# Measuring Iran's success in achieving Millennium Development Goal 4: a systematic analysis of under-5 mortality at national and subnational levels from 1990 to 2015

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## Summary

**Background** Child mortality as one of the key Millennium Development Goals (MDG 4—to reduce child mortality by two-thirds from 1990 to 2015), is included in the Sustainable Development Goals (SDG 3, target 2—to reduce child mortality to fewer than 25 deaths per 1000 livebirths for all countries by 2030), and is a key indicator of the health system in every country. In this study, we aimed to estimate the level and trend of child mortality from 1990 to 2015 in Iran, to assess the progress of the country and its provinces toward these goals.

**Methods** We used three different data sources: three censuses, a Demographic and Health Survey (DHS), and 5-year data from the death registration system. We used the summary birth history data from four data sources (the three censuses and DHS) and used maternal age cohort and maternal age period methods to estimate the trends in child mortality rates, combining the estimates of these two indirect methods using Loess regression. We also used the complete birth history method to estimate child mortality rate directly from DHS data. Finally, to synthesise different trends into a single trend and calculate uncertainty intervals (UI), we used Gaussian process regression.

**Findings** Under-5 mortality rates (deaths per 1000 livebirths) at the national level in Iran in 1990, 2000, 2010, and 2015 were 63·6 (95% UI 63·1–64·0), 38·8 (38·5–39·2), 24·9 (24·3–25·4), and 19·4 (18·6–20·2), respectively. Between 1990 and 2015, the median annual reduction and total overall reduction in these rates were 4·9% and 70%, respectively. At the provincial level, the difference between the highest and lowest child mortality rates in 1990, 2000, and 2015 were 65·6, 40·4, and 38·1 per 1000 livebirths, respectively. Based on the MDG 4 goal, five provinces had not decreased child mortality by two-thirds by 2015. Furthermore, six provinces had not reached SDG 3 (target 2).

**Interpretation** Iran and most of its provinces achieved MDG 4 and SDG 3 (target 2) goals by 2015. However, at the subnational level in some provinces, there is substantial inequity. Local policy makers should use effective strategies to accelerate the reduction of child mortality for these provinces by 2030. Possible recommendations for such strategies include enhancing the level of education and health literacy among women, tackling sex discrimination, and improving incomes for families.

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## Introduction

Child mortality is an indicator of the health and social development of populations.[1,2] Despite many efforts, investments, and interventions to improve child survival in response to the Millennium Development Goals (MDGs), however, child mortality remains a major source of concern in most countries worldwide.[3,4] Many countries have high child mortality rates (CMRs) and about 6 million children aged younger than 5 years died in 2015.[5,6] Evidence suggested that many low-income countries would be unlikely to achieve the MDG 4 child health targets by 2015.[6]

Now that 2015 is behind us, there is much focus on the assessment of progress made towards these goals, especially regarding child mortality. Moreover, the Sustainable Development Goals (SDGs), include a new target on the reduction of child mortality to fewer than 25 deaths per 1000 livebirths for all countries by 2030.[7] We aimed to do so for Iran.

Iran, like many developing countries, has an incomplete death registration system (DRS).[8–10] National and international researchers have attempted to use other methods and data sources to produce

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## Research in context

### Evidence before this study

We searched PubMed using the terms (["Child Mortality"[Mesh]) OR "Infant Mortality"[Mesh]) OR "Infant Death"[Mesh])) OR ("under-five mortality" OR "under-5 mortality" OR "under five mortality" OR "under 5 mortality" OR "summary birth history" OR "complete birth history")) AND ("Iran OR Persian OR (Persia*") OR "I. R. Iran" OR (iran*); SCOPUS with the terms TITLE-ABS-KEY ("child mortality") OR ("infant mortality") OR ("neonatal mortality") OR ("under-five mortality") OR ("under-5 mortality") OR ("under five mortality") OR ("under 5 mortality") OR ("summary birth history") OR ("complete birth history") OR ("Infant Deaths" ) AND ("iran") OR ("persia*") OR AFFIL ("iran) OR (persia*"); and Web of Science using ("child mortality" OR "infant mortality" OR "neonatal mortality" OR "under-five mortality" OR "under-5 mortality" OR "under five mortality" OR "under 5 mortality" OR "summary birth history" OR "complete birth history" OR "Infant Deaths" OR "Death, Infant" OR "Deaths, Infant") AND TOPIC ("iran OR (persia*)"). We identified 115 articles in PubMed, 286 in SCOPUS, and 82 in Web of Science; we excluded 370 papers by removing duplicates. We also searched in Farsi web search engines including Irandoc, Iranmedex, and SID and extracted 337 articles. We screened articles according to inclusion criteria that were related to estimates of child mortality in Iran using population-based data sources. We included reports that had valid data sources, addressed the incompleteness of the Death Registration System (DRS) and applied demographic methods including censuses, and data from the DRS, and Demographic and Health Surveys (DHS). We ended up assessing four reports from all articles based on these criteria. The reports that provided the longest and most complete trends and levels for child mortality were the Global Burden of Disease (GBD) articles on child mortality estimation, which provided estimates at a national, not subnational, level for Iran. We also identified a systematic review from different data sources published in 2004 that reported child mortality only at a national level for Iran, without addressing issues with incompleteness. Another study published in 2014 that estimated child mortality in Iran and its 31 provinces by indirect methods from 2006 and 2011 censuses (a shorter period compared with our study) did not use all available data including censuses from previous years and DHS, and also did not provide interval estimations. Neither study reported completeness nor trends and levels of child mortality in Iran and provinces from 1990 to 2015 by using all available and valid data sources.

