

## Original Article

# Disability-Adjusted Life-Years (DALYs) for 315 Diseases and Injuries and Healthy Life Expectancy (HALE) in Iran and its Neighboring Countries, 1990–2015: Findings from Global Burden of Disease Study 2015

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## Abstract

**Background:** Summary measures of health are essential in making estimates of health status that are comparable across time and place. They can be used for assessing the performance of health systems, informing effective policy making, and monitoring the progress of nations toward achievement of sustainable development goals. The Global Burden of Diseases, Injuries, and Risk Factors Study 2015 (GBD 2015) provides disability-adjusted life-years (DALYs) and healthy life expectancy (HALE) as main summary measures of health. We assessed the trends of health status in Iran and 15 neighboring countries using these summary measures.

**Methods:** We used the results of GBD 2015 to present the levels and trends of DALYs, life expectancy (LE), and HALE in Iran and its 15 neighboring countries from 1990 to 2015. For each country, we assessed the ratio of observed levels of DALYs and HALE to those expected based on socio-demographic index (SDI), an indicator composed of measures of total fertility rate, income per capita, and average years of schooling.

**Results:** All-age numbers of DALYs reached over 19 million years in Iran in 2015. The all-age number of DALYs has remained stable during the past two decades in Iran, despite the decreasing trends in all-age and age-standardized rates. The all-cause DALY rates decreased from 47,200 in 1990 to 28,400 per 100,000 in 2015. The share of non-communicable diseases in DALYs increased in Iran (from 42% to 74%) and all of its neighbors between 1990 and 2015; the pattern of change is similar in almost all 16 countries. The DALY rates for NCDs and injuries in Iran were higher than global rates and the average rate in High Middle SDI countries, while those for communicable, maternal, neonatal, and nutritional disorders were much lower in Iran. Among men, cardiovascular diseases ranked first in all countries of the region except for Bahrain. Among women, they ranked first in 13 countries. Life expectancy and HALE show a consistent increase in all countries. Still, there are dissimilarities indicating a generally low LE and HALE in Afghanistan and Pakistan and high expectancy in Qatar, Kuwait, and Saudi Arabia. Iran ranked 11<sup>th</sup> in terms of LE at birth and 12<sup>th</sup> in terms of HALE at birth in 1990 which improved to 9<sup>th</sup> for both metrics in 2015. Turkey and Iran had the highest increase in LE and HALE from 1990 to 2015 while the lowest increase was observed in Armenia, Pakistan, Kuwait, Kazakhstan, Russia, and Iraq.

**Conclusions:** The levels and trends in causes of DALYs, life expectancy, and HALE generally show similarities between the 16 countries, although differences exist. The differences observed between countries can be attributed to a myriad of determinants, including social, cultural, ethnic, religious, political, economic, and environmental factors as well as the performance of the health system. Investigating the differences between countries can inform more effective health policy and resource allocation. Concerted efforts at national and regional levels are required to tackle the emerging burden of non-communicable diseases and injuries in Iran and its neighbors.

**Keywords:** Disability-adjusted life-year, global burden of disease, healthy life expectancy, Iran

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## Introduction

Iran is a large country in the Middle East with a unique geopolitical position in terms of its spread along a wide range of latitudes, diverse climate, and diversity of cultures and ethnicities.<sup>1,2</sup> In 2015, the population of Iran reached 79 million.<sup>3</sup> This country has faced numerous social and economic challenges during the past four decades.<sup>1,2</sup> A rapid demographic and epidemiologic transition is still ongoing in Iran.<sup>4</sup> Urbanization has increased and the fertility rate has decreased following the 1979 revolution.<sup>5</sup> The overall socio-economic status has improved substantially.<sup>1,2,6</sup> However, these changes have not been independent of overall trends in the Middle East, South Asia, and Central Asia. Iran has vast borders with 15 other countries that are located in various regions defined by the World Bank.<sup>3</sup> Iran has substantial trade with its neighbors as well as exchange of workforce and migrants, leading to exchange of culture and life style.<sup>5,6</sup> Therefore, the socio-economic status and the general health status in Iran are likely to be influenced by its neighbors. It is very important to estimate health status as well as its trends during the past two decade in Iran and to compare it with its neighbors. For this purpose, consistent summary measures are required to make comparisons across countries and time.

With the replacement of millennium development goals (MDGs)<sup>7</sup> with sustainable development goals (SDGs) in 2015,<sup>8</sup> summary measures of health have gained even more importance in identifying gaps, needs and priorities in health, and in guiding investments in health systems at national, regional, and global

scales.<sup>9,10</sup> SDGs encompass comprehensive targets that address non-communicable diseases (NCDs) and various factors that affect health. A summary metric that can measure the progress of nations towards SDGs, especially those related to health and well-being of people across the globe, can be very useful.<sup>11</sup> Summary metrics can provide insight into the health status of nations and performance of the health systems. It is also important to measure what percentage of health loss is attributable to death and what percentage is lost due to disability. With aging of populations, a higher percentage of life is lost due to disability.<sup>12,13</sup> The novel metrics devised in Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) provide the possibility of disaggregating years of life lost (YLL) to premature mortality and years of lived with disability (YLD). The disability-adjusted life-year (DALY) is the sum of YLL and YLD that shows the life lost either to death as well as years lived at sub-optimal health with disability. DALY is the main measure that shows the gap in health.

The second type of summary metrics measure health and life expectancy (LE). A single metric to measure healthy life expectancy (HALE) in populations was first developed by Sullivan.<sup>14,15</sup> In calculating HALE, years lived are weighted by a measure of functional health loss before death. A comprehensive range of causes of health loss are captured by HALE.<sup>12</sup>

GBD is the most comprehensive study so far on summary metrics of health.<sup>16</sup> To the best of our knowledge, there is hardly any other study that can cover the range of times and places captured in GBD and the methods used by it to measure uncertainties.

In this paper, we aim to present the levels and trends in DALYs, LE, and HALE in Iran and its 15 neighboring countries, based upon the estimated mortality and morbidity in previous steps of GBD 2015. The methods are generally similar to previous iterations of GBD.<sup>12,17,18</sup> However, new data sources from new geographies have been included and methods have been improved. Additionally, the association of DALY and HALE with the development status of nations has been investigated.<sup>12</sup> The progress of nations is monitored and observed health status is compared with the expected status based on the position of countries within the spectrum of development. We have presented the levels as well as trends in DALYs, LE, and HALE for Iran and its 15 neighboring countries. Investigating the differences in health status and causes of death and disability between neighboring countries and countries with similar socio-economic, cultural, and political characteristics can inform more effective health policy and resource allocation in poorly performing countries.

## Methods

The GBD is a systematic effort to measure health that can be comparable across time and place.<sup>16</sup> The details of GBD 2015 methodology for estimating DALYs, LE, and HALE have been described elsewhere.<sup>12,13,16-22</sup> The results and data sources used for GBD 2015 are available through interactive tools on the website of the Institute of Health Metrics and Evaluation (IHME).<sup>23</sup> Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) have been followed in all steps of analysis.<sup>24,25</sup>

In short, GBD results cover 195 countries and territories in 21 regions and 7 super-regions. There are four levels in the GBD cause hierarchy. Causes in each level are mutually exclusive and collectively exhaustive. The full list of GBD causes is available in

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previous publications.<sup>13,19</sup>

Mortality and non-fatal health loss in terms of YLL and YLD, respectively, have been estimated in GBD 2015. The details of their estimation are described in previous publications.<sup>12,13,19,26,27</sup> DALYs have been estimated by summing YLLs and YLDs by sex, age, country, and year for each cause. In GBD 2015, methods developed by Sullivan<sup>14,15</sup> have been used to calculate HALE. To estimate 95% Uncertainty Intervals (UIs), 1000 draws from posterior distribution were taken for each estimation step. UIs capture uncertainty from multiple sources including sampling as well as model estimation and specification. The uncertainty in age-specific YLDs is assumed to be independent of age-specific YLLs used in DALYs and death rates in HALE.

