

Original Article

Mortality Attributable to Nutritional Deficiencies among Iranian Children under the Age of Five at National and Sub-national Level: 1995–2015

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Abstract

Background: Under-five mortality is considered an indicator of population well-being and health equality in societies. Under-five mortality caused by nutritional deficiencies is a public health concern in developing countries. In this study, we aimed to report the trend and mortality rate of nutritional deficiencies from 1995 to 2015 in children aged under five years.

Methods: In this study, we used the death registration system (DRS) data to estimate age- and sex-specific nutritional deficiency mortality rates at national and sub-national levels in Iran from 1995 to 2015. The Iranian DRS used the 10th revision of International Classification of Diseases (ICD-10) but we report our results based on Global Burden of Diseases (GBD) study codes. We used the average annual percent change (AAPC) to quantify trend in under-five mortality rate attributable to nutritional deficiencies from 1995 to 2015.

Results: At national level, mortality rates in both sexes were 8.53 (95% uncertainty interval [UI]: 7.69–9.47), 1.04 (0.86–1.36), and 0.37 (95% UI: 0.28–0.57) per 100,000 in 1995, 2005, and 2015, respectively. AAPC was estimated between 1995 and 2015. At sub-national level, the highest and lowest mortality rates across provinces ranged from 17.7 per 100,000 in 1995 to 1.1 per 100,000 in 2015. In the latest years, protein-energy malnutrition (PEM) was the most frequent cause of mortality among other nutritional deficiencies.

Conclusion: The results show a substantial reduction in terms of mortality caused by nutritional deficiencies at national, as well as provincial, level among children under-five years of age.

Keywords: Child mortality, Malnutrition, Micronutrient deficiencies, Nutritional deficiency, Under-five

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Introduction

The under-five mortality rate has declined remarkably worldwide by nearly half from 1995 to 2015; nevertheless, it is estimated that 56 million deaths will occur before the fifth birthday of children by the year of 2030,¹ assuming that all countries accomplish the Sustainable Development Goals (SDG 3, target 2) “to reduce under-five mortality to 25 or lower deaths per 1000 live births”.² Under-five child

mortality, as an indicator of population well-being and health equality in societies,³ is projectable by childhood malnutrition.⁴

Child malnutrition, in two major forms of protein-energy malnutrition (PEM) and micronutrient deficiencies,^{5,6} contributes to about half of child deaths (3.1 million child deaths annually) ranging from 44.8% to 60.7% of deaths due to measles and diarrhea, respectively.^{7–10}

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Malnutrition in early life is also a major risk factor for overweight and diet-related non-communicable diseases (NCDs) including cardiovascular disease such as heart attacks and stroke, type-2 diabetes, and some cancers in later life, known as the world's biggest killers.^{11,12} Globally, 155 million children under-five (almost 23%) who are chronically malnourished and 41 million children who are now overweight are at increased risk of NCDs throughout life.¹³ Children in low- and middle-income countries, where the burden of malnutrition is greater, are more prone to mortality, morbidity and disability from NCDs.^{14,15}

Lack of access to enough food, inadequate food intake, poor breastfeeding, limited access to health services, and diseases are some of the factors that expose children to malnutrition.¹⁶ Malnourished children are susceptible to immune system impairment and increased risk of frequent infection, and dying from treatable diseases such as malaria, diarrhea, pneumonia, and measles.^{9,17}

As mentioned above, malnutrition has a significant role in the lives of under-five children. Although the prevalence and disease burden of malnutrition have declined globally,^{18,19} in developing nations, despite the progress in tackling this phenomenon, child malnutrition still remains a problem.^{20,21} Simultaneously, the burden of NCDs and their metabolic risks have increased.^{18,22} Similar to many other developing countries, malnutrition is still a health issue in Iran and threatens children. Studies on the prevalence of child malnutrition and strategies for reducing childhood malnutrition have been discussed previously²³⁻²⁸; however, to the best of our knowledge, no comprehensive population-based study has assessed the mortality rate in nutritional deficiencies among Iranians under five years of age. Therefore, the present study, as a component of the National and Sub-National Burden of Diseases (NASBOD) study, illustrates the nutritional deficiencies mortality trends in terms of PEM, iron and iodine in under-five children at national and sub-national level from 1995 to 2015.²⁹⁻³²

Materials and Methods

In this study, we used death registration system (DRS) data collected by the Iranian Ministry of Health and Medical Education (MOHME) to estimate age- and sex-specific nutritional deficiency mortality rates for children under 5 years of age at national and sub-national levels in Iran from 1995 to 2015. Iranian DRS used the 10th revision of International Classification of Diseases (ICD-10). So, with regard to our target, we converted ICD codes into Global Burden of Diseases (GBD) 2010 study codes. Therefore, we focused on PEM (E40-E46, E64.0), iodine deficiency (E00-E02), iron-deficiency anemia (D50, D64.9) and other nutritional deficiencies (D51-D53, E51-E63.9, E64.2-E64.3) ICD10 codes and converted them to nutritional deficiencies (A.6) in the corresponding GBD 2010 code.^{22,33} The methods of converting have

been described in details elsewhere.³⁴

Our study is part of the NASBOD project which is defined to estimate the burden of diseases at national and sub-national levels from 1990 to 2015.^{29,32,35} Unfortunately, nutritional deficiency as a cause of death suffers from considerable misclassification in the first years of data collection; therefore, we eliminated the time period before 1995 because of inadequate sources of data.