### Added value of this study

Child mortality estimation is an important indicator of, and has substantial effect on, public health. This is the first study to estimate trends and levels of child mortality at national and subnational levels in Iran between 1990 and 2015. Different data sources were used in this project, particularly censuses from 1996 and 2006 (the 2011 census was omitted because of low quality), DHS 2000 (2010 was omitted because of low quality), and also DRS from 1995 to 2010 for our target timespan. We also constructed various covariate datasets from Household Income and Expenditure Surveys including wealth index, years of schooling, and urbanisation. We developed novel statistical models, which were applied for the first time in a GBD report. The models included demographic characteristics models (summary and complete birth history) and statistical models (spatiotemporal and Gaussian process regression). We used these models to predict mortality rate during the years that we had datapoints for, up to 2015.

### Implications of all the available evidence

Reducing child mortality rate is a key Sustainable Development Goal. Policy makers should be aware of the baseline estimation of child mortality rates at a provincial level, to be more efficient in resource allocation and to address child mortality inequalities between provinces. Since this study was commissioned by the Iranian Ministry of Health, the results could be directly used by policy makers.

acceptable estimates of CMRs for Iran. These estimations are useful, but have some limitations and cannot portray the full picture. Some of these studies, which were undertaken nationally, did not use robust or reliable methods to produce accurate estimates for the level of mortality and long-term assessments of interventions.[11] Other studies did not include uncertainty intervals for their estimates, and therefore we cannot assess their precision.[11,12] Some international bodies such as the Institute for Health Metrics and Evaluation and the UN Interagency Group for Child Mortality Estimation (IGME) have used appropriate methods to calculate CMR, yet their estimations are only at the national level and do not give subnational figures, potentially masking inequalities across the country.[5,13]

In this report, which is part of the Iranian National and Subnational Burden of Diseases (NASBOD) project,[14] we aimed to present the national and subnational estimates of CMR during 1990–2015. We used widely accepted methods[13] and the maximum number of available data sources to assess the progress made by Iran and its provinces towards MDG 4 and SDG 3.

## Methods

### Data sources

The first step in estimating the levels and trends of child mortality is to identify relevant data sources. Generally, three data sources exist for measuring child mortality: the DRS, and summary and complete birth histories obtained from censuses and demographic and health

surveys (DHS).[9,15] We searched all the national surveys to find the databases related to child mortality in Iran, especially the Statistical Center of Iran.[16] Our searches showed that Iran's censuses of 1996, 2006, and 2011 contained questions on summary birth history. The DHS for 2000 and 2010 contained questions on both summary and complete birth history. Also, DRS data were available from 1995 to 2010.

Before analysis and to ensure the validity of our final estimates, we determined two quality criteria for our data sources. First, we examined the extent of missing values for key variables required for the analyses (the cutoff for missing data was considered between 5–10%).[17,18] In summary for birth history, we examined the percentage of missing values for children ever born and children who ever survived. Our analysis showed that in the census for 2011 and DHS for 2010, the percentages of missing values were 42% and 28%, respectively. Moreover, the percentage of missing values for date of birth, age at death, and survival status of children, which are required for the complete birth history method, were about 20%, whereas the missing values of the same variables for other datasets we used were less than 1%.

Second, the sex ratio (ratio of boys to girls) in both census 2011 and DHS 2010 was more than 1·06; a sex ratio for a population of more than 1·06 or less than 1·00 is considered implausible.[19] We extended our estimation of the sex ratio at a provincial level and it depicted that in these two datasets, most provinces had a sex ratio either more than 1·06 or less than 1·00, which is inconsistent with reports from the Statistical Center of Iran that give this ratio as 1·02 at the national level (varying from 1·01 to 1·06 at the provincial level).[16] Therefore, according to these two criteria, we excluded DHS 2010 and census 2011 from the final datasets.

We compared DRS estimates with estimates from other sources. There is a substantial level of incompleteness for all years between 1995 and 2005 (more than 50%). This underestimation of death records becomes worse at the subnational level and does not add any unbiased information for the final estimations. Therefore we excluded DRS data from 2005 and before from the final datasets.

