Original Article

Burden of Vaccine-Preventable Diseases—Measles, Tetanus, Diphtheria and Whooping Cough—in Iran: Findings from the GBD study 2010

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Abstract

Background: Vaccination has been one of the most successful and cost-effective public health interventions in the last century and has saved millions of lives. In 1984, the Expanded Program on Immunization (EPI) was launched in Iran as one of the main components of Primary Health Care (PHC).

Objectives: We aimed to investigate the burden of four vaccine-preventable diseases from 1990 to 2010 in Iran.

Methods: GBD study 2010 includes death rates, Years of Life Lost (YLLs), Years Lived with Disability (YLDs) and Disability Adjusted Life Years (DALYs). YLLs is calculated through multiplying the number of deaths in each age group by a reference life expectancy for the same age group, while YLDs can be obtained from the prevalence of a disease multiplied by the disability weight (DW) for the same disease. The sum of these two indices yields DALYs. In the present study, we tried to produce new graphs and explain more about Iran results. We also describe the GBD study limitations.

Results: Regardless of gender differences, DALYs rates for measles at all ages were 86.1220 and 5.5703 per 100 000 in 1990 and 2010, respectively, indicating approximately 94% decrease in this disease. The maximum and minimum rates of deaths from whooping cough for males aged under 5 was 4.0674 and 0.2713 per 100 000 in 1990 and 2000, respectively, which shows 93% decline in whooping cough from in this period.

Conclusion: This study demonstrated that vaccination has had a positive impact on the control of communicable diseases. But the results of this study have some limitations similar to GBD study which may pave the way for decision makers about other public health interventions. Moreover, since measuring the impact of various diseases on health plays an important role in public health, it can be an important step toward prioritization in health.

Keywords: Diphtheria, Iran, measles, tetanus, vaccine, whooping cough

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Introduction

Vaccination has been one of the most successful and cost-effective public health interventions in the last century and has saved millions of people from different diseases.[1] In 1974, the World Health Organization (WHO) established the Expanded Program on Immunization (EPI) to ensure that all children have access to routinely recommended vaccines.[2] In 1984, the EPI was launched in Iran as one of the main components of Primary Health Care (PHC). The coverage of vaccination in Iran at the beginning of the EPI was less than 40% which increased to 99% by 2011.[3-5]

Iran has achieved considerable success in the health sector including vaccination against communicable diseases during the past decades.[6,7] Between 1990 and 2010, the life expectancy of has increased from 64.6 to 71.6 years for males and from 71 to 77.8 years, for females.[8] In addition, in 2010, life expectancy in Tehran were calculated as 74.6 years for males and 78.4 years for females.[9]

According to WHO estimation in 2008, 1.5 million deaths among children under 5 years were due to diseases that could be prevented by vaccines recommended through the EPI. This group is the cause of 17% of global mortality in under aged 5.[10] Worldwide under 5 mortality has dropped from 11.9 million deaths in 1990 to 7.7 million deaths in 2010.[6] In the Eastern Mediterranean region, about 1.24 million children under five years of age died in 2008. Approximately 20% of these deaths are attributed to diseases for which potent vaccines are available.[11] Under 5 mortality rate in Iran has reduced about 83%, from 183.1 to 31.1 per 1000 from 1970 to 2010. Infant mortality rate has also fallen by 49% (53.1 to 27.1 per 1000) during this period.[6]

Since the public health importance of different diseases cannot

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be sufficiently compared only based on their morbidity or mortality data, it is recommended to calculate all health effects, duration and severity of diseases to estimate their total impact, namely the burden of a disease.[12,13] In this regard, the Institute for Health Metrics and Evaluation (IHME) has performed a series of comprehensive systematic reviews and calculated the Global Burden of Disease (GBD) for the years 1990, 1995, 2000, 2005 and 2010.[14]

In this study, we aim to summarize the burden attributable to four vaccine-preventable diseases including measles, diphtheria, tetanus and whooping cough from 1990 to 2010 using GBD study 2010 results. We also provide a new view about their condition in Iran along with the existing limitations of GBD estimations and the probable reasons for these limitations. Eventually, we recommend some strategies to eliminate them.