In this paper, we report GBD 2015 results on DALYs by cause, LE, and HALE for Iran and all countries which have land or marine borders with Iran: Afghanistan, Bahrain, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, Turkey, and United Arab Emirates in the region of Middle East and North Africa; Pakistan in South Asia; Armenia, Azerbaijan, Kazakhstan, and Turkmenistan in Central Asia; and Russia in Eastern Europe. Results have been estimated by sex, age (20 age groups), country, and year for each cause.

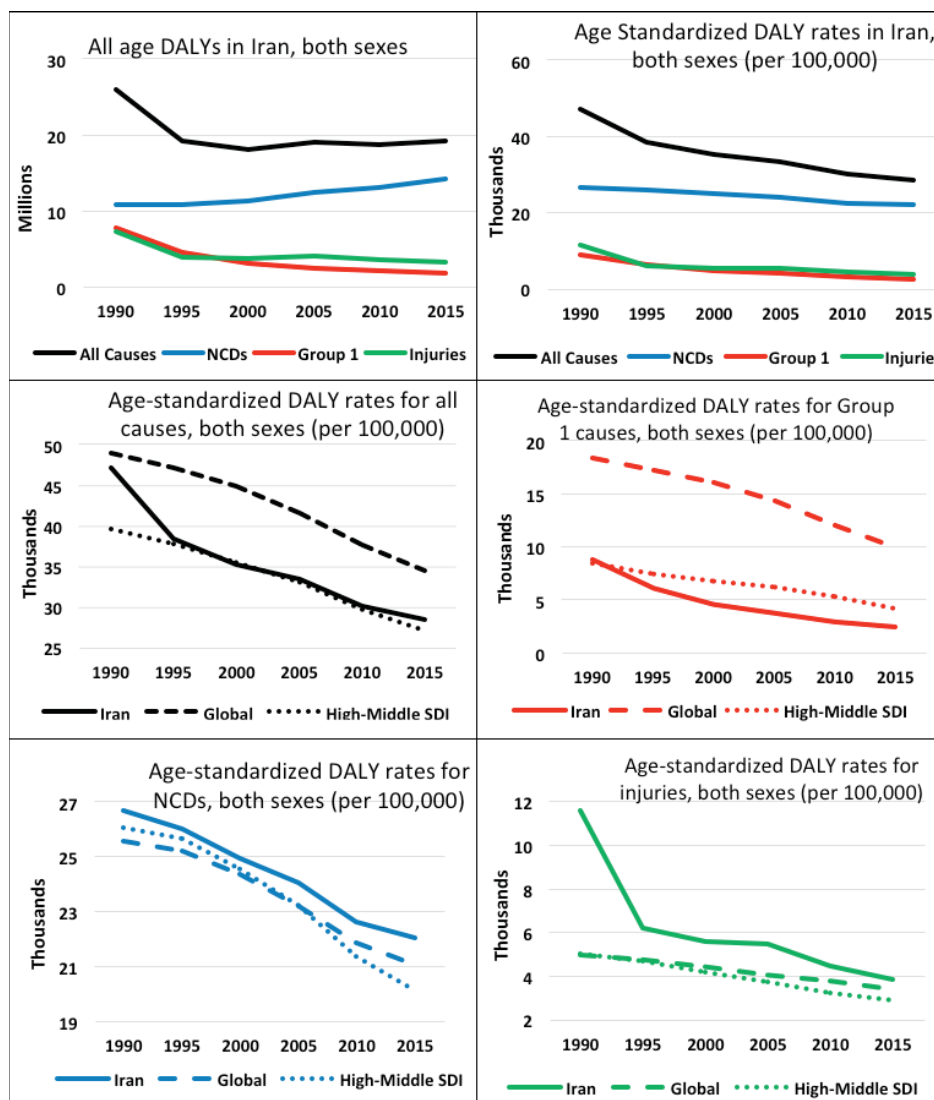
In the GBD 2015, the association of the Socio-demographic

Index (SDI) with DALY and HALE are investigated. SDI is the geometric mean of 3 indicators: 1) income per capita; 2) average years of schooling in people who are aged 15 years or more, and 3) the total fertility rate. SDI values range between 0 and 1, with 0 indicating the lowest income and schooling and highest fertility rate and 1 indicating the inverse. SDI values are calculated for each country for each year from 1980 to 2015. Expected LE and number of DALYs at each level of SDI have been estimated with the use of spline regressions. The observed life expectancy has been compared with expected life expectancy for all countries and years. The observed to expected DALYs for each country have been calculated.

## Results

### DALYs in Iran

All-age DALYs for all causes in Iran were 25.9 million years (95% UI: 23.3 – 28.5) in 1990 and 19.2 million years (95% UI: 16.2 – 22.3) in 2015. All-age DALYs decreased from 1990 to 2000 (18.0 million years; 95% UI: 16.0 – 20.3), increased very slowly from 2000 to 2005, but remained relatively stable between 2005 and 2015 (Figure 1). The share of Group 1 causes



**Figure 1.** All age DALYs and age standardized DALY rates in both sexes in Iran from 1990 to 2015 (DALY: Disability Adjusted Life Years; Group 1 diseases comprise communicable, maternal, neonatal, and nutritional diseases).