Consequently, the final dataset that we used in the analysis contained five measurements of child mortality: two summary birth histories from censuses (1996 and 2006), one summary birth history from DHS 2000, one complete birth history from DHS 2000, and the mortality rates of the DRS from 2006 to 2010 (all available datasets).

## Data analysis

We analysed summary birth history data using two approaches—maternal age cohort and maternal age period[13]—then combined the two estimates using Loess regression.[20] In the maternal age cohort method, for each 5-year group of women (aged 15–49 years) we calculated the proportion of dead children (the number of dead children divided by the number of children ever born) and the average parity (the number of children ever born divided by the population of each age group of women). Then, using a life-table model, the relation between the proportions of children dead and the probability of dying were determined. More explanations are in the appendix.

See Online for appendix

The maternal age period method shows two distinct probability distributions: one for children's birth days and the other for death days. These distributions were obtained according to the region, age, and the number of children ever born (for the probability distribution of child birth days) and dead children (for the probability distribution of death days). Then, using these distributions, the expected numbers of children ever born and children who died were calculated for every year before the surveys. In the next stage, we aggregated the numbers of children ever born and children who died for all strata and for every year. Finally, using the life-table model, we noted the relation between the expected proportions of child death to the probabilities of death (appendix).[20]

Since the summary birth history estimates were generated through two different approaches (maternal age cohort and maternal age period), we smoothed and combined the two estimates using Loess regression.[21] The bandwidth parameter was chosen as 0·5. The weight of each datapoint was equal to the inverse of the number of points, which were generated by maternal age cohort and maternal age period. At this stage, we excluded the rate estimated from mothers aged 15–19 years, because the estimate of maternal age cohort by this age group might overestimate CMR (appendix).[20]

To calculate CMR from complete birth history data, we divided the total weighted number of under-5 deaths by

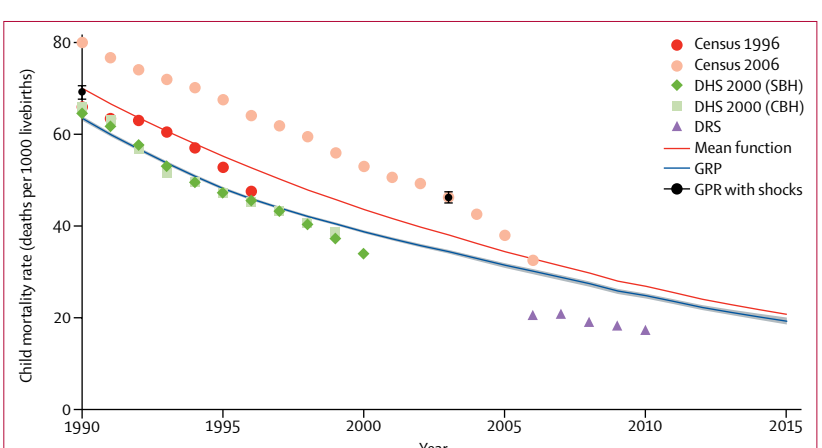


***Figure 1*: Trend in child mortality rates at national level from 1990 to 2015**
DHS-Demographic and Health Survey. SBH=summary birth history. CBH=complete birth history. GPR=Gaussian process regression.