Data Source

We used data from the Iranian DRS that is established by the MOHME. The DRS does not include deaths in two major cities in Iran (Tehran and Isfahan). We included deaths from two cemeteries including Beheshteh-Zahra cemetery (Tehran) and Baghe-Rezvan cemetery (Isfahan) in the existing data sources of deaths. Methods of dealing with these issues and data cleaning are provided elsewhere.³⁴ The problem of incompleteness of data in DRS was solved using a demographical model. In brief, we used the summery birth history method for Demographic and Health Survey (DHS) 2000, censuses 1986, 1996, 2006, and complete birth history for DHS 2000, to estimate child mortality rates.³⁵ Maternal age period and maternal age cohort methods were used to analyze summary of birth history. We then combined these methods with LOESS regression.³² In addition, we predicted all-causes mortality rates for genders, years, and provinces that were missing using the spatiotemporal and Gaussian process regression models.^{34,36,37} Interested readers could find details of these models in published protocols.^{34,38} The national Iranian population structure of 2015 was used to estimate the age-standardized death rates in children under the age of five. We also calculated the average annual percent change (AAPC) to find the trends and annual changes in terms of mortality rates from 1995 to 2015 using the segmented regression model.³⁹ We used R statistical software (version 3.1.2) for statistical analysis and visualizing results in this paper.

Results

In an overall view, the nutritional deficiency mortality rate in Iran dramatically declined from 8.53 (95% uncertainty interval: 7.69 to 9.47) deaths per 100 000 population in 1995 to 0.37 (95% uncertainty interval [UI]: 0.28 to 0.57) and 1.04 (95% UI: 0.86 to 1.36) deaths per 100 000 population in 2005 and 2015 respectively, with an AAPC of -13.98 (95% CI -14.27 to -13.68) (Table 1, Figure 1). Similarly, the total number of deaths from nutritional deficiencies has also declined (Table 1).

The findings indicated no difference in mortality rates between boys and girls at national level (Table 2). The mortality rates in girls were 8.21 (95% UI: 7.37 to 9.16), and 0.42 (95% UI: 0.32 to 0.63) per 100 000 population in 1995 and 2015, respectively [(AAPC:-13.34, 95% UI: -13.64 to -13.04)], while for boys, these rates were

Table 1. Nutritional Deficiency Mortality Rate (Per 100000) and Death Numbers for Both Sexes and Average Annual Percentage of Changes in Iran