Materials and Methods

GBD study 2010 includes 291 diseases and injuries in 20 age groups and both sexes. It was carried out in 187 countries and used several measures to describe the results, including deaths and death rates, YLLs, YLDs and disability-adjusted life-years (DALYs). Elements of the data, statistical modeling and metrics are described elsewhere.[8,12,14-18] YLLs is calculated through multiplying the number of deaths in each age group by a reference life expectancy for the same age group, while YLDs can be obtained from the prevalence of a disease multiplied by the disability weight (DW) for the same disease. Disability weights are scaled from 0 to 1 in which 0 implies that a health state corresponds to full health and 1 means the health state is equivalent to death. In GBD 2010 study, disability weights were measured for 220 unique health conditions that cover 1160 diseases and injuries.[13,18] The sum of these two indices yields DALY. Moreover, the level of uncertainty for each cause-specific DALY was calculated through combining uncertainty at the levels of all-cause mortality, cause-specific mortality, prevalence and disability weights.[14,17]

The estimates for most diseases were prepared based on a database covering all age-sex-country year groups and through utilizing a Bayesian meta-regression method established for the GBD 2010 (DisMod-MR).[19,20] The GBD study 2010 attained an estimate for every disease via a systematic analysis of published and available unpublished data sources on prevalence, incidence, remission and excess mortality.[21] Causes of death were estimated using a comprehensive database of vital registration, verbal autopsy, surveillance and other sources by covering 187 countries from 1990 to 2010.[14]

Global team used CODEM (cause of death ensemble modeling) for all causes of death, except HIV.[16] Vaccine-preventable diseases were one of the most important groups within infectious diseases category which were measured in GBD by DALYs. In addition to the abovementioned methods, some other modeling methods, including natural history models, were used for measles and whooping cough as two vaccine-preventable diseases.[14]

The method of the present study is extraction of data about the burden of vaccine-preventable diseases (measles, tetanus, diphtheria and whooping cough) in Iran based on the GBD 2010 by new graphs and tables, criticizing the results and limitations of GBD.

Results

DALYs and Death rates

Regardless of gender differences, DALYs and death rates for measles at all ages declined by 94% from 1990 to 2010. The maximum and minimum DALYs rates for tetanus were 45.619 and 6.7657 from 1990 to 2010, respectively, which shows a reduction of 85%. The maximum and minimum DALYs rates for whooping cough were 59.728 and 2.3316 from 1990 to 2010, respectively, indicating 96% reduction. The maximum and minimum death rates for diphtheria were calculated as 0.0315 and 0.0049 per 100.000 people in 1990 and 2010, respectively, which show a decline of 84% (Table 1 & Figure 1).

DALYs and Death rates for under 5 age group

Table 2 and Figure 2 show DALYs rates and death rates for under 5 age group. The maximum and minimum death rates of measles for males were 5.2785 and 0.0116 per 100.000 people in 1990 and 2005, respectively, indicating a reduction of 87% during this period of time. Moreover, the maximum and minimum death rates due to this disease among females were 5.0227 and 0.0114 per 100.000 people in 1990 and 2005, respectively, showing 87% reduction. The maximum and minimum death rates of whooping cough in males were 4.0674 and 0.2713 per 100.000 people in 1990 and 2000, respectively, which show a 93% reduction in 2010 compared to 1990. Finally, the maximum and minimum death rates among females were observed in 1990 and 2000—3.9825 and 0.2715 per 100.000, respectively, which were reduced by 92% (Table 2).

Figure 2 shows YLDs, YLLs and DALYs rates for the years 1990 and 2010. DALYs rates of diphtheria for males and females in 1990 were 12.2498 and 12.1745 per 100.000 people, respectively. These rates were 3.09368 and 2.84608 per 100.000 people, respectively, for males and females in 2010. Therefore, during the study period, the reduction of diphtheria among males and females was 75% and 77%, respectively. DALYs rate of tetanus for males and females in 1990 were estimated 289.409 and 172.715 per 100.000 people, respectively. They were 15.2227 and 9.77614 per 100.000 people in 2010, respectively. It means that the reduction for tetanus among males and females in 2010 compared to 1990 was 95% and 94%, respectively (Figure 2).