| | 1990 | 2000 | 2010 | 2015 |
|---|---|---|---|---|
| Markazi | 63·9 (62·3–65·7) | 37·3 (35·0–40·2) | 22·3 (18·2–24·5) | 16·8 (12·8–19·2) |
| Gilan | 47·8 (47·0–48·7) | 29·6 (28·9–30·2) | 18·7 (18·0–19·4) | 15·0 (13·9–16·2) |
| Mazandaran | 48·7 (47·6–49·8) | 25·5 (25·0–26·3) | 12·4 (11·6–13·1) | 8·9 (8·0–9·5) |
| Azerbaijan, East | 74·6 (73·2–76·5) | 43·0 (42·0–43·9) | 23·1 (21·5–25·2) | 17·0 (15·0–19·6) |
| Azerbaijan, West | 88·3 (85·7–92·3) | 52·0 (47·7–55·9) | 32·1 (25·9–37·4) | 25·8 (19·2–31·5) |
| Kermanshah | 63·3 (62·3–64·5) | 39·9 (38·7–40·9) | 27·9 (26·3–28·8) | 22·6 (20·7–24·1) |
| Khuzestan | 59·0 (57·8–60·2) | 37·9 (36·7–38·8) | 23·4 (21·7–25·9) | 18·7 (16·4–21·7) |
| Fars | 53·8 (52·1–55·8) | 36·1 (34·2–38·2) | 29·4 (25·0–35·3) | 26·3 (20·8–34·6) |
| Kerman | 64·5 (63·2–65·9) | 38·6 (38·1–39·3) | 25·1 (24·1–26·1) | 20·2 (19·0–21·4) |
| Khorasan, Razavi | 87·1 (84·1–88·8) | 49·4 (48·1–50·7) | 30·6 (28·3–32·7) | 24·2 (21·6–26·3) |
| Isfahan | 54·2 (52·8–55·4) | 27·6 (22·6–28·9) | 21·4 (10·5–25·3) | 19·1 (7·3–24·6) |
| Sistan and Baluchistan | 100·5 (99·3–101·8) | 60·3 (59·4–61·4) | 34·0 (31·0–38·4) | 26·7 (23·2–32·8) |
| Kordestan | 112·2 (110·7–113·4) | 60·4 (59·2–62·4) | 37·8 (33·6–41·8) | 30·3 (24·8–35·2) |
| Hamadan | 63·9 (62·3–65·6) | 37·1 (35·4–39·9) | 24·5 (20·4–27·6) | 19·4 (15·2–23·1) |
| Chahar Mahaal and Bakhtiari | 62·6 (61·5–64·3) | 36·4 (35·1–38·9) | 21·1 (19·5–23·2) | 16·5 (14·5–18·5) |
| Lorestan | 71·0 (69·9–72·3) | 39·8 (38·4–40·4) | 20·8 (19·6–21·9) | 15·8 (14·1–17·4) |
| Ilam | 67·5 (65·5–69·6) | 39·9 (38·8–41·2) | 22·8 (20·8–26·3) | 18·1 (14·7–22·8) |
| Kohgiluyeh and Boyer–Ahmad | 65·2 (57·3–83·5) | 37·7 (33·0–48·2) | 24·7 (20·8–32·1) | 19·8 (16·5–26·2) |
| Bushehr | 64·0 (62·1–65·4) | 37·8 (36·7–38·8) | 23·1 (20·2–25·2) | 17·6 (14·7–20·4) |
| Zanjan | 95·6 (94·0–96·7) | 48·7 (47·3–50·4) | 27·0 (24·3–29·7) | 21·1 (18·2–24·3) |
| Semnan | 67·3 (66·5–68·1) | 39·7 (38·7–40·4) | 24·3 (23·0–25·9) | 18·8 (17·0–20·7) |
| Yazd | 52·7 (50·9–54·2) | 30·9 (29·3–33·0) | 24·2 (20·1–29·9) | 20·6 (16·4–28·4) |
| Hormozgan | 71·9 (70·2–73·7) | 47·0 (45·8–48·2) | 30·3 (28·9–31·6) | 23·2 (21·2–25·0) |
| Tehran | 56·8 (54·7–57·7) | 35·6 (33·8–38·7) | 21·6 (18·8–25·8) | 15·0 (11·2–22·2) |
| Ardabil | 82·9 (80·9–84·4) | 44·0 (42·0–46·4) | 23·6 (19·6–27·6) | 18·1 (13·7–23·3) |
| Qom | 56·3 (54·9–57·6) | 29·5 (28·8–30·7) | 15·9 (14·8–17·7) | 12·0 (10·9–13·7) |
| Qazvin | 66·8 (65·3–68·6) | 37·8 (37·0–38·8) | 20·0 (18·6–21·8) | 15·0 (13·4–17·2) |
| Golestan | 73·4 (72·4–76·2) | 39·7 (38·9–40·6) | 21·2 (19·4–22·6) | 16·7 (14·3–18·5) |
| Khorasan, North | 103·0 (100·6–106·1) | 55·4 (53·8–57·6) | 35·5 (33·3–37·4) | 31·3 (26·4–36·0) |
| Khorasan, South | 113·3 (106·9–116·0) | 65·8 (61·9–68·7) | 49·9 (45·9–53·6) | 47·0 (42·6–52·0) |
| Alborz | 57·2 (55·7–58·6) | 35·1 (33·3–36·5) | 17·4 (14·3–22·1) | 12·2 (8·1–19·4) |
| National | 63·6 (63·1–64·0) | 38·8 (38·5–39·2) | 24·9 (24·3–25·4) | 19·4 (18·6–20·2) |

Data are rate (95% uncertainty interval) per 1000 livebirths.

***Table 1*: Under-5 mortality rates in Iranian provinces for the years 1990, 2000, 2010, and 2015**

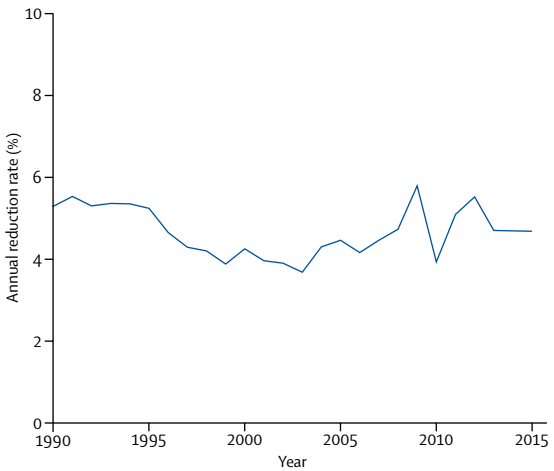


***Figure 2*: Trend in annual reduction rate at national level from 1990 to 2015**

the total weighted person-time of exposure for each year before the survey (appendix).[19]