National/ Subnational	Mortality Rate (Per 100000)										Rank of AAPC	Difference Rate 2015 and 1995	
	Number of Death		2005		2015		1995		2005				2015
National	2216.04 (1997.84 to 2461.26)	230.45 (189.68 to 299.74)	101.46 (75.51 to 155.6)	8.53 (7.69 to 9.47)	1.04 (0.86 to 1.36)	0.37 (0.28 to 0.57)	-13.98 (-14.27 to -13.68)	—	-8.16				
Alborz	15.29 (4.24 to 56.06)	1.48 (0.03 to 33.19)	1.02 (0.01 to 31.51)	2.95 (0.82 to 10.82)	0.25 (0 to 5.67)	0.13 (0 to 3.88)	-14.16 (-14.57 to -13.75)	15	-2.82				
Ardebil	58.45 (28.48 to 118.88)	8.32 (2.35 to 43.28)	2.78 (0.17 to 34.59)	10.54 (5.14 to 21.44)	2.17 (0.61 to 11.28)	0.64 (0.04 to 7.94)	-12.16 (-12.75 to -11.58)	23	-9.9				
Azar East	102.47 (60.67 to 173.13)	9.63 (3.04 to 45.36)	3.87 (0.44 to 36.37)	7.89 (4.67 to 13.32)	0.92 (0.29 to 4.32)	0.3 (0.03 to 2.81)	-14.47 (-15.01 to -13.92)	11	-7.59				
Azar West	95 (54.11 to 165.38)	10.58 (3.57 to 46.69)	3.76 (0.42 to 36.19)	8.02 (4.57 to 13.97)	1.09 (0.37 to 4.8)	0.31 (0.03 to 2.99)	-14.29 (-14.68 to -13.89)	14	-7.71				
Bushehr	31.3 (11.23 to 79.56)	3.73 (0.43 to 37.4)	2.37 (0.11 to 33.9)	8.87 (3.18 to 22.54)	1.21 (0.14 to 12.1)	0.52 (0.02 to 7.43)	-12.83 (-13.2 to -12.46)	20	-8.35				
Chahar Mahal	37.65 (14.42 to 92.28)	4.88 (0.79 to 38.22)	3.29 (0.3 to 35.44)	9.99 (3.83 to 24.49)	1.67 (0.27 to 13.1)	0.92 (0.08 to 9.92)	-10.34 (-10.98 to -9.7)	29	-9.07				
Fars	114.8 (70.98 to 186.56)	10.49 (3.5 to 46.98)	5.21 (0.98 to 38.43)	7.03 (4.34 to 11.42)	0.82 (0.27 to 3.66)	0.32 (0.06 to 2.39)	-13.75 (-14.01 to -13.49)	16	-6.7				
Gilan	52.68 (25.38 to 108.79)	5.01 (0.85 to 38.23)	2.33 (0.1 to 33.84)	6.47 (3.12 to 13.37)	0.87 (0.15 to 6.61)	0.4 (0.02 to 5.86)	-12.21 (-12.63 to -11.79)	22	-6.07				
Golestan	82.59 (46.73 to 146.77)	5.66 (1.1 to 39.8)	2.61 (0.14 to 34.32)	12.01 (6.79 to 21.34)	1.03 (0.2 to 7.24)	0.33 (0.02 to 4.35)	-15.72 (-16.24 to -15.2)	5	-11.68				
Hamedan	40.84 (16.2 to 94.53)	5.64 (1.1 to 39.5)	2.72 (0.19 to 34.47)	5.37 (2.13 to 12.42)	1.15 (0.22 to 8.04)	0.47 (0.03 to 5.91)	-10.68 (-11.36 to -10)	28	-4.9				
Hormozgan	35.12 (12.74 to 87.61)	11.83 (4.35 to 48.46)	6.82 (1.73 to 40.8)	6.13 (2.22 to 15.28)	2.12 (0.78 to 8.68)	0.89 (0.23 to 5.33)	-9.37 (-10.03 to -8.7)	31	-5.24				
Ilam	30.8 (10.32 to 80.6)	3.64 (0.4 to 36.86)	1.45 (0.01 to 32.31)	12.78 (4.28 to 33.46)	2.13 (0.23 to 21.55)	0.78 (0.01 to 17.31)	-12.62 (-13.09 to -12.16)	21	-12.01				
Isfahan	60.63 (30.35 to 119.13)	9.48 (3.03 to 45.32)	6.14 (1.3 to 39.88)	4.14 (2.07 to 8.14)	0.75 (0.24 to 3.59)	0.39 (0.08 to 2.55)	-10.17 (-10.94 to -9.39)	30	-3.75				
Kerman	107.21 (63.69 to 180.65)	11.86 (4.33 to 48.4)	4.93 (0.85 to 38)	11.47 (6.81 to 19.33)	1.27 (0.46 to 5.19)	0.38 (0.07 to 2.97)	-15.02 (-15.32 to -14.71)	9	-11.09				
KermanShah	70.97 (37.29 to 132.65)	5.7 (1.12 to 39.88)	1.97 (0.05 to 33.22)	8.89 (4.67 to 16.62)	1.04 (0.2 to 7.3)	0.32 (0.01 to 5.46)	-15.02 (-15.3 to -14.74)	8	-8.57				
Khorasan North	72.04 (37.18 to 135.41)	7.19 (1.8 to 42.11)	2.58 (0.14 to 34.27)	19 (9.8 to 35.71)	2.51 (0.63 to 14.7)	0.66 (0.04 to 8.78)	-15.23 (-15.68 to -14.79)	7	-18.34				
Khorasan Razavi	296.49 (222.66 to 397.71)	15.59 (6.63 to 53.53)	4.59 (0.68 to 37.51)	13.49 (10.13 to 18.1)	0.81 (0.35 to 2.79)	0.19 (0.03 to 1.54)	-18.76 (-19.12 to -18.4)	2	-13.3				
Khorasan South	41.59 (16.41 to 96.89)	7.79 (2.07 to 42.46)	3.3 (0.29 to 35.45)	15.61 (6.16 to 36.36)	3.39 (0.9 to 18.48)	1.16 (0.1 to 12.45)	-11.72 (-12.1 to -11.34)	24	-14.45				
Khuzestan	81.36 (45.51 to 146.68)	10.47 (3.51 to 46.52)	6.43 (1.43 to 40.31)	4.25 (2.38 to 7.66)	0.69 (0.23 to 3.05)	0.32 (0.07 to 2.03)	-11.06 (-11.72 to -10.4)	27	-3.93				
Kohkiluyeh	33.79 (11.76 to 87.08)	4.54 (0.67 to 37.75)	1.79 (0.03 to 32.9)	11.27 (3.92 to 29.05)	1.97 (0.29 to 16.4)	0.62 (0.01 to 11.36)	-13.06 (-13.52 to -12.59)	19	-10.65				
Kordestan	50.45 (22.33 to 108.97)	7.25 (1.84 to 41.84)	2.15 (0.07 to 33.53)	7.51 (3.32 to 16.21)	1.58 (0.4 to 9.14)	0.4 (0.01 to 6.3)	-13.06 (-13.66 to -12.46)	18	-7.1				
Lorestan	100.32 (58.15 to 172.47)	9.52 (3 to 45.01)	3.76 (0.42 to 36.2)	12.93 (7.5 to 22.23)	1.75 (0.55 to 8.29)	0.6 (0.07 to 5.82)	-13.09 (-14.16 to -11.99)	17	-12.33				
Markazi	26 (7.74 to 73.79)	3.35 (0.31 to 36.14)	1.8 (0.03 to 32.92)	5.15 (1.53 to 14.61)	0.87 (0.08 to 9.43)	0.4 (0.01 to 7.31)	-11.44 (-11.92 to -10.97)	26	-4.75				
Mazandaran	47.19 (21.97 to 100.37)	2.52 (0.12 to 34.75)	0.78 (0 to 31.06)	5 (2.33 to 10.65)	0.33 (0.02 to 4.58)	0.09 (0 to 3.75)	-17.52 (-17.94 to -17.09)	4	-4.91				
Qazvin	40.81 (17.98 to 93.45)	1.74 (0.03 to 33.39)	0.67 (0 to 30.85)	9.69 (4.27 to 22.18)	0.5 (0.01 to 9.53)	0.17 (0 to 7.66)	-18.43 (-18.89 to -17.97)	3	-9.52				
Qom	10.23 (1.13 to 49.78)	1.6 (0.02 to 33.22)	0.99 (0 to 31.47)	2.68 (0.29 to 13.03)	0.45 (0.01 to 9.36)	0.21 (0 to 6.76)	-11.5 (-11.91 to -11.09)	25	-2.46				
Semnan	20.1 (4.9 to 65.76)	2.34 (0.1 to 34.24)	0.95 (0 to 31.38)	10.77 (2.63 to 35.21)	1.37 (0.06 to 20.08)	0.47 (0 to 15.65)	-14.44 (-14.85 to -14.03)	13	-10.29				
Sistan	209.68 (145.03 to 307.46)	33.98 (20.09 to 77.06)	12.98 (5.06 to 49.55)	20.35 (14.07 to 29.83)	2.75 (1.63 to 6.24)	0.81 (0.32 to 3.08)	-14.49 (-14.88 to -14.09)	10	-19.54				
Tehran	161.71 (109.2 to 240.69)	9.07 (2.66 to 44.98)	5.27 (0.99 to 38.53)	5.27 (3.56 to 7.85)	0.3 (0.09 to 1.49)	0.15 (0.03 to 1.11)	-15.54 (-16.12 to -14.95)	6	-5.12				
Yazd	25.4 (7.83 to 72.84)	2.74 (0.16 to 35.03)	1.43 (0.01 to 32.28)	7.83 (2.41 to 22.45)	0.85 (0.05 to 10.82)	0.31 (0 to 6.92)	-14.46 (-14.71 to -14.21)	12	-7.52				
Zanjan	71.92 (37.96 to 135.53)	3.46 (0.33 to 36.2)	0.71 (0 to 30.93)	16.8 (8.86 to 31.65)	1.16 (0.11 to 12.18)	0.19 (0 to 8.22)	-19.58 (-19.97 to -19.2)	1	-16.61				

