
	Mortality Yearbooks	**Notifiable Diseases Bulletin NDB**	**Under estimation ratio**	**Adjusted deaths**	**Registered**	**Occurred**	**PF**	**registration /occurrence ratio**	**Adjusted births**	
2000	9649				544416	554987	1.00	1.0	554987	
2001	9353				529552	534785	1.00	1.0	534785	
2002	8949				492678	488678	1.00	1.0	522885	
2003	10276	5810	0.56	10276	555614	523627	1.00	1.1	523627	19.6
2004	9272	5444	0.58	9272	637799	509979	1.00	1.3	509979	18.2
2005	9093	5084	0.55	9093	665997	514784	1.00	1.3	514784	17.7
2006	8371	6104	0.72	8371	646225	531760	0.99	1.2	534471	15.7
2007	8323	4745	0.57	8323	615371	531151	0.99	1.2	534564	15.6
2008	8307	5187	0.62	8307	581480	538848	0.99	1.1	543808	15.3
2009	8577	5083	0.59	8577	593845	537148	0.99	1.1	544548	15.8
2010	8965	5839	0.65	8965	591303	542856	0.98	1.1	555825	16.1
2011	8900	5873	0.65	8900	615132	542164	0.97	1.1	559770	15.9
2012	8881	7009	0.78	8881	619530	474020	0.85	1.3	563772	15.8
2013	8757	8273	0.94	8757	597902			1.1	559738	15.6
2014		8005	0.81	9852	597773			1.1	559617	17.6
2015		8812	0.84	10377	600875			1.1	562521	18.4
2016		11443	0.87	12866	600746			1.1	562401	22.9

1.3. Others demographic databases

A third group of IMR estimations is obtained through indirect methods on census data from the 1990 [10], 2001 [11] and 2011[6] census round carried out by VNIS and a recent National Survey of Living Conditions of Venezuelan Population ENCOVI-2016. [12]. Census data and ENCOVI-2016 gleaned information about the number of children ever born and children dead by women's age. This information known as Summary Birth Histories (SBH) is used to apply Brass' model-based method to estimate IMR.

SBH does not provide enough data for direct calculation of IMR because deaths do not precise exposure times. The analysis is done considering an average exposure-time indirectly approaches from mothers' age. [13] Then, the probability of dying $q_{(a)}$ depends on mother's age($M_{(x,5)}$) and the proportion of dead children ($D_{(x,5)}$)

$$q_{(a)} = M_{(x,5)} * D_{(x,5)}$$

Through fertility and mortality model age patterns, mothers' age is converted into a standard life table function. Here, we used Trussell's variant of Brass method. This variant calculated multipliers to transform proportions of dead children into cohort–specific probabilities of dying through regression approach. [14] For all estimation west model of Coale-Demeny life tables were considered. Results are in Table 3.

Table 3: Infant mortality rates indirect methods on others demographic databases

Year	Census 2011	Census 2001	Census 1990	ENCOVI 2016
1985				
1986			31.3	
1987		31.8		
1988			33.9	
1989				
1990		29.3	39.7	
1991				
1992		27.3		
1993				
1994				
1995		26.4		
1996				
1997	19.6	27.1		
1998				
1999		29.3		
2000	17.6			
2001		27.0		22.3
2002	15.6			
2003				
2004				13.1
2005	15.2			
2006				
2007	14.5			
2008				
2009	14.6			
2010	14.3			
2011				
2012				
2013				22.0

2. Estimating long-term infant mortality rates

Pursuing the aim to smooth and synthetize all previous IMR estimations were combined in a p-splines model. This model allowed to eliminate irregularities in the series introduce by the combination of several data sources and methods of adjustment, without losing possible changes in the pattern. [15] We intended to estimate not necessary the most exact IMR but for sure the most probable ones due to the available estimations in the country. Our long-term estimation from 1985 to 2016 is shown in Table 4.

The p-spline method uses the independent variable to build a base for the regression. Later on, by introducing a penalty based on differences between adjacent coefficients, the likelihood function of the model is modified. To apply the p-splines method is necessary to select the degree and location of the nodes *k*, it means the function that will build the base and the form of penalty *y*. To generate the base, we used the cubic thin plate function expressed as a mixed model:

$$y_i = f(x_i) + \varepsilon_i. \quad \varepsilon_i \sim N(0.\sigma_\varepsilon^2)$$

Where, y_i refers to the years and x_i to the IMR previous estimation, while ε_i to the error. Then f(x) is given by:

$$f(x) = \beta_0 + \beta_1 x + \sum_{k=1}^{K} u_k \, |x - k_k|^3$$

With the random effects u:

$$u = [u1. \ldots\ldots uK]^T \sim N\left(0.\sigma_u^2 \Omega^{-1/2} \left(\Omega^{-1/2}\right)^{\mathrm{T}}\right)$$

and its matrix of variances and covariance is:

$$\Omega = \left[\left|k_{\mathrm{k}} - k_{\mathrm{k}'}\right|^3{}_{1 \le \mathrm{k}.\mathrm{k}' \le \mathrm{K}}\right]$$

The number of knots k and their places k_{k} were automatically selected using the expressions:

$$K = min\left(\frac{n}{4}.20\right).$$

In which n is the number of IMR previous estimations inserted in the model and $k_K = \left(\frac{k+1}{K+2}\right)$ th simple quantile of the unique $x_{i.}$

The smoothing parameter was selected as the quotient of random effects variance and fixed effects variance, $\sigma_u^2/\sigma_\varepsilon^2$ which in turn were calculated using the restricted maximum likelihood method.