These statistical analyses produced five time trends: three 25-year trends from summary birth histories, one 10-year trend from complete birth histories, and one 5-year trend from DRS. The final step in CMR estimation was to generate a single time trend using information from different data sources. We used Gaussian process regression,[22] which is a Bayesian technique that uses the information of estimated rates and defines a flexible model with hierarchical priors for its parameters (appendix). The Gaussian process has both a mean and covariance function. In this study, these functions were defined as the spatiotemporal model and the Matérn function, respectively. Gaussian process regression uses a spatiotemporal model to determine the central tendency of the final result and impute missing values in our time trend using space and time correlations and additional information from relevant covariates.[23] Since this model considers the information of neighbouring provinces and nearby timepoints, it can improve mortality estimates compared to other alternatives (appendix). As the covariance function in Gaussian process regression, the Matérn function determines the amount of borrowing neighbourhood correlation in our timespan. It has three parameters that control correlation and smoothness of the time trend (appendix). Additionally, we considered both sampling and non-sampling errors in the final uncertainty intervals (UI; appendix).

We used the Markov Chain Monte Carlo method to combine the empirical data and model priors and to draw samples (n=50 000) from the posterior distributions of model parameters and estimated mortality rates. The median, 2·5 percentile, and 97·5 percentile of this distribution were used as point estimates of lower and upper UIs, respectively.[22] At this stage, uncertainty is generated by considering both cross-sectional and over-time uncertainties. Gaussian process regression also takes into account the incompleteness of DRS in the estimated CMRs and the corresponding 95% UIs at both national and provincial levels. To do the Markov Chain Monte Carlo calculations, we used the RStan package in R software, version 3.2.0 (appendix).[24]

Given that disasters such as earthquakes, floods, and war, can affect mortality rates, we took into account shock effects in the model. For example, Bam's earthquake in 2003 led to a substantial increase in the number of under-5 deaths, which directly increased CMR for this year. It should be noted that only shock effects that resulted in mortality higher than one death per 10 000 of the population were considered significant and included

in the model. Regarding this criterion, we had 12 eligible datapoints for the shocks during our timespan. We obtained the shock effect by calculating the mean of the empirical measurements in the year of the shock and then replaced the Gaussian process regression estimates with these empirical means.[13] More details on methods are in the appendix.

### Data sharing

The raw data for this study are available online: https://data.mendeley.com/datasets/9z3pzd6rmd/1.

### Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, and or writing of the report. FF, as the corresponding author, had full access to the data in the study and had final responsibility for the decision to submit for publication.

## Results

CMRs (deaths per 1000 livebirths) in 1990, 2000, 2010, and 2015 were 63·6 (95% UI 63·1–64·0), 38·8 (38·5–39·2), 24·9 (24·3–25·4), and 19·4 (18·6–20·2) at the national level, respectively (figure 1, table 1). This overall 70% reduction indicates that Iran achieved MDG 4—ie, a two-thirds reduction between 1990 and 2015. Additionally, Iran has already achieved the SDG target for child mortality (25 per 1000 livebirths by 2030). The median annual reduction rate (ARR) of child mortality from 1990 to 2015 for the country was 4·9%. However, the ARR was not consistent over time (figure 2). The ARRs for the periods 1990–2000, 2000–10, and 2010–15 were 5·1%, 4·7%, and 5·0%, respectively.

In 2015, the CMRs at the provincial level ranged from 8·9 (95% UI 8·0–9·5) in Mazandaran to 47·0 (42·6–52·0) in South Khorasan (table 1, figure 3). The range between the highest and lowest mortality rates across provinces was 65·6 per 1000 livebirths in 1990, which reduced to 40·4 in 2000 (appendix). The convergence of trends of CMR between provinces continued until 2005 when it reached a difference of 38·1 deaths per 1000 livebirths. Although the level of CMR in all provinces decreased after 2005, the range between the highest and lowest CMR across provinces remained almost the same between 2005 and 2015.

In 2015, six of 31 provinces had CMRs higher than the SDG 3 target of 25 deaths per 1000 livebirths by 2030 (figure 4), while four provinces had fewer than 15 per 1000 livebirths. The other provinces lay between these two ends of the spectrum. Additionally, the results of the median ARRs showed that five provinces had ARRs lower than 4·4%, while the remaining provinces had ARRs higher than 4·4% (table 2; appendix). Furthermore, in 2015 five provinces had seen a smaller reduction than the MDG 4 expected level [67%]), whereas the total reduction for the rest was higher than 67% (figure 5).