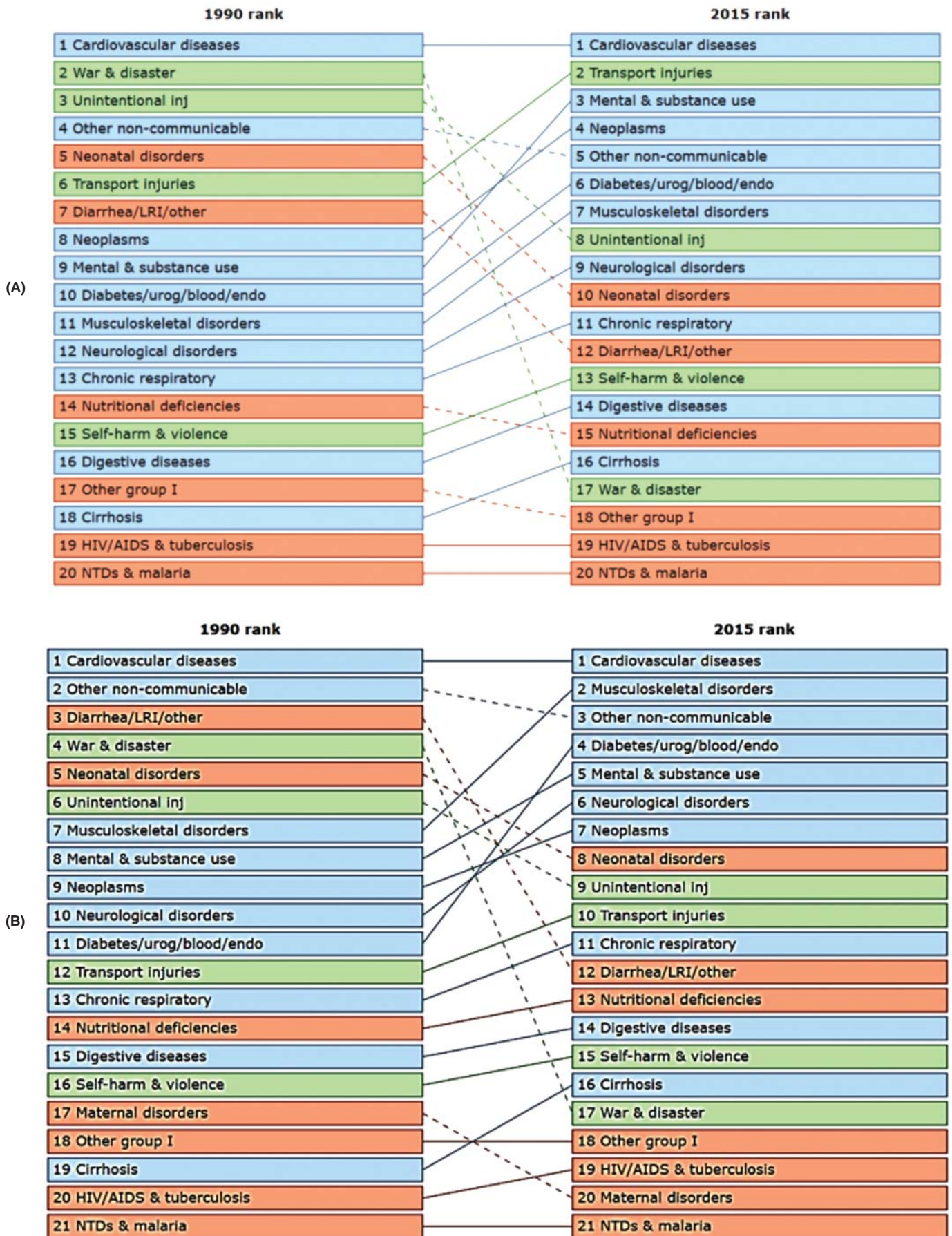
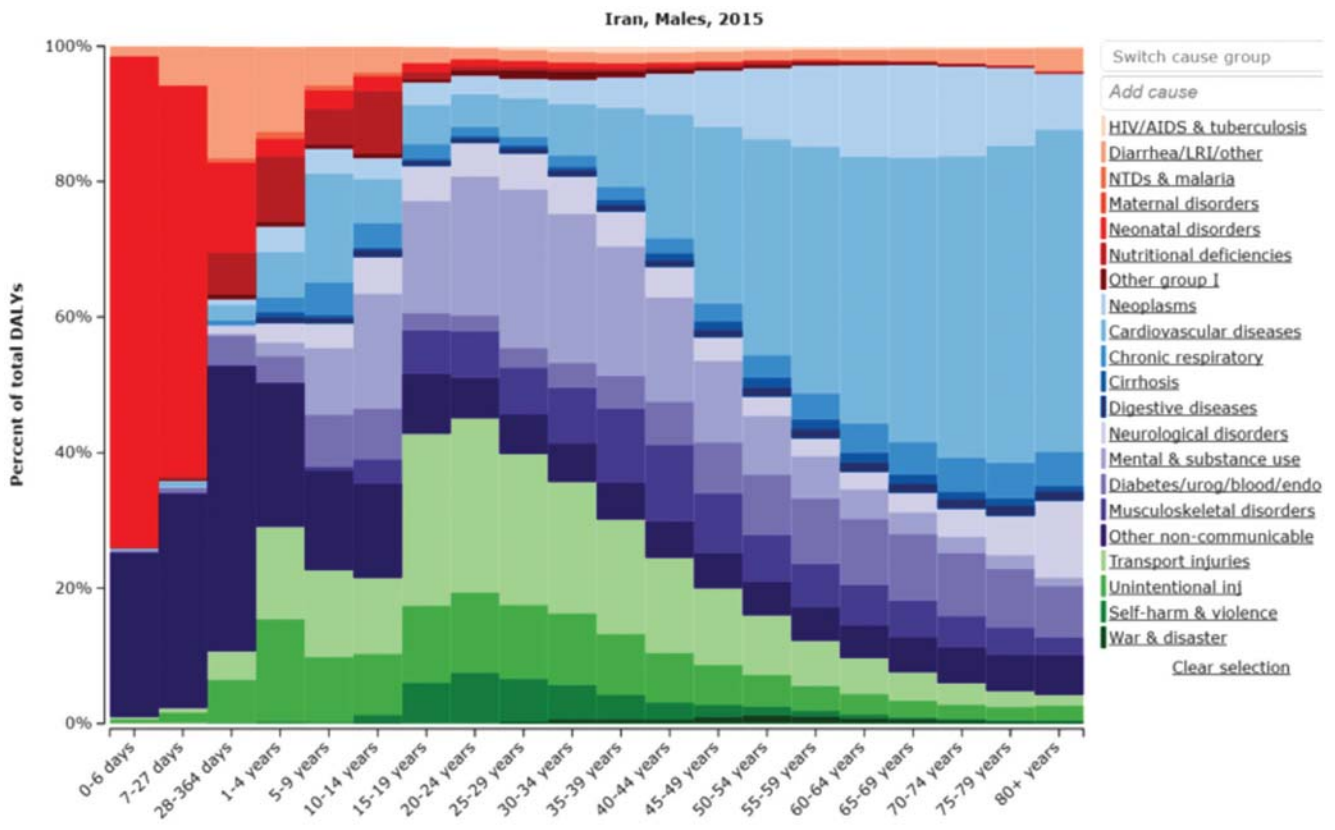
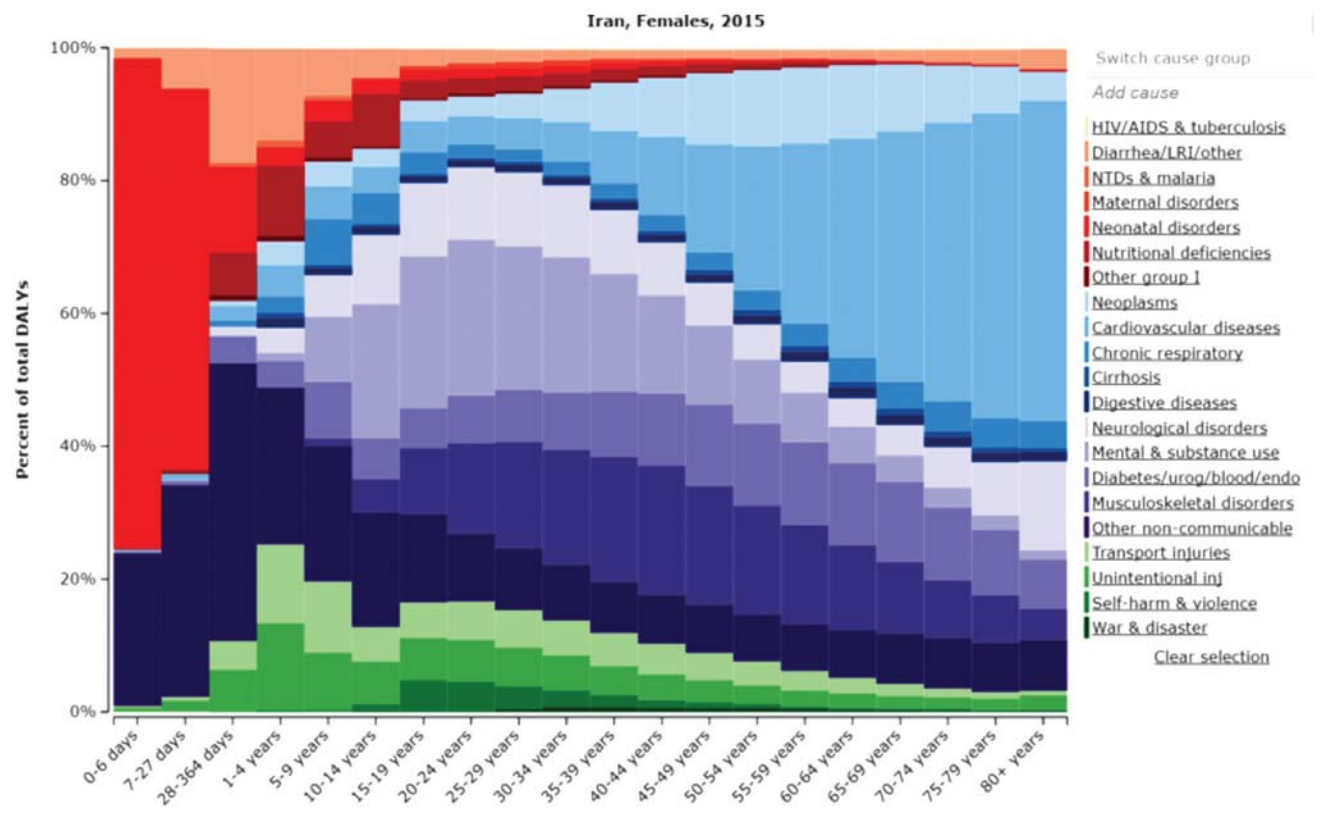


Figure 2. Leading causes of age standardized DALY rates per 100,000 in 1990 and 2015 in Iran. A) Men; B) Women. (Group 1 diseases are presented in red, non-communicable diseases in blue, and injuries in green).