DALYs number for under 5 age group

Table 3 shows the DALYs number for under 5 age group. The maximum DALYs numbers due to measles among males in 1990, 1995 and 2010 were calculated as 21187.6, 5153.89 and 1825.91, respectively, that shows about 91% reduction in 2010 compared to 1990. The observed values for diphtheria, tetanus and whooping cough were 83%, 96%, and 95%, respectively. In general, the maximum DALYs among males in 2000 and 2005 were 1534.3 and 1017.28 that were caused by tetanus and whooping cough, respectively.

The maximum DALYs numbers caused by measles among females in 1990, 1995 and 2010 were 19297.5, 4716.8 and 1709.33, respectively. The DALYs number due to measles among females decreased by 91%, in 2010 compared to 1990. The observed values for diphtheria, tetanus and whooping cough were 84%, 96%, and 95%, respectively. The reduction was roughly similar among males and females.

Discussion

The results of this study demonstrate the burden of four vaccine-

Table 1. DALY rate and death rate (per 100 000) by disease, calendar year, and age groups for both sexes.

Measles	Death Rate			DALY Rate		
	1990	2000	2010	1990	2000	2010
Under 5	5.1534	0.3141	0.6665	442.9200	26.6810	57.5870
5–14	0.4760	0.0272	0.0524	37.7930	2.1185	4.1905
15–49	0.0458	0.0029	0.0043	3.0032	0.1920	0.2827
50–69	0.0049	0.0003	0.0006	0.1661	0.0106	0.0237
All ages	1.0176	0.0393	0.0657	86.1220	3.2585	5.5703
Diphtheria	**Death Rate**			**DALY Rate**		
	1990	2000	2010	1990	2000	2010
Under 5	0.1440	0.0591	0.0350	12.2130	5.0203	2.9726
5–14	0.0207	0.0106	0.0072	1.6154	0.8263	0.5580
15–49	0.0028	0.0017	0.0011	0.1636	0.0986	0.0643
50–69	0.0036	0.0023	0.0020	0.1169	0.0759	0.0662
All ages	0.0315	0.0096	0.0049	2.5862	0.7608	0.3759
Whooping cough	**Death Rate**			**DALY Rate**		
	1990	2000	2010	1990	2000	2010
Under 5	4.0259	0.2714	0.3025	352.9100	25.8900	27.0970
5–14	0.0290	0.0023	0.0031	2.3290	0.2093	0.2582
15–49	0.0065	0.0006	0.0009	0.3798	0.0410	0.0538
50–69	0.0156	0.0015	0.0027	0.5141	0.0605	0.0983
All ages	0.6839	0.0277	0.0264	59.7280	2.6420	2.3316
Tetanus	**Death Rate**			**DALY Rate**		
	1990	2000	2010	1990	2000	2010
Under 5	2.6960	0.4287	0.1456	232.3400	36.9970	24.7640
5–14	0.1072	0.0396	0.0142	8.2509	3.0229	4.5740
15–49	0.1268	0.0515	0.0208	6.8910	2.7682	4.8170
50–69	0.4889	0.2141	0.0883	13.7550	5.9917	10.7390
70+	1.0067	0.4813	0.2331	13.6480	6.3809	11.8190
All ages	0.5977	0.1115	0.0457	45.6190	6.5778	6.7657

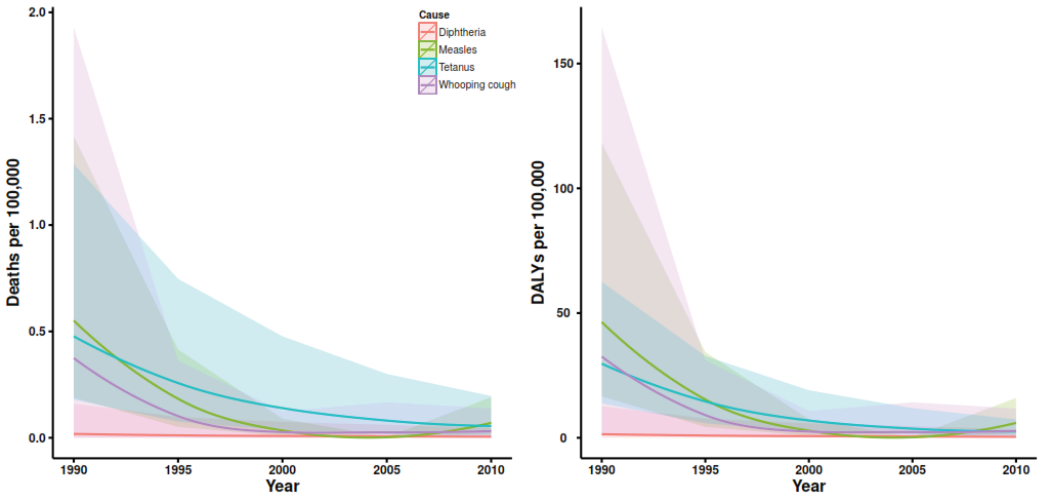

Figure 1. DALY rate and death rate (per 100 000) by calendar year and disease for both sexes.