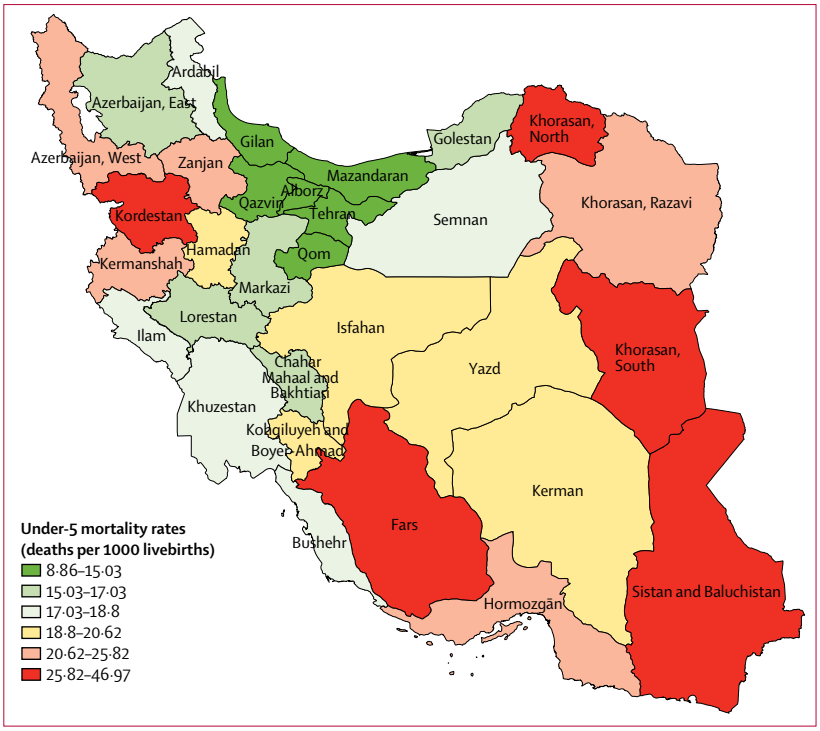


*Figure* 3: **Status of provinces of Iran, in terms of child mortality rates (per 1000 livebirths) in 2015**

Some provinces achieved the SDG target, but not the MGD target.

For the **raw data for this study** see http://ncdrc.info/index.php/en/projects/item/391-nasbod-child-mortality

## Discussion

Based on five empirical measurements, we showed that the survival of Iranian children has impressively improved over time, to such an extent that the probability of dying before the age of 5 years dropped by 70% from 1990 to 2015 at the national level, surpassing the two-thirds reduction called for by MDG 4. The fact that CMR reached 19 deaths per 1000 livebirths in 2015 also confirms that Iran has already achieved SDG 3 (target 2).

Iranian national estimates provided by the Global Burden of Disease (GBD) and IGME support our results regarding the achievement of MDG 4 and SDG 3 (target 2) in 2015. The GBD 2015 estimates for CMRs in Iran was 75 per 1000 livebirths (95% CI 66–86) in 1990 and 15 (11–20) in 2015, and in the IGME annual report, CMRs for Iran were estimated to be 58 (95% CI 53–63) per 1000 livebirths in 1990 and 16 (12–21) per 1000 livebirths in 2015.[5,13] Both estimates have no significant differences in terms of identifying completeness and variance components in their model. For comparison between GBD, IGME, and our study, we have provided a graph in the appendix. We chose GBD methodology for this study since it considers both cross-sectional and over-time uncertainties.[25–27]

Iran's child mortality decline is probably attributable to health and non-health measures. Regarding health