(A)



(B)

Figure 3. The distribution of causes of DALYs across age groups by sex in 2015 in Iran. A) Men; B) Women.

**Table 1.** Age standardized DALY rates per 100,000 in 1990, 2005, and 2015 for all causes in both sexes in 16 countries and the SDI category to which each country belongs.

	1990	2005	2015	SDI category
Afghanistan	96,500 (84,800 – 109,300)	88,700 (77,300 – 101,000)	82,000 (71,000 – 94,500)	Low SDI
Armenia	36,900 (34,000 – 40,100)	32,600 (29,800 – 35,700)	27,400 (24,600 – 30,500)	High–Middle SDI
Azerbaijan	46,900 (43,800 – 50,400)	39,700 (36,400 – 43,100)	30,800 (27,600 – 34,300)	High–Middle SDI
Bahrain	33,900 (30,100 – 38,000)	26,700 (23,500 – 30,300)	22,400 (18,900 – 26,100)	High–Middle SDI
<b>Iran</b>	47,200 (42,200 – 52,000)	33,400 (29,000 – 38,100)	28,400 (24,300 – 32,900)	High–Middle SDI
Iraq	47,500 (42,100 – 53,200)	47,300 (41,500 – 54,600)	43,400 (36,900 – 50,300)	Middle SDI
Kazakhstan	40,900 (38,000 – 44,300)	46,300 (43,200 – 49,600)	35,600 (32,100 – 39,300)	High–Middle SDI
Kuwait	25,300 (22,200 – 28,900)	23,300 (20,500 – 26,500)	20,000 (17,000 – 23,300)	High SDI
Oman	34,600 (29,400 – 40,200)	27,100 (23,700 – 30,600)	25,300 (21,500 – 29,100)	High–Middle SDI
Pakistan	56,100 (51,900 – 60,500)	55,500 (51,100 – 60,400)	46,700 (42,100 – 52,100)	Low–Middle SDI
Qatar	29,500 (26,100 – 33,000)	26,300 (22,800 – 29,900)	21,500 (18,100 – 25,500)	High–Middle SDI
Russia	38,400 (35,300 – 41,900)	47,000 (44,000 – 50,000)	34,600 (31,500 – 38,000)	High SDI
Saudi Arabia	31,200 (27,900 – 35,300)	24,000 (21,200 – 27,200)	21,500 (18,500 – 24,700)	High–Middle SDI
Turkey	42,600 (39,200 – 46,300)	27,200 (24,200 – 30,500)	22,700 (19,600 – 26,100)	High–Middle SDI
Turkmenistan	49,800 (46,300 – 53,800)	44,900 (41,200 – 49,000)	36,100 (32,800 – 39,700)	High–Middle SDI
United Arab Emirates	36,000 (30,700 – 41,600)	27,700 (24,300 – 31,300)	26,800 (22,500 – 31,900)	High SDI

Figures in parentheses show the 95% uncertainty intervals. DALY: disability-adjusted life years. SDI: socio-demographic index.

(communicable, maternal, neonatal, and nutritional diseases) from all-cause DALYs were 30% in 1990, 17% in 2000, and 10% in 2015. The respective figures were 42%, 63%, and 74% for NCDs, and 28%, 20%, and 16% for injuries. These estimates show a decrease in the share of Group 1 causes and injuries along with a steep increase in the share of NCDs. DALY rates due to all causes showed a consistent decrease from 1990 to 2015 in Iran. All-cause DALY rates were 47,200 per 100,000 population in 1990, which decreased to 33,400 in 2005 and ultimately to 28,400 in 2015. The trend for Group 1 causes decreased similarly, from 8,800 per 100,000 in 1990 to 3,900 in 2005 and 2,500 in 2015. The respective figures for injuries were 11,600 per 100,000 in 1990, which decreased to 5,500 in 2005 and ended in 3,900 in 2015. The trend of DALY rates due to NCDs differed from their all-age numbers. The DALY rates of NCDs were 26,700 per 100,000 in 1990, 24,100 in 2005, and 22,100 in 2015 (Figure 1). Figure 1 also demonstrates that the levels of DALY rates for all causes in Iran were lower than global estimates and almost similar to levels in High Middle SDI countries. The levels of DALY rates for Group 1 causes in Iran were much lower than estimates at global level and High Middle SDI countries, while the levels for NCDs and injuries were much higher.

Figure 2 demonstrates the top 20 causes of age-standardized DALY rates in 1990 and 2015 in Iran. Ten out of 20 leading causes in both years were NCDs. Cardiovascular diseases (CVDs) ranked first in both sexes in 1990 and 2015. Among men, the next leading causes of DALYs were transport injuries, mental disorders and substance use, and neoplasms. Among women, the leading causes of DALYs following CVDs were musculoskeletal disorders, other NCDs, and diabetes, urogenital, blood, and endocrine diseases. The highest rise in ranking pertained to mental disorders and substance use, neoplasms, musculoskeletal disorders, other NCDs, and diabetes, urogenital, blood, and endocrine diseases in both men and women, and transport injuries only in men.

Figure 3 demonstrates the distribution of causes of DALYs across various age groups by sex in 2015 in Iran. The figure shows

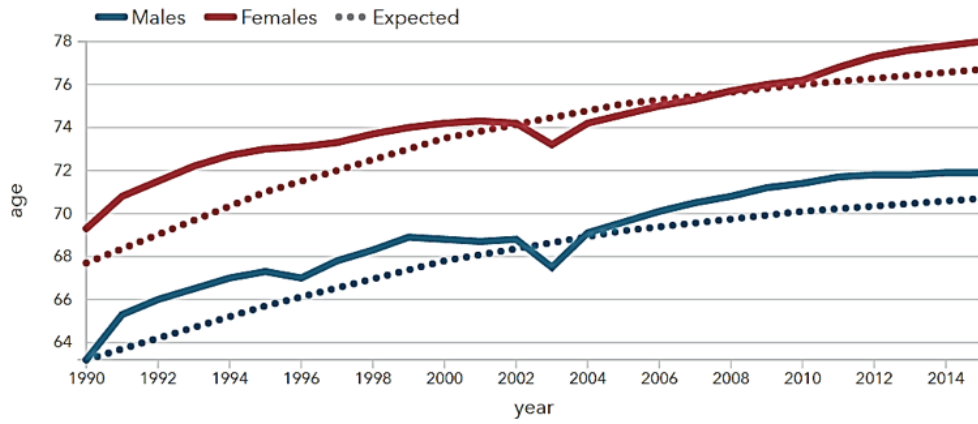
that neonatal disorders were the main causes of DALYs in infants in both sexes. Among men in middle age groups, mental disorders and substance use, transport injuries, and unintentional injuries gained more importance, while among women in the same age groups, diabetes, urogenital, blood, and endocrine diseases, along with mental disorders and substance use, as well as musculoskeletal disorders were more important. Cardiovascular diseases were by far the most common causes of DALYs in old ages in both men and women in 2015. Neurological diseases also showed a rising trend among age groups older than 70 years.