AAPC, average annual percent change.

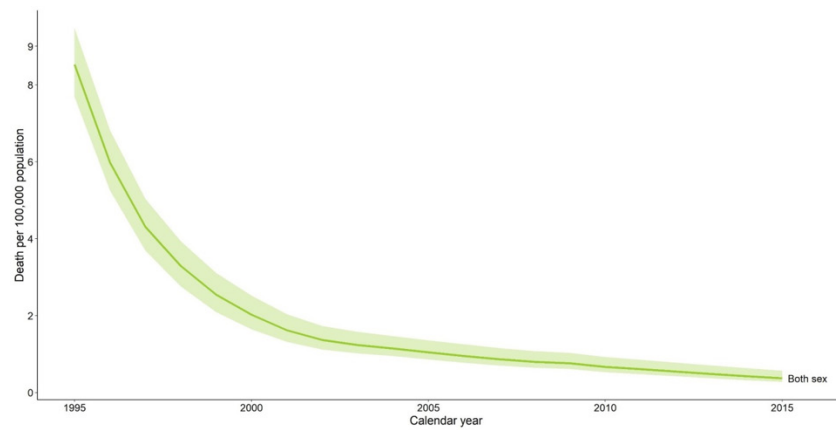


Figure 1. Trend in Child Mortality Rate Due to Nutritional Deficiencies in Both Sexes at National Level From 1995 to 2015.