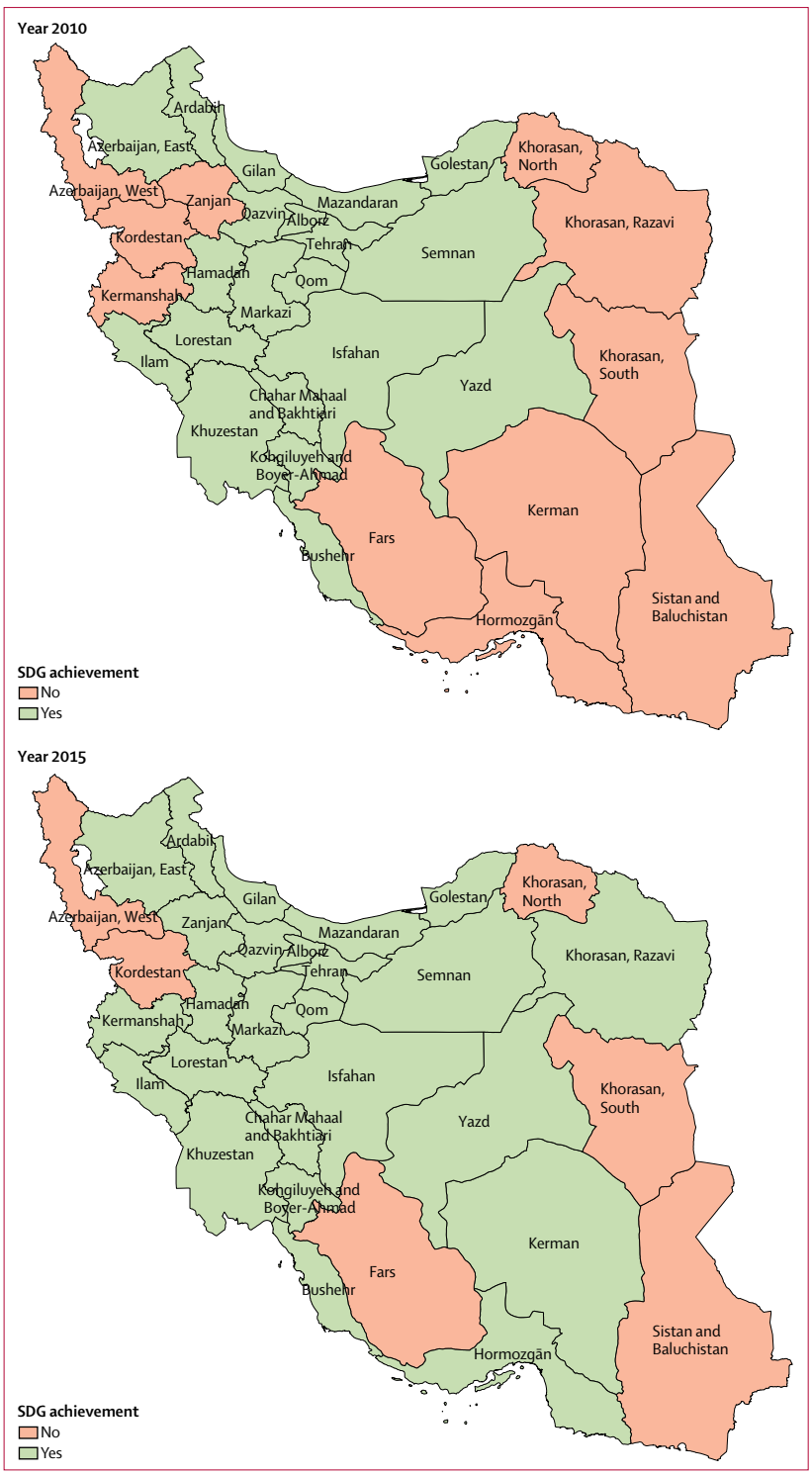


*Figure 4*: **Status of provinces of Iran, in terms of achieving Sustainable Development Goal (SDG) 3 in 2010 and 2015.**

| | Annual reduction rate (%) | Total reduction (%) |
|---|---|---|
| Markazi | 6·1 (3·18–10·62) | 74 (69·31–79·45) |
| Gilan | 4·6 (2·12–8·62) | 69 (62·15–74·33) |
| Mazandaran | 6·7 (2·17–12·16) | 82 (79·65–85·2) |
| Azerbaijan, East | 6·0 (3·2–10·13) | 77 (74·98–80·3) |
| Azerbaijan, West | 4·5 (3·13–7·79) | 71 (65·66–77·21) |
| Kermanshah | 4·6 (1·15–9·46) | 64 (59·11–69·9) |
| Khuzestan | 4·6 (0·16–10·25) | 68 (64·76–72·53) |
| Fars | 2·5 (0·06–5·49) | 51 (49·86–54·02) |
| Kerman | 4·7 (1·14–9·86) | 69 (66·73–72·5) |
| Khorasan, Razavi | 4·9 (3·13–7·72) | 72 (66·92–76·03) |
| Isfahan | 2·7 (0·07–5·98) | 65 (62·45–76·23) |
| Sistan and Baluchistan | 5·0 (2·14–7·98) | 73 (67·67–78·9) |
| Kurdistan | 4·8 (3·15–8·04) | 73 (66·32–77·04) |
| Hamadan | 5·2 (2·21–9·59) | 70 (68·32–74·06) |
| Chahar Mahaal and Bakhtiari | 5·1 (3·16–8·38) | 74 (69·74–76·46) |
| Lorestan | 5·8 (3·12–8·9) | 78 (73·32–79·91) |
| Ilam | 5·0 (2·2–14·69) | 73 (71·33–75·37) |
| Kohgiluyeh and Boyer–Ahmad | 4·8 (2·13–8·87) | 70 (68·33–73) |
| Bushehr | 5·6 (2·16–10·62) | 72 (66·83–74·68) |
| Zanjan | 5·1 (3·11–8·1) | 78 (72·73–81·5) |
| Semnan | 5·2 (3·14–8·48) | 72 (69·3–74·26) |
| Yazd | 3·4 (3·15–7·65) | 61 (58·87–632) |
| Hormozgan | 5·0 (2·13–9·71) | 68 (66·73–69·78) |
| Tehran | 7·1 (4·24–11·98) | 74 (71·38–77·25) |
| Ardabil | 5·4 (2·18–10·35) | 78 (72·63–82·83) |
| Qom | 5·7 (4·15–8·41) | 79 (77·37–80·3) |
| Qazvin | 5·8 (3·14–9·29) | 78 (75·33–81·72) |
| Golestan | 5·0 (3·11–8·07) | 77 (72·7–81·31) |
| Khorasan, North | 3·0 (1·08–5·69) | 70 (67·83–73·96) |
| Khorasan, South | 1·6 (0·06–3·47) | 59 (55·83–64·86) |
| Alborz | 7·0 (2·18–13·28) | 79 (73·97–84·2) |
| National | 4·9 (2·1–8·85) | 70 (66·93–74·53) |