#### LE and HALE in Iran

Life expectancy at birth increased from 63.2 years in 1990 to 69.6 years in 2005 and 71.9 years in 2015 in men. The respective estimates in women were 69.3 years in 1990, 74.6 years in 2005, and 78.0 in 2015. The observed life expectancy was similar to the expected value in 1990 in men. However, among women, the observed life expectancy was higher than expected in the same year. In 2003, the observed life expectancy fell below the expected value in both men and women due to an earthquake of high magnitude in Central Iran in that year. The observed value surpassed the expected value in 2004 in men and in 2010 in women (Figure 4). In men, the HALE at birth increased from 61.0 years in 2005 to 63.0 years in 2015. The respective estimates in women were 64.3 years in 2005 and 67.1 years in 2015. The increase in LE and HALE were almost similar in both men and women.

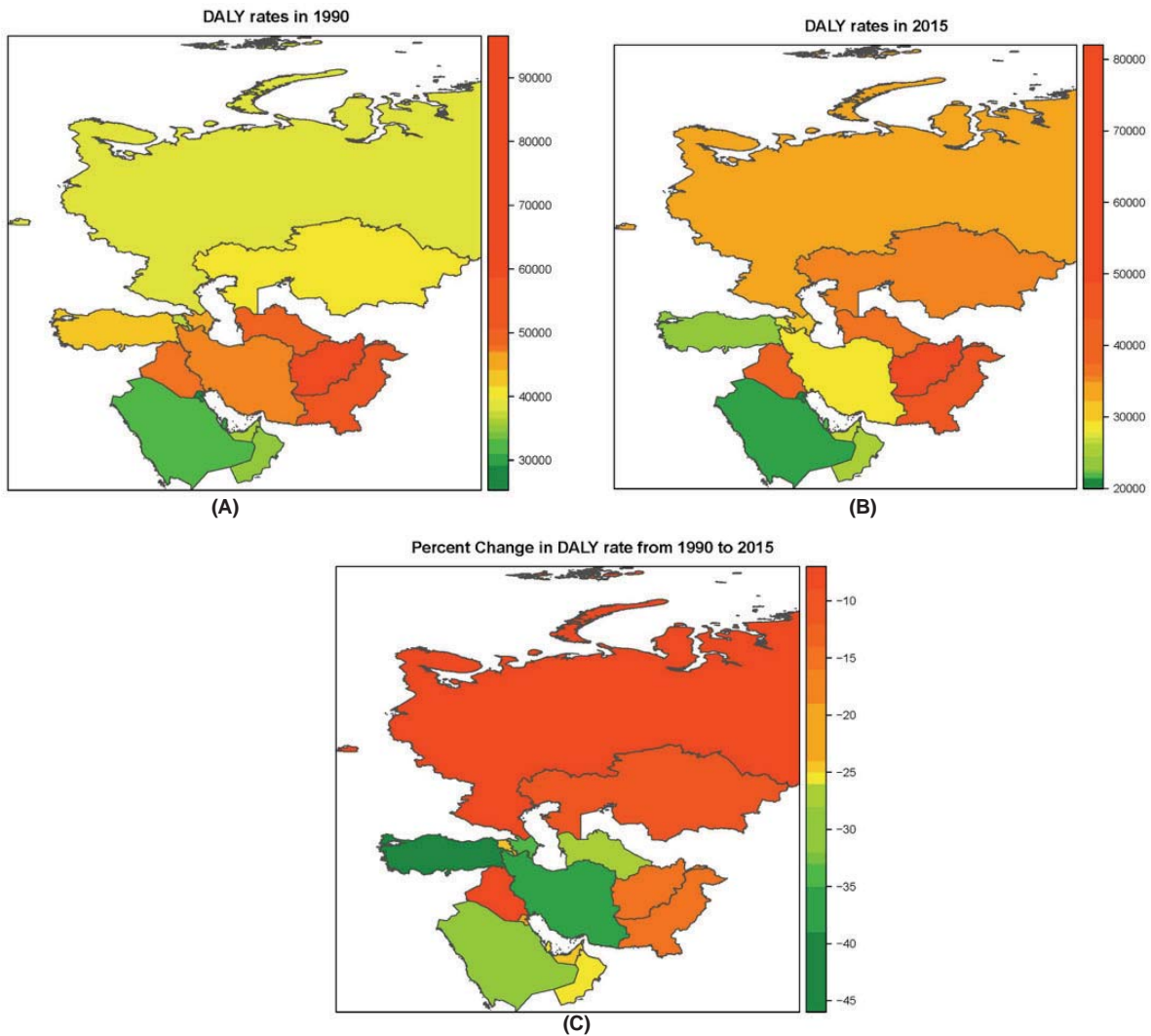
#### DALYs in Iran and its neighbors

Table 1 presents the age-standardized DALY rates per 100,000 in Iran and its 15 neighboring countries in 1990, 2005, and 2015 along with the SDI category to which they belong. Figure 5 also demonstrates the age-standardized DALY rates in 1990 and 2015 and the percent change in rates from 1990 to 2015 in both sexes in the 16 countries. Afghanistan had the highest rates in 1990, 2005, and 2015. The second rank belonged to Pakistan in all years. The



	Expected		Observed	
	1990	2015	1990	2015
Males	63.2	70.7	63.2	71.9
Females	67.7	76.7	69.3	78.0

**Figure 4.** Life Expectancy at birth in Iran, from 1990 to 2015 (The expected life expectancy is calculated based on the Socio-Demographic Index (SDI) for High-Middle Income countries, the category to which Iran belongs. The sharp decrease in life expectancy for both women and men in 2003 is due to the earthquake in central Iran in that year).



**Figure 5.** The age-standardized rate of DALYs per 100,000 for all causes in 1990 and 2015 and the percent change in rates from 1990 to 2015 in both sexes in 16 countries. **A)** DALY rates per 100,000 in 1990; **B)** DALY rates per 100,000 in 2015; **C)** Percent change in DALY rates from 1990 to 2015.