Table 2. Mortality Rate Among Boys and Girls in 1995, 2005 and 2015

National/ Subnational	Girls Mortality Rate (per 100000)			Boys Mortality Rate (Per 100000)		
	1995	2005	2015	1995	2005	2015
National	8.21 (7.37 to 9.16)	1.13 (0.94 to 1.46)	0.42 (0.32 to 0.63)	8.83 (7.99 to 9.77)	0.96 (0.79 to 1.26)	0.33 (0.24 to 0.51)
Alborz	1.44 (0.12 to 8.8)	0.16 (0 to 5.65)	0.08 (0 to 3.87)	4.38 (1.48 to 12.73)	0.35 (0.01 to 5.68)	0.17 (0 to 3.9)
Ardebil	10.87 (5.27 to 22.16)	1.93 (0.47 to 11.17)	0.65 (0.04 to 8.27)	10.23 (5.01 to 20.76)	2.39 (0.74 to 11.37)	0.63 (0.04 to 7.64)
Azar East	8.61 (5.2 to 14.3)	0.91 (0.28 to 4.4)	0.32 (0.04 to 2.92)	7.2 (4.16 to 12.4)	0.92 (0.3 to 4.24)	0.28 (0.03 to 2.71)
Azar West	8.24 (4.63 to 14.45)	1.09 (0.36 to 4.9)	0.29 (0.03 to 3.02)	7.82 (4.51 to 13.51)	1.08 (0.37 to 4.71)	0.33 (0.04 to 2.96)
Bushehr	6.98 (2.05 to 20.19)	1.33 (0.17 to 12.56)	0.64 (0.04 to 7.79)	10.67 (4.26 to 24.78)	1.09 (0.11 to 11.67)	0.4 (0.01 to 7.09)
Chahar Mahal	10.62 (4.13 to 25.55)	1.74 (0.29 to 13.49)	1.1 (0.12 to 10.39)	9.38 (3.53 to 23.46)	1.61 (0.25 to 12.74)	0.76 (0.05 to 9.48)
Fars	6.16 (3.65 to 10.45)	0.78 (0.25 to 3.69)	0.42 (0.1 to 2.58)	7.84 (5 to 12.33)	0.85 (0.3 to 3.64)	0.23 (0.02 to 2.2)
Gilan	6.22 (2.87 to 13.16)	0.72 (0.09 to 6.53)	0.34 (0.01 to 5.88)	6.71 (3.36 to 13.56)	1.01 (0.2 to 6.69)	0.46 (0.03 to 5.85)
Golestan	10.16 (5.25 to 19.27)	0.99 (0.18 to 7.31)	0.37 (0.02 to 4.46)	13.79 (8.28 to 23.33)	1.07 (0.22 to 7.18)	0.29 (0.01 to 4.24)
Hamedan	5.52 (2.18 to 12.75)	1.06 (0.18 to 8.13)	0.34 (0.01 to 5.84)	5.22 (2.08 to 12.1)	1.23 (0.26 to 7.96)	0.58 (0.06 to 5.97)
Hormozgan	5.46 (1.81 to 14.51)	2.49 (0.99 to 9.32)	1.25 (0.39 to 5.95)	6.77 (2.62 to 16.03)	1.77 (0.58 to 8.07)	0.55 (0.07 to 4.74)
Ilam	12.91 (4.34 to 34.13)	1.87 (0.15 to 21.65)	0.74 (0 to 17.69)	12.67 (4.23 to 32.82)	2.37 (0.31 to 21.46)	0.82 (0.01 to 16.96)
Isfahan	3.84 (1.83 to 7.84)	0.57 (0.14 to 3.4)	0.38 (0.07 to 2.58)	4.43 (2.3 to 8.43)	0.92 (0.33 to 3.77)	0.41 (0.09 to 2.53)
Kerman	12.11 (7.2 to 20.26)	1.42 (0.55 to 5.48)	0.49 (0.1 to 3.19)	10.86 (6.45 to 18.44)	1.13 (0.38 to 4.92)	0.29 (0.03 to 2.76)
KermanShah	8.66 (4.43 to 16.55)	1.12 (0.23 to 7.58)	0.35 (0.01 to 5.7)	9.11 (4.9 to 16.69)	0.98 (0.18 to 7.04)	0.3 (0.01 to 5.23)
Khorasan North	20.87 (10.9 to 38.81)	2.75 (0.72 to 15.3)	0.76 (0.05 to 9.11)	17.23 (8.77 to 32.8)	2.29 (0.54 to 14.15)	0.57 (0.02 to 8.47)
Khorasan Razavi	11 (7.89 to 15.4)	0.89 (0.39 to 2.93)	0.21 (0.03 to 1.6)	15.86 (12.27 to 20.67)	0.74 (0.3 to 2.65)	0.17 (0.02 to 1.49)
Khorasan South	13.27 (4.56 to 33.79)	3.34 (0.85 to 18.8)	1.34 (0.14 to 12.99)	17.83 (7.68 to 38.8)	3.44 (0.95 to 18.18)	0.99 (0.06 to 11.93)
Khuzestan	3.51 (1.76 to 6.85)	0.72 (0.24 to 3.15)	0.35 (0.08 to 2.1)	4.95 (2.96 to 8.43)	0.66 (0.22 to 2.95)	0.3 (0.06 to 1.96)
Kohkiluyeh	11.64 (4.02 to 30.07)	1.96 (0.27 to 16.7)	0.58 (0.01 to 11.39)	10.92 (3.84 to 28.1)	1.99 (0.31 to 16.1)	0.65 (0.01 to 11.32)
Kordestan	7.31 (3.09 to 16.24)	1.88 (0.54 to 9.74)	0.39 (0.01 to 6.39)	7.69 (3.54 to 16.19)	1.3 (0.27 to 8.58)	0.41 (0.01 to 6.22)
Lorestan	11.61 (6.3 to 21.01)	2.02 (0.68 to 8.83)	0.71 (0.09 to 6.19)	14.18 (8.62 to 23.39)	1.51 (0.43 to 7.79)	0.51 (0.04 to 5.47)
Markazi	5.09 (1.47 to 14.79)	0.88 (0.08 to 9.61)	0.45 (0.01 to 7.61)	5.2 (1.6 to 14.44)	0.87 (0.08 to 9.25)	0.35 (0 to 7.03)
Mazandaran	4.25 (1.74 to 9.83)	0.31 (0.01 to 4.61)	0.08 (0 to 3.77)	5.72 (2.89 to 11.43)	0.35 (0.02 to 4.54)	0.1 (0 to 3.72)
Qazvin	9.74 (4.12 to 22.69)	0.48 (0.01 to 9.76)	0.16 (0 to 7.86)	9.63 (4.41 to 21.69)	0.51 (0.01 to 9.31)	0.17 (0 to 7.47)
Qom	2.43 (0.21 to 13.02)	0.42 (0 to 9.51)	0.23 (0 to 7.05)	2.91 (0.38 to 13.04)	0.48 (0.01 to 9.22)	0.19 (0 to 6.49)
Semnan	11.7 (2.91 to 36.51)	1.39 (0.06 to 20.59)	0.43 (0 to 15.65)	9.87 (2.35 to 33.97)	1.36 (0.05 to 19.59)	0.51 (0 to 15.66)
Sistan	24.46 (17.38 to 34.8)	3.94 (2.52 to 7.75)	1.02 (0.44 to 3.43)	16.33 (10.85 to 25)	1.6 (0.76 to 4.77)	0.61 (0.2 to 2.76)
Tehran	4.92 (3.24 to 7.5)	0.35 (0.11 to 1.58)	0.19 (0.04 to 1.19)	5.61 (3.87 to 8.19)	0.26 (0.07 to 1.4)	0.11 (0.01 to 1.03)
Yazd	6.53 (1.68 to 20.92)	0.81 (0.04 to 10.97)	0.34 (0 to 7.08)	9.06 (3.11 to 23.89)	0.87 (0.06 to 10.68)	0.28 (0 to 6.76)
Zanjan	18.25 (9.76 to 33.74)	1.17 (0.11 to 12.46)	0.13 (0 to 8.26)	15.41 (8.01 to 29.65)	1.16 (0.12 to 11.91)	0.25 (0 to 8.17)