Table 4: Long-term Infant mortality rates

Year	IMR	Low CI	High CI
1985	28.9	25.5	32.2
1986	28.4	25.8	30.9
1987	27.9	25.9	29.9
1988	27.5	25.8	29.2
1989	27.0	25.4	28.6
1990	26.5	24.9	28.2
1991	26.1	24.4	27.8
1992	25.5	23.8	27.3
1993	24.9	23.2	26.6
1994	24.3	22.6	25.9
1995	23.5	22.0	25.1
1996	22.8	21.2	24.3
1997	22.0	20.5	23.5
1998	21.2	19.8	22.6
1999	20.4	19.0	21.8
2000	19.6	18.2	20.9
2001	18.8	17.5	20.1
2002	18,0	16.8	19.3
2003	17.3	16,0	18.6
2004	16.7	15.4	18,0
2005	16.1	14.8	17.4
2006	15.7	14.4	16.9
2007	15.4	14.1	16.6
2008	15.2	14,0	16.5
2009	15.3	14,0	16.6
2010	15.5	14.2	16.8
2011	15.9	14.6	17.1
2012	16.4	15.1	17.7
2013	17.1	15.7	18.5
2014	18,0	16.3	19.7
2015	19.1	16.9	21.3
2016	20.3	17.5	23.2

3. Comparing with others infant mortality estimations

We compared our estimation with international organizations IMR's estimation. For the comparison, we set as benchmark our estimations and used to determine de proportional difference with the others estimations. Three time series were chosen and they are presented in Table 5:

1) United Nation Economic Commission for Latin America and the Caribbean (ECLAC), estimate long-term mortality rates for the period 1950 to 2015 and project its pattern until 2050. This estimation was built on the basis of life tables, implicit in the population projections with corrections to the anomalies derived from mistakes in the recording of data. [16] ECLAC has updated all its estimation in 2016 considering last census round and recent assessments on vital statistic records.

2) United Nations Inter-Agency Group for estimating infant mortality (IGME) produces an annual report on trends in neonatal, infant and under-five mortality for all United Nations members combining all available sources of information in each country. Mortality rates are calculated from data on births and deaths in life tables, censuses and household surveys and when possible through vital registration systems. Estimates based on DHS surveys come directly from complete birth history or indirectly if the information is gathered in summary births histories (Brass's method). IGME does not use any covariates to derive its estimates. It only applies a curve fitting method to good-quality empirical data to derive trend estimates after data quality assessment. [17] IGME harmonizes trends over time, and produce up-to-date estimates. IGME latest update was in 2017, however the most update Venezuelan data remained as IMR estimated by the Venezuela National Institute of Statistic (VNIS) and World Health Organization (WHO) on 2013 death and birth counts. IMR estimations published by IGME for the period after 2013 were done on the assumption of a continuous decrease in infant mortality.

3) World Health Organization (WHO) estimates annual mortality bases on the information given by the countries. In Venezuela's case, estimations are based on data reported by the Ministry of Health (VMH). These estimations were updated during the year 2016 but as said before, the latest reported death counts published by VMH were in 2013. WHO adjusts both death and birth counts base on to its coverage assessment of the vital statistic system.