Table 2. Death rate (per 100 000) for under 5 age group by disease, calendar year, and sex.

Male					
	Death rate				
	1990	**1995**	**2000**	**2005**	**2010**
Measles	5.2785	1.5034	0.3182	0.0116	0.6736
Diphtheria	0.1444	0.0825	0.0603	0.0498	0.0364
Tetanus	3.3558	1.2526	0.5410	0.3035	0.1763
Whooping cough	4.0674	0.7676	0.2713	0.3737	0.3045
Female					
	Death rate				
	1990	**1995**	**2000**	**2005**	**2010**
Measles	5.0227	1.4388	0.3098	0.0114	0.6591
Diphtheria	0.1436	0.0799	0.0580	0.0468	0.0335
Tetanus	2.0064	0.8056	0.3113	0.1734	0.1135
Whooping cough	3.9825	0.7494	0.2715	0.3762	0.3004

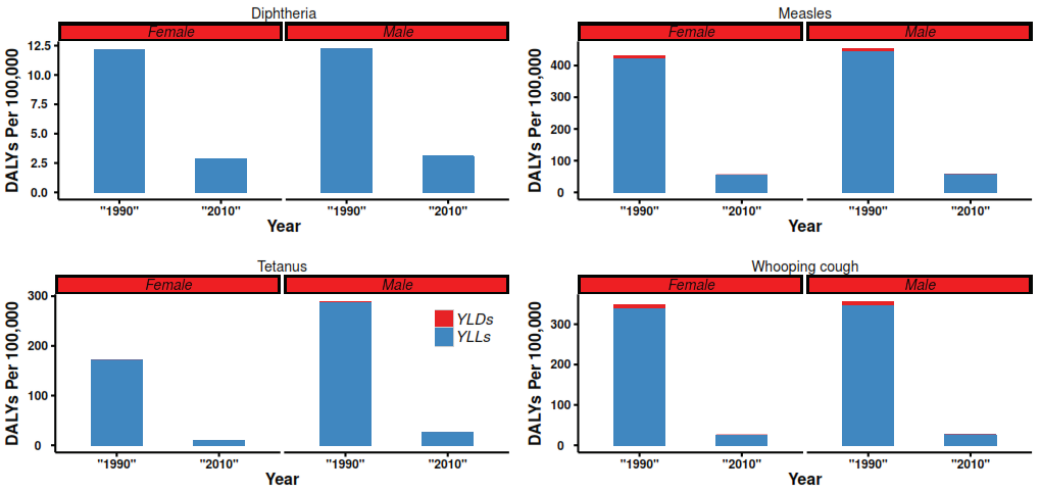

Figure 2. DALY rate for people aged under 5 by disease, sex, and calendar year.

Table 3. DALY number for under 5 age group by disease, calendar year and sex.

Male					
	DALY number				
	1990	**1995**	**2000**	**2005**	**2010**
Measles	21187.6	5153.89	887.57	30.77	1825.91
Diphtheria	572.19	281.55	167.92	128.45	97.09
Tetanus	13518.4	4351	1534.3	795.60	477.78
Whooping cough	16647	2830.61	848.70	1017.28	855.72
Female					
	DALY number				
	1990	**1995**	**2000**	**2005**	**2010**
Measles	19297.5	4716.8	825.98	28.73	1709.33
Diphtheria	544.13	261.01	154.49	115.45	85.39
Tetanus	7719.43	2670.38	841.76	433.36	293.31
Whooping cough	15610.8	2651.04	814.04	979.77	807.79

preventable diseases, including measles, tetanus, diphtheria and whooping cough in Iran. According to EPI, there are a number of immunization programs for many infectious diseases. In the present study, we tried to explain the trend of changes in DALYs number, DALY and death rates over a 20-year period. Almost all rates decreased during this time. Diphtheria and tetanus DALYs and death rates reduced continually, but there were no persistent decreasing trends for measles. In this regard, DALYs rate for measles was 5.5703 in 2010 which had increased compared to its DALYs rate in 2000 that was 3.2585 per 100.000 people. This rise may be due to some small outbreaks of measles occurring in rural areas of Chabahar district in southeast Iran in 2009 and 2010.[22] In another study in Iran, Nejati *et al* (2013) reported an increasing trend in measles rate in Sistan and Bluchistan province during 2006 to 2011as a hot spot for measles.[23]