Table 3. Mortality Rate (Per 100 000) and Death Numbers Attributable to PEM, Iron and Iodine Deficiency

Cause of Death	Number of Death			Mortality Rate (Per 100,000)			AAPC 1995-2015 (95% CI)
	1995	2005	2015	1995	2005	2015	
Protein-energy malnutrition	431.64 (375.45 to 494.12)	229.56 (189.68 to 275.42)	101.45 (75.51 to 133.46)	6.64 (5.78 to 7.61)	4.16 (3.44 to 4.99)	1.48 (1.1 to 1.95)	-6.98 (-7.27 to -6.7)
Iodine deficiency	0.02 (0 to 8.33)	0.01 (0 to 7.53)	0 (0 to 7.38)	0 (0 to 0.13)	0 (0 to 0.14)	0 (0 to 0.11)	-8.41 (-8.62 to -8.19)
Iron-deficiency anemia	1051.27 (963.27 to 1145.46)	0.75 (0 to 9)	0 (0 to 7.38)	16.18 (14.83 to 17.63)	0.01 (0 to 0.16)	0 (0 to 0.11)	-50.51 (-51.97 to -49.01)
Other nutritional deficiencies	733.11 (659.12 to 813.36)	0.13 (0 to 7.79)	0 (0 to 7.38)	11.28 (10.15 to 12.52)	0 (0 to 0.14)	0 (0 to 0.11)	-56.41 (-57.87 to -54.9)

AAPC, average annual percent change.

8.83 (95% UI: 7.99 to 9.77), and 0.33 (95% UI: 0.24 to 0.51) deaths per 100 000, in 1995 and 2015, respectively [(AAPC:-14.63, 95% UI: -14.94 to -14.33)] (Table 2).

According to our results, in 1995, the greatest number of death was due to iron and other micronutrients which reached close to zero in 2015. Also, in 1999, PEM accounted for over half of deaths (61.01%) in 1999 and remained the leading cause of death until 2015 with 99% of deaths (Table 3, Figure 2).

At the provincial level, the range between the highest and lowest mortality rates across provinces was 17.67 per 100 000 in 1995, which was reduced to 1.07 in 2015 (Table 1). The mortality rate of nutritional deficiencies ranged from 0.09 (95% UI: 0 to 3.75) in Mazandaran to 1.16 (95% UI: 0.1 to 12.45) in South Khorasan in 2015 (Table 1, Figure 3). In 2015, Ilam, Kohgiluyeh and Boyer-Ahmad, Chaharmahal and Bakhtiari, North and South Khorasan, Hormozgan, and Sistan & Baluchistan provinces had the highest rate of mortality, and mortality rate in South Khorasan was at the outmost point in comparison with other provinces for both sexes (Table 1, Figure 3). Our findings showed that the largest reduction in mortality rate pertained to Zanjan (AAPC=-19.58, 95% UI: -19.97 to -19.2), Khorasan Razavi (AAPC=-18.76, 95% UI: -19.12 to -18.4), Qazvin (AAPC=-18.43, 95% UI: -18.89 to -17.97), Mazandaran (AAPC=-17.52, 95% UI: -17.94 to -17.09), Golestan (AAPC=-15.72, 95% UI: -16.24