Table 5: Comparison with international infant mortality estimations

Year	IMR Estimates	IGME		ECLAC		WHO	
		IMR	% Difference	IMR	% Difference	IMR	% Difference
1985	28.9	30.2	-4	31.7	-10	26.0	10
1986	28.4	29.3	-3	30.5	-8	25.0	12
1987	27.9	28.3	-1	29.4	-5	23.8	15
1988	27.5	27.3	1	28.2	-3	22.7	17
1989	27.0	26.2	3	27.1	0	23.1	15
1990	26.5	25.3	5	25.9	2	25.2	5
1991	26.1	24.4	7	24.8	5	24.1	8
1992	25.5	23.6	7	23.6	7	21.9	14
1993	24.9	23.1	7	22.5	10	22.1	11
1994	24.3	22.8	6	21.4	12	23.2	5
1995	23.5	22.4	5	21.0	11	23.0	2
1996	22.8	21.8	4	20.6	10	21.5	6
1997	22.0	21.2	4	20.1	8	20.3	8
1998	21.2	20.4	4	19.7	7	19.3	9
1999	20.4	20.1	2	19.3	5	18.4	10
2000	19.6	19.4	1	18.9	4	17.4	11
2001	18.8	18.2	3	18.5	2	16.6	11
2002	18.0	17.7	2	18.1	0	15.9	11
2003	17.3	17.2	1	17.7	-2	16.6	4
2004	16.7	16.7	0	17.3	-3	16.8	-1
2005	16.1	16.2	0	16.8	-5	15.7	3
2006	15.7	15.7	0	16.4	-5	14.9	5
2007	15.4	15.2	1	16.0	-4	14.2	8
2008	15.2	14.9	2	15.6	-3	14.1	7
2009	15.3	14.8	4	15.2	1	14.3	7
2010	15.5	14.7	5	14.8	5	14.8	5
2011	15.9	14.7	8	14.4	10	15.0	6
2012	16.4	14.7	10	14.0	15	14.8	10
2013	17.1	14.7	14	13.5	21	14.7	14
2014	18.0	14.6	19	13.1	27		
2015	19.1	14.4	25	12.8	33		
2016	20.3	14.2	30	12.6	38		

4. Some infectious and parasitic diseases

Several epidemiological alerts have been emitted by the WHO in recent years about infectious disease outbreaks in Venezuela. Three diseases are the one showing the biggest increase Malaria [18], Diphtheria [19] and Measles [20]. We gather all information found not just in the WHO epidemiologic alert or update but also in Morbidity yearbooks [21] and Notifiable Diseases Bulletins [22] published by the Venezuelan Ministry of Health.

We cross the information on reported and confirmed cases of these diseases in the country with reported deaths in Mortality yearbooks to establish a *lethality* rate as a ratio between reported death and cases per one thousand inhabitants. Likewise, we examine the incidence of the diseases through total population. This estimation of a *morbidity rate* is the ratio of reported cases and total population estimated by the National Institute of Statistics based on census 2011. Morbidity rate is presented per one hundred thousand inhabitants (100,000).

Table 6: Malaria, Diphtheria and Measles reported cases and deaths

Year	MALARIA					DIPHTHERIA				MEASLE			
	Reported Cases*	Death Total Population	Death under one year	Lethality$	Morbidity rate+	Reported Cases*	Death Total Population	Lethality$	Morbidity rate+	Reported Cases*	Death Total Population	Lethality$	Morbidity rate+
1995	22501	47	6	0.21	102.1	0	0	0	0.0	172	2	1.2	0.8
1996	21852	68	11	0.31	97.1	0	0	0	0.0	85	0	0.0	0.4
1997	22400	56	4	0.25	97.6	0	0	0	0.0	27	0	0.0	0.1
1998	21815	62	4	0.28	93.2	0	0	0	0.0	4	0	0.0	0.0
1999	19086	24	4	0.13	80.0	0	0	0	0.0	0	0	0.0	0.0
2000	29736	24	2	0.08	121.9	0	0	0	0.0	24	0	0.0	0.1
2001	20006	28	7	0.14	80.7	0	0	0	0.0	123	0	0.0	0.5
2002	29491	23	3	0.08	117.0	0	0	0	0.0	2391	3	0.1	9.5
2003	31719	40	2	0.13	123.8	0	0	0	0.0	0	0	0.0	0.0
2004	46655	35	1	0.08	179.2	0	0	0	0.0	0	0	0.0	0.0
2005	45049	17	1	0.04	170.4	0	0	0	0.0	0	0	0.0	0.0
2006	37062	11	0	0.03	138.0	0	0	0	0.0	95	0	0.0	0.4
2007	41749	16	0	0.04	153.1	0	0	0	0.0	23	1	4.3	0.1
2008	32037	9	1	0.03	115.7	0	0	0	0.0	0	0	0.0	0.0
2009	35828	12	0	0.03	127.5	0	0	0	0.0	0	0	0.0	0.0
2010	45155	18	2	0.04	158.3	0	0	0	0.0	nd	nd	nd	nd
2011	45824	16	1	0.03	158.3	0	0	0	0.0	286	0	0.0	1.0
2012	52803	11	0	0.02	179.8	0	0	0	0.0	391	0	0.0	1.3
2013	78643	38	2	0.05	264.0	0	0	0	0.0	178	0	0.0	0.6
2014	90708	nd	nd	nd	300.3	0	0	0	0.0	240	0	0.0	0.8
2015	136402	nd	nd	nd	445.5	0	0	0	0.0	296	0	0.0	1.0
2016	240613	nd	nd	nd	775.5	324	17	52.5	1.0	324	0	0.0	1.0
2017	319765	nd	nd	nd	1017.4	1040	103	99.0	3.3	727	0	0.0	2.3
2018 (Jan-April)	nd	nd	nd	nd	nd	352	40	113.6	0.7	904	2	0.2	2.8

*nd=No data available

+Morbidity Rate= Reported cases per 100,000 inhabitants

$Lethality= D**e**ath per 1,000 reported cases

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