Data are % reductions (95% uncertainty intervals).

***Table 2:*** **Reduction of child mortality in Iranian provinces from 1990 to 2015**

measures, expanding the health networks in the 1980s with low-cost primary health workers (known as *behvarzes*), and improving access to essential service packages for children in urban and particularly rural areas could be considered as crucial factors in child survival in Iran. The service package includes free of charge expanded programme on immunisation, integrated management of childhood illness, family planning, and improved access to clean water, which all are effective interventions for child survival.[11,28–32]

Regarding non-health measures affecting child mortality, the Iranian population has experienced socioeconomic development during the past three decades. The increase in women's literacy from 56% in 1990 to 88% in 2015 is an example of social changes in the Iranian population.[30,33] Improved economic status and urbanisation improves child mortality through better access to the health-care system.[11] We also examined the association between the trends of CMRs (before extrapolation) and socioeconomic indicators, and the

results indicated a strong correlation between child mortality and years of schooling (r=–0·79), wealth index (r=–0·84), and degree of urbanisation (r=–0·75).

Six of 31 provinces had not achieved SDG 3 (target 2) by 2015, which indicates a discrepancy between provinces. This discrepancy could be also attributed to health and non-health factors. Most of the six provinces are at the borders of the country and share several features. For example, they had a low human development index at the beginning of the millennium compared with other provinces.[34] Furthermore, most of the six provinces have a lower density of health-care providers compared with other provinces.[11,35,36]

This study had several limitations. First, we could not use two valuable data sources, especially for recent years: census 2011 and DHS 2010. As discussed in the Methods, these two datasets were not eligible to be included in the study because of missing values and having implausible sex ratios. Additionally, the estimated CMR in these two data sources was significantly lower than the estimates obtained from other sources. The summary birth history estimates of CMR were 8·4 and 10·0 per 1000 livebirths in census 2011 and DHS 2010, respectively. The complete birth history estimate of CMR was 4·6 per 1000 livebirths in DHS 2010. These results are significantly lower than than DRS estimates (17 deaths per 1000 livebirths), which we believe is an underestimation of the true CMR.

Another limitation was related to information bias in the recorded datasets. This bias might ensue when mothers cannot recall the date of birth and death correctly, which are required information for the complete birth history method. Moreover, some mothers cannot distinguish between stillbirths and neonatal deaths, and this problem might affect the results of summary birth histories.[20]

In conclusion, our results show that Iran and most of its provinces had achieved MDG 4 and SDG 3 (target 2) for child mortality by 2015. However, there are wide inequalities in child mortality at the provincial level. Possible recommendations to reduce these inequalities could be to increase the number of health personnel, recruiting low-cost human resources for health (*behvarzes*), training and retraining health staff, and establishing advanced health-care facilities for children and newborn babies—eg, neonatal intensive care units, in the provinces with little progress.[37,38] Coverage of supplement therapy such as ferrous sulfate, folic acid, and multivitamins in these provinces could be other remedies.[39,40] Additional policies could be enhancing the level of education, especially women's literacy, taking affirmative actions to reduce gender discrimination,[41–43] improving the income level of families or communities (job creation), or taking any possible action to increase very poor families' ability to protect child health such as cash transfers.[44,45]

Our results suggest the need to revise the SDG 3 target for child mortality for the high-achieving 25 provinces. Finally, to be more efficient in policy-making processes and resource allocation, we recommend estimating CMRs at a district level.


*Figure 5*: **Status of provinces of Iran, in terms of achieving Millennium Development Goal (MDG) 4 in 2015**

### Contributors

FF designed the study. EK, SA, AK, and MC collected the data. YM, MP, PM, AM, EK, SA, NR, AK, AS, AK, and FD processed the data. FF, YM, and AK did the demographic analysis. FF, MP, and PM did the statistical analysis. FF, YM, PM, HJ, and BL wrote the first draft. FF, YM, MP, PM, KY, MM-L, NR, AK, HJ, and BL interpreted the results. FF, MP, KY, MM-L, MA-L, RH, AK, HJ, and BL revised the final draft. FF was the principal investigator of the study and supervised the study design and implementation.

### Declaration of interests

We declare no competing interests.

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