to -15.2), and Tehran (AAPC=-15.54, 95% UI: -16.12 to -14.95), respectively, whereas the lowest decline was seen in Hormozgan (AAPC=-9.37, 95% UI: -10.03 to -8.7), Isfahan (AAPC=-10.17, 95% UI: -10.94 to -9.39), Chaharmahal and Bakhtiari (AAPC=-10.34, 95% UI: -10.98 to -9.7), Hamedan (AAPC=-10.68, 95% UI: -11.36 to -10), Khuzestan (AAPC=-11.06, 95% UI: -11.72 to -10.4), and Markazi (AAPC=-11.44, 95% UI: -11.92 to -10.97), respectively (Table 1, Figure 3).

Discussion

This study showed downward trends of mortality rate attributable to nutritional deficiencies in under-five children with a similar pattern among most provinces across the country, with nearly an average 14% reduction annually from 1995 to 2015. Our results are in line with the estimation of GBD 2015 which reported a significant reduction in under-five total deaths due to nutritional deficiencies between 2005 and 2015.²² Our results are also consistent with the findings of other studies in different parts of the world.⁴⁰⁻⁴³ However, in South Africa, mortality trends due to malnutrition have been oscillating over the years from 1997 to 2009.^{44,45} Reduced child mortality attributable to malnutrition in Iran is partly due to fostering progress in health network and developing primary healthcare system throughout the country over the past three decades, which has led to reduction in

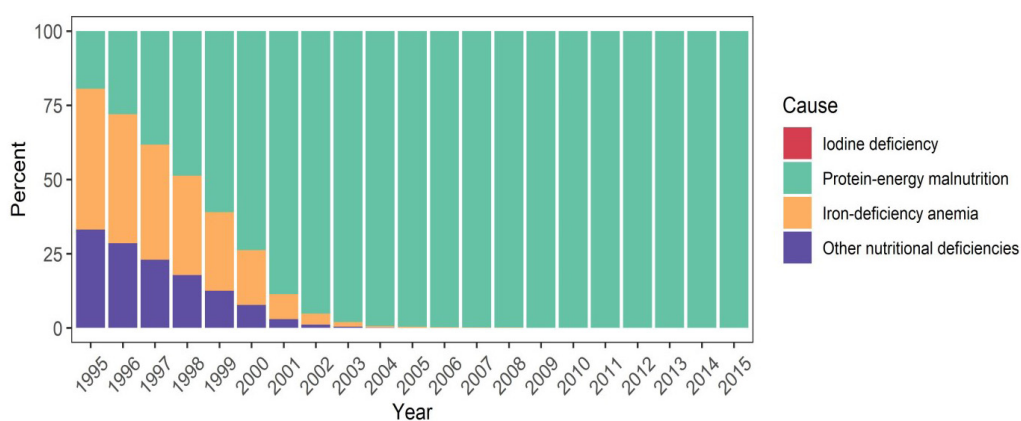


Figure 2. Percentage of Deaths Due to Each Major Cause at National Level From 1995 to 2015. Note. Due to the low number of iodine deficiency deaths, it is not clear in the figure.

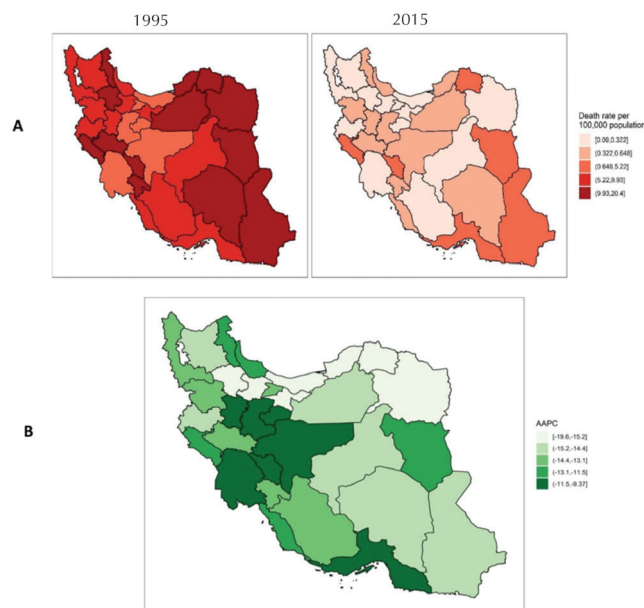


Figure 3. Status of Provinces of Iran in Terms of (A) Child Mortality Rate Attributed to Nutritional Deficiencies; (B) Average of Annual Percent Change (AAPC) Attributed to Nutritional Deficiencies.

morbidity and mortality from diarrhea, lower respiratory infection, and other common infectious diseases^{3,46,47} well-known as causes of children's growth retardation and malnutrition.^{48,49}