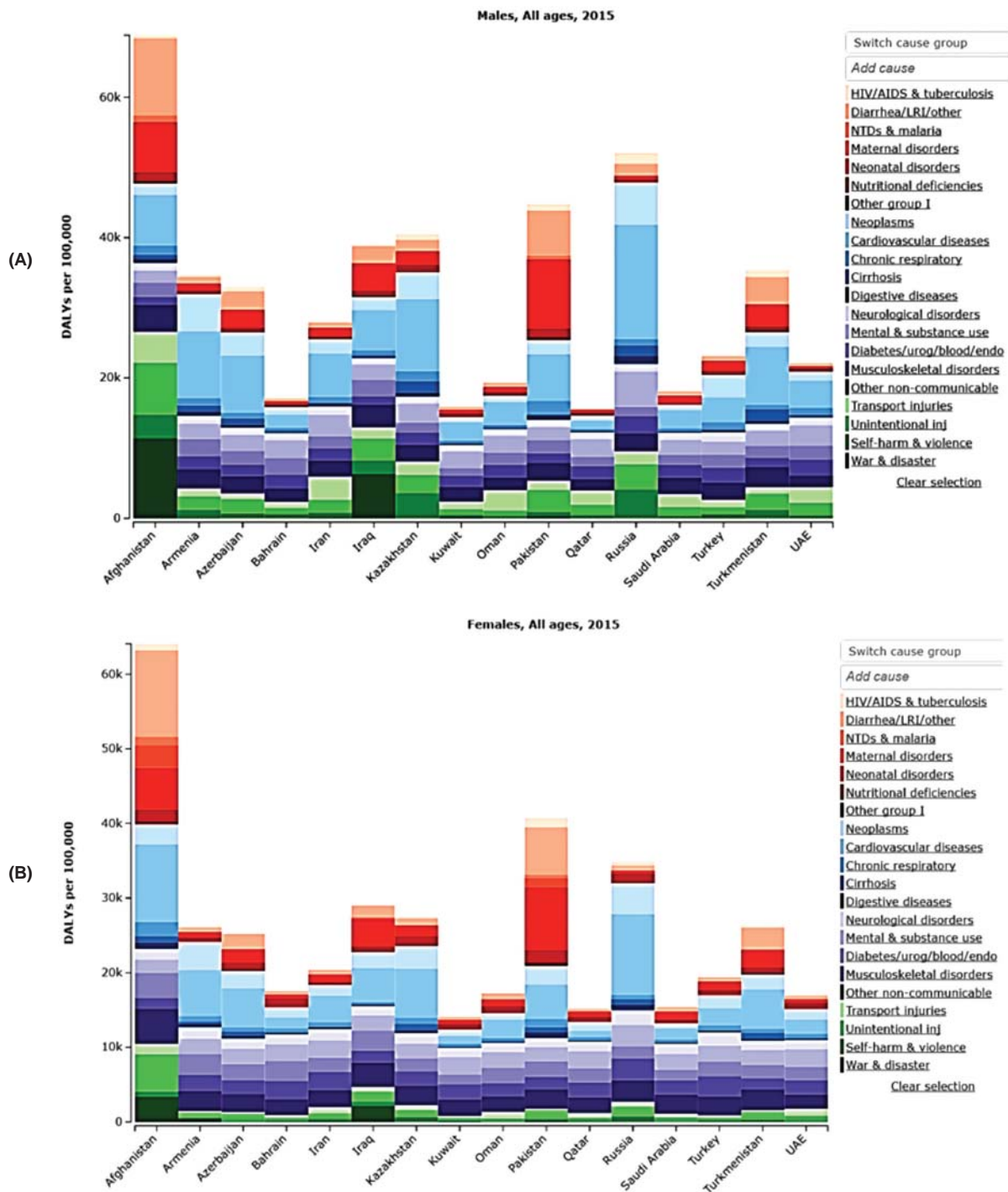


Figure 6. Distribution of causes of DALY rates across countries in 2015. A) Men; B) Women

lowest rates belonged to Kuwait in all 3 years. Iran ranked 12<sup>th</sup> in 1990, which improved to 9<sup>th</sup> in 2005 and 2015. The steepest decrease in DALY rates occurred in Turkey and Iran, while there was not a substantial decrease in Iraq and Russia.

Figure 6 demonstrates the distribution of major causes of DALYs in the 16 countries in 2015. A large portion of DALY rates in Afghanistan, Iraq, and Russia were caused by injuries in both sexes. The share of Group 1 diseases was still quite high in Afghanistan and Pakistan (34% and 46% respectively). Cardiovascular diseases contributed to a large share of DALY

rates in Russia and Kazakhstan. Afghanistan suffered from the triple burden of communicable and non-communicable diseases as well as injuries. In Iran, cardiovascular diseases had the largest share of DALY causes in both sexes.

Figure 7 demonstrates the ranking of top 20 causes of all age DALY rates in the 16 countries. In men, cardiovascular diseases had the highest rank in 15 countries, but ranked second in Bahrain. Transport injuries ranked second in Iran. War and disaster ranked second in Afghanistan and Iraq. Mental disorders and substance abuse ranked 3<sup>rd</sup> or 4<sup>th</sup> in Bahrain, Iran, Kazakhstan, Kuwait,



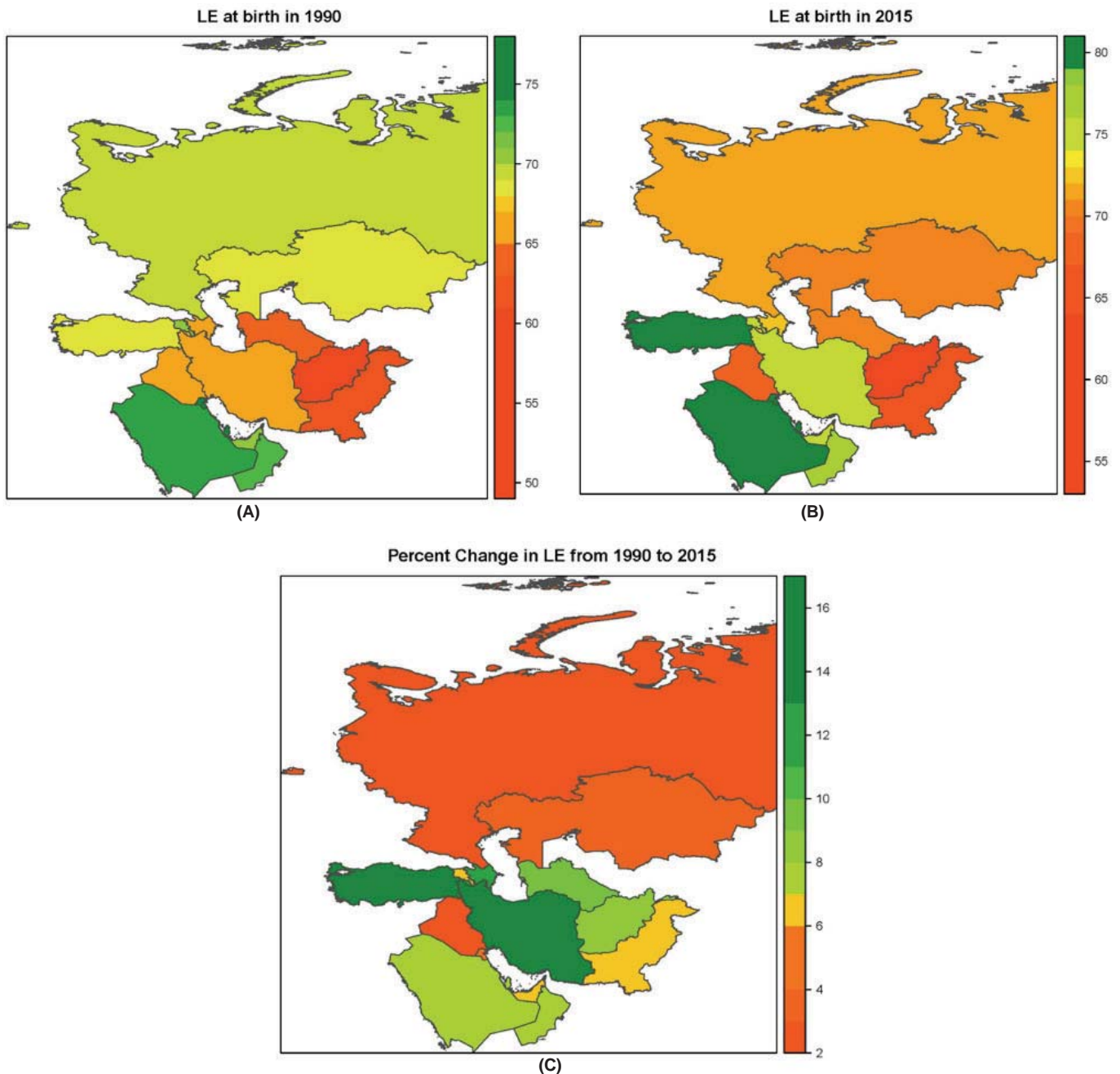
	Afghanistan	Armenia	Azerbaijan	Bahrain	Iran	Iraq	Kazakhstan	Kuwait	Oman	Pakistan	Qatar	Russia	Saudi Arabia	Turkey	Turkmenistan	UAE
Cardiovascular diseases	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1
Transport injuries	5	12	13	9	2	12	9	8	3	11	6	8	6	10	14	7
Mental & substance use	12	5	7	4	3	7	4	3	5	9	4	3	4	6	8	3
Neoplasms	9	2	2	6	4	5	2	6	7	5	7	2	9	2	4	5
Other non-communicable	10	3	3	3	5	6	6	2	4	7	3	6	2	3	3	4
Diabetes/urog/blood/endo	7	4	6	1	6	3	10	5	2	8	2	11	3	5	7	2
Musculoskeletal disorders	14	7	9	5	7	11	8	4	6	10	5	7	5	4	10	6
Unintentional inj	3	6	8	8	8	4	5	9	10	4	8	5	7	11	6	8
Neurological disorders	13	9	10	7	9	13	14	7	8	12	9	13	8	7	11	9
Neonatal disorders	6	8	5	12	10	8	12	12	11	2	10	16	10	8	5	13
Chronic respiratory	11	11	12	10	11	14	7	11	12	6	11	15	12	9	15	10
Diarrhea/LRI/other	4	13	4	11	12	10	13	10	9	3	12	9	11	12	2	11
Self-harm & violence	8	10	14	13	13	9	3	14	15	16	14	4	14	13	12	15
Digestive diseases	17	15	16	16	14	18	17	16	16	15	16	14	17	15	17	16
Nutritional deficiencies	16	16	17	14	15	15	15	13	13	14	13	17	15	14	16	12
Cirrhosis	15	14	11	15	16	16	11	15	14	20	15	12	13	16	9	14
War & disaster	2	18	20	20	17	2	20	17	20	19		20	20	19	20	
Other group I	20	19	18	17	18	19	18	18	17	18	17	18	18	17	18	18
HIV/AIDS & tuberculosis	18	17	15	18	19	17	16	19	18	13	18	10	16	18	13	17
NTDs & malaria	19	20	19	19	20	20	19	20	19	17	19	19	19	20	19	19