In 2002, the Iranian Ministry of Health and Medical Education (MOHME) ran a comprehensive vaccination program for measles and rubella (MR) for all people aged 5 to 25 years old. Finally, as of 2004, routine vaccination program for measles has started.[23] According to WHO/UNICEF immunization summary in Iran, in spite of a cut in 2005 in national coverage rates for vaccine-preventable disease, an increasing trend was reported from 1980 through 2011.[24]

In comparison to high, upper-middle, lower-middle and low-income countries, Iran as an upper-middle income country[25] has a reasonably good condition in controlling communicable diseases. For instance, age-standardized DALYs rate of diphtheria in Qatar, as a high-income country, in 2010 was estimated 0.15 in comparison to 0.40 per 100.000 for Iran. Age-standardized DALYs rate of measles for Turkey as a cohort, upper-middle income country, in 2010 was 14.35 compared with 5.97 per 100.000 people for Iran. The gap can be attributed to far-reaching consequence of good implementation of the immunization program. On the other hand, age-standardized death rate of tetanus in 2010 for Pakistan was calculated 2.57 in comparison to 0.054 per 100.000 for Iran, whereas age-standardized death rate of whooping cough for Afghanistan, as a low-income country, in 2010 was estimated 2.85 in comparison to 0.028 per 100.000 people for Iran. According to Yang *et al*.,[21] age-standardized DALYs rate of measles in 1990 and 2010 in China were 149.6 and 3.6 per 100.000 people, respectively whereas these figures for Iran were estimated 46.88 and 5.97 per 100.000 people, respectively. This gap of age-standardized DALYs rate among different countries in 1990 could be due to a good coverage of immunization in Iran, while the narrow gap in 2010 could be attributed to small outbreaks in some parts of Iran.

In the present study, among the four aforementioned diseases, the maximum age-standardized death rate was observed in measles; in Mathers's study (2007), except for measles, none of the other vaccine-preventable diseases were among the top 20 causes of death.[26]

Here, we should mention that although GBD study is an important and valuable study for determining the burden of diseases all around the world, it has some limitations. One of its most important limitations in estimating the vaccine-preventable diseases is over-reporting of vaccination coverage.[27] In fact, vaccination coverage is usually over-reported. Therefore, we can assume this challenge continues for every time point during this 20-year period, although this challenge has no effect on the measured trends. Another noteworthy limitation of the present study is that IHME used a new model based on imputed data. It is obvious that model-driven estimations have lower values against data-driven estimations. Moreover, the GBD estimations are at national level. Nevertheless, it is important for policy makers to know the burden of diseases both at national and sub-national levels to make appropriate policies for vaccine-preventable diseases. In this regard, the Non-Communicable Diseases Research Center (NCDRC) of Tehran University of Medical Sciences (TUMS) is conducting a study on the national and sub-national burden of diseases (NASBOD) in Iran.[28] The above-mentioned study is a comprehensive study that benefits from two advanced statistical methods[29-31] for an exact estimation.

In conclusion, this study demonstrated that vaccination as one of the most important public health interventions has had a positive impact on the control of vaccine-preventable diseases. The results of this study may pave the way for making decision about more appropriate public health interventions on this field. Moreover, for a better conclusion, it is better to estimate the burden of all diseases including vaccine-preventable diseases at both national and sub-national levels.

Abbreviations

IHME: Institute for Health Metrics and Evaluation
GBD: Global Burden of Disease
DALYs: Disability Adjusted Life Years
NCDs: Non-Communicable Disease
NASBOD: National and Sub-National Burden of Diseases
EPI: Expanded Program on Immunization

Competing interests

The authors declare that they have no competing interests.

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