According to our findings, nutritional deficiencies mortality rate declined strongly between 1995 and 2005 and has decreased slightly since then until 2015 with a similar pattern among most provinces across the country. Findings from the National Anthropometric Nutritional Indicators Survey (ANIS 1) in 1998 contained basic information for health providers to implement national interventions for improving nutrition and child growth. The findings of the second survey in 2004 (ANIS 2) with the aim of determining the trend of malnutrition prevalence over a ten-year period showed a significant reduction in the prevalence of child malnutrition across the country, which illustrates the success of interventions for malnutrition-related death in this time interval.^{50,51} Another intervention program with the aim of reducing children malnutrition in rural areas in Iran ran as pilot in three different geographical regions (Ilam, Kerman, and Bushehr provinces) from 1996 to 1999.²⁷ This study was designed according to the triple-A (Assessment–Analysis–Action) strategy introduced by UNICEF⁵² and resulted in reducing all indicators of malnutrition (wasting, underweight, and stunting)

According to the results of the current study, in recent years, PEM was the most common cause of death in Iranian children under five years of age and micronutrient deficiencies accounted for fewer deaths. Food-based strategies implemented in Iran such as flour enrichment with iron, salt iodization, and extensive supplementation with vitamins A and D⁵³⁻⁵⁶ have been able to combat micronutrient deficiencies and their related deaths in the

past two decades.

According to our results, despite significant declines in under-five mortality rate attributable to malnutrition, we observed provincial disparities in terms of mortality. As mentioned earlier, in recent years, Ilam, Kohgiluyeh and Boyer-Ahmad, Chaharmahal and Bakhtiari, North and South Khorasan, Hormozgan, and Sistan & Baluchistan provinces had the highest mortality rate caused by malnutrition. Furthermore, during the 21 years of our study, Zanjan and Hormozgan had the greatest and smallest rates of change, respectively. According to the report on Iran's human development (1999) which represented the level of social, cultural, political and economic development in a country, Sistan & Baluchistan province had the lowest human development index (0.545) compared to other provinces.⁵⁷ Unfortunately, this inequality has not changed in some parts of Iran in recent years, as Sistan and Baluchistan is still at the bottom of development level among other provinces and is known as the most deprived province in the country. Hormozgan, North Khorasan and Kohgiluyeh and Boyer-Ahmad also hold low ranks in terms of development status.⁵⁸ Also, based on a situation analysis of food security in the Iranian provinces, Hormozgan, Kohgiluyeh and Boyer-Ahmad, and Sistan and Baluchistan were classified as very insecure provinces and the rest of the provinces mentioned, had different degrees of insecurity.⁵⁹ It is noteworthy that, according to a World Bank report, Zanjan was among the poorest provinces in the country; nevertheless, it has shown the most progress in under-five mortality rates.⁶⁰ Zanjan had the greatest development in terms of mortality related to malnutrition in our study, too. This shows that the country's policies might have been successful in improving access to primary health care and eliminating health inequalities over the past 20 years.⁶⁰

This study has some strengths and limitations. This is the first survey on the under-five mortality rate due to nutritional deficiencies at national and sub-national level. Likewise, as noted earlier, the pattern of nutritional deficiencies mortality rate is consistent with the mortality pattern reported by the Institute for Health Metrics and Evaluation.⁶¹ Although we addressed many issues in DRS data by cleaning data and using novel modelling approaches, some issues remained unsolved. Sparsity of data in the initial years of DRS affected estimations in this period. Since we did not have any information about the pattern of nutritional deficiency mortality rates in these years, we preferred to put away these estimations and predict these rates using statistical modelling that we mentioned above. Another limitation pertained to other nutritional deficiencies as causes of under-five mortality because there was no detailed information on the deficiency of any nutrient (except iron and iodine) and their related deaths. Especially, lack of some micronutrients involved in inflammatory processes and immune regulations such as vitamin A, Zn, and vitamin D indirectly leads to mortality due to infectious diseases.^{52,62} It is important to highlight that identifying micronutrient deficiencies and related deaths is difficult,⁶³ Also, some of these may be causes of disability-adjusted life-years, but not a cause of death.⁵⁵

In conclusion, to the best of our knowledge, this is the first national and provincial level report of the nutritional deficiencies related mortality rate in Iran. It showed a dramatic drop in nutritional deficiencies mortality rates in under-five children in Iran from 1995 to 2015. With respect to the high prevalence of food insecurity among children in Iran on the one hand,⁶⁴ and socioeconomic inequality in malnutrition among Iranian children on the other,⁶⁵ Iran's policy makers are expected to take urgent interventions and give priority to provinces with lower human development index to reduce malnutrition and its consequences, and compensate for these inequalities.

Authors' Contribution

Designing the study: MSKH, AKH; Carrying it out: MM, SHN, NM, ZM, AD, KR, MCH; Analyzing the data: MY, AKH, KG, ASH; Writing the manuscript: MSKH, AKH; Revised the manuscript: MSKH, AKH, MM, SHN, NM, ZM, AD, KR, MCH, MY, AKH, KG, ASH.

Conflict of Interest Disclosures

None.

Ethical Statement

This study is re-analysis of the exiting data, and the medical ethics committee of Tehran University of medical Sciences exempted it from regular reviews. The allocated ethics code to this study is IR.TUMS.EMRI.REC.1396.100175.

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