(A)

	Afghanistan	Armenia	Azerbaijan	Bahrain	Iran	Iraq	Kazakhstan	Kuwait	Oman	Pakistan	Qatar	Russia	Saudi Arabia	Turkey	Turkmenistan	UAE
Cardiovascular diseases	1	1	1	2	1	1	1	1	1	1	3	1	1	3	1	1
Musculoskeletal disorders	11	6	7	3	2	5	5	3	4	7	4	5	3	1	8	4
Other non-communicable	6	3	2	4	3	4	3	2	3	6	2	4	2	2	2	3
Diabetes/urog/blood/endo	3	4	4	1	4	2	6	5	2	5	1	8	5	5	6	2
Mental & substance use	13	5	6	5	5	6	4	4	5	8	5	3	4	4	7	6
Neurological disorders	12	7	9	7	6	9	7	6	6	10	7	6	6	6	9	7
Neoplasms	4	2	3	6	7	3	2	7	7	4	6	2	7	7	4	5
Neonatal disorders	9	8	8	12	8	7	8	12	11	2	8	14	8	8	5	13
Unintentional inj	5	11	10	11	9	10	10	11	13	13	11	9	10	12	10	10
Transport injuries	17	16	16	14	10	12	15	13	9	21	10	12	12	13	18	8
Chronic respiratory	7	12	12	9	11	15	11	10	12	9	12	17	11	9	13	9
Diarrhea/LRI/other	2	9	5	10	12	11	13	8	8	3	13	11	9	11	3	11
Nutritional deficiencies	15	10	11	8	13	14	9	9	10	11	9	7	13	10	12	12
Digestive diseases	16	13	14	13	14	17	16	14	14	14	14	15	14	14	14	14
Self-harm & violence	20	17	17	15	15	13	14	17	17	19	16	10	17	15	16	16
Cirrhosis	14	15	13	16	16	18	12	15	15	16	15	13	15	16	11	15
War & disaster	10	14	21	21	17	8	21	16	21	20		21	21	19	21	
Other group I	21	18	15	17	18	20	18	18	16	17	17	18	19	17	17	17
HIV/AIDS & tuberculosis	18	19	18	19	19	19	17	19	18	12	19	16	16	20	15	18
Maternal disorders	8	20	19	18	20	16	20	20	19	15	18	19	18	18	19	19
NTDs & malaria	19	21	20	20	21	21	19	21	20	18	20	20	20	21	20	20

(B)

Figure 7. Ranks of top 20 causes of age standardized DALY rate per 100,000 in 16 countries. A) Men; B) Women



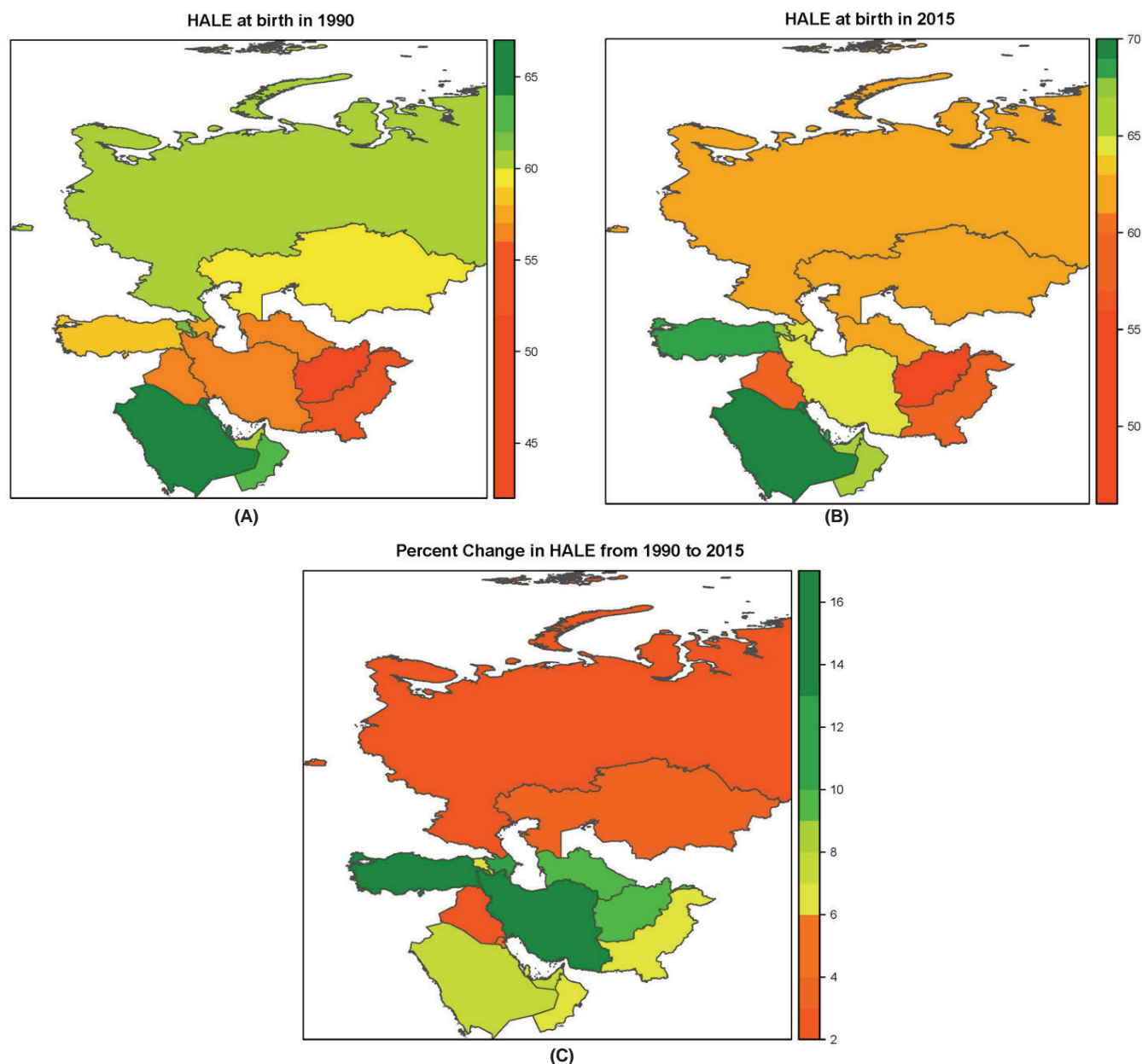
**Figure 8.** Life expectancy (LE) at birth in 16 countries in 1990 and 2015 and their percent change during this time period. **A)** LE at birth in 1990; **B)** LE at birth in 2015; **C)** Percent change in LE from 1990 to 2015.

Qatar, Russia, Saudi Arabia, and the United Arab Emirates (UAE). Neonatal disorders still ranked second in Pakistan. Neoplasms held the second rank in Armenia, Azerbaijan, Kazakhstan, Russia, and Turkey. Diabetes, urogenital, blood, and endocrine diseases, unintentional injuries, musculoskeletal, neonatal, and neurological disorders, chronic respiratory diseases, infectious diseases, as well as self-harm and violence occupied the middle ranks. The lowest ranks belonged to nutritional deficiencies, digestive diseases and cirrhosis, HIV/AIDS, tuberculosis, war and disaster, neglected tropical diseases (NTDs), and malaria.

The pattern was almost similar in women. Cardiovascular diseases ranked first in 13 countries, second in Bahrain, and third in Qatar and Turkey. Diarrhea, lower respiratory infections and other infections ranked second in Afghanistan and third in

Pakistan and Turkmenistan. The pattern of middle ranked causes was similar to men, the main difference being the generally lower rankings of transport injuries, self-harm and violence, as well as war and disasters.

Table 2 demonstrates the ratio of observed to expected number of DALYs for top 10 causes in each country, based on the SDI category to which each country belongs. Generally, ischemic heart disease (IHD), diabetes, neonatal encephalopathy, and road injuries were among the top causes of DALYs with observed to expected ratio of over 1.00. War was the top cause in Afghanistan and Iraq, with an observed to expected ratio of over 1,000 in both countries. The ratios for back and neck pain and depression were generally low, while the patterns for other causes showed more variability.



**Figure 9.** Healthy life expectancy (HALE) at birth in 16 countries in 1990 and 2015 and their percent change during this time period. **A)** HALE at birth in 1990; **B)** HALE at birth in 2015; **C)** Percent change in HALE from 1990 to 2015.

#### LE and HALE in Iran and its neighbors

Figures 8 and 9 demonstrate the life expectancy (LE) and healthy life expectancy (HALE) at birth in the 16 countries in 1990 and 2015 and their percent change during this time period. Qatar, Kuwait, and Saudi Arabia had the largest LE and HALE at birth both in 1990 and 2015. Pakistan and Afghanistan had the lowest LE and HALE at birth at these two time points. Iran ranked 11<sup>th</sup> in terms of LE at birth and 12<sup>th</sup> in terms of HALE at birth in 1990 which improved to 9<sup>th</sup> in both metrics in 2015. Between 1990 and 2015, Turkey had the highest change in terms of both LE and HALE at birth. As a result, Turkey's rank improved from 9<sup>th</sup> in terms of LE and 10<sup>th</sup> in terms of HALE to 4<sup>th</sup> for both metrics in 2015. After Turkey, Iran had the second steepest increase in LE and HALE at birth. LE at birth increased from 66.0 years in 1990 to 74.6 years in 2015 in Iran. Respective figures for HALE were 57.0

years in 1990 and 64.9 years in 2015. Azerbaijan, Afghanistan, Bahrain, and Turkmenistan were the next countries with the highest increase in their LE and HALE at birth. At the other end of the spectrum, Armenia, Pakistan, Kuwait, Kazakhstan, Russia, and Iraq had the least increase in their LE and HALE at birth.

LE at birth in 2005 and 2015 and those at age 65 years in 2015 for all 16 countries are demonstrated by sex in Table 3. The results mirror those presented in Figures 8 and 9. At almost all time points, LE and HALE were considerably higher in women compared to men; exceptions were LE and HALE at birth in 2005 and LE and HALE at age 65 years in 2015 in Afghanistan. The greatest gap between LE and HALE at birth between men and women was observed in Russia in 2005, where the LE and HALE at birth in women were 13.5 and 10.2 years more than those in men. The next greatest gaps between men and women were observed in

**Table 2.** Leading ten causes of DALYs with the ratio of observed DALYs to DALYs expected on the basis of SDI in 2015, by location

	1	2	3	4	5	6	7	8	9	10
Afghanistan	War (1033.96)	LRI (0.70)	IHD (4.31)	Congenital (1.56)	Stroke (2.15)	NN Preterm (0.77)	Road (2.38)	Other Unint (9.71)	Diarrhea (0.24)	Violence (4.00)
Armenia	IHD (1.52)	Stroke (0.87)	Diabetes (1.71)	Back & Neck (1.00)	Sense (1.03)	Lung C (1.29)	Depression (1.01)	Congenital (1.21)	COPD (0.93)	Road (0.64)
Azerbaijan	IHD (2.31)	LRI (3.36)	Stroke (1.25)	Back & Neck (0.98)	NN Enceph (7.12)	Diabetes (1.53)	NN Preterm (2.17)	Sense (1.08)	Depression (1.02)	Congenital (1.07)
Bahrain	Diabetes (3.31)	Back & Neck (0.95)	IHD (0.83)	Depression (1.11)	Skin (1.04)	Road (0.57)	Other MSK (1.92)	Sense (1.02)	Congenital (0.90)	Migraine (1.07)
Iran	IHD (1.24)	Road (1.69)	Back & Neck (1.03)	Stroke (0.76)	Diabetes (1.20)	Congenital (1.02)	Depression (1.05)	Sense (0.94)	Other Cardio (3.76)	Drugs (4.09)
Iraq	War (1932.51)	IHD (1.83)	Congenital (1.22)	NN Preterm (0.70)	Diabetes (1.78)	Stroke (1.14)	NN Sepsis (2.44)	Road (0.68)	Back & Neck (1.08)	LRI (0.40)
Kazakhstan	IHD (2.77)	Stroke (2.18)	Back & Neck (1.04)	Self-harm (2.14)	Road (1.46)	NN Preterm (2.88)	Iron (2.40)	Congenital (1.21)	LRI (1.76)	Sense (1.10)
Kuwait	IHD (1.94)	Back & Neck (0.88)	Depression (1.18)	Congenital (1.62)	Road (1.32)	Diabetes (2.18)	Migraine (1.06)	Skin (0.88)	Sense (1.09)	Iron (1.18)
Oman	Road (1.60)	Other Cardio (9.17)	Back & Neck (0.95)	Diabetes (2.26)	IHD (0.79)	Depression (1.07)	Congenital (0.71)	Sense (1.01)	Migraine (1.10)	Skin (0.86)
Pakistan	NN Enceph (2.86)	IHD (1.73)	NN Preterm (0.85)	LRI (0.61)	Diarrhea (0.88)	Stroke (0.86)	Iron (1.02)	TB (1.32)	Diabetes (1.31)	Other Unint (4.33)
Qatar	Road (1.48)	Back & Neck (0.94)	Diabetes (2.92)	Depression (1.15)	IHD (0.67)	Migraine (1.12)	Skin (0.94)	Congenital (1.13)	Sense (0.96)	Anxiety (1.05)
Russia	IHD (3.28)	Stroke (2.49)	Back & neck (1.20)	Self-harm (2.00)	Sense (1.30)	CMP (9.71)	Road (2.09)	Alcohol (10.72)	Drugs (5.90)	Depression (1.14)
Saudi Arabia	Back & Neck (0.99)	IHD (0.84)	Road (1.23)	Congenital (1.29)	Depression (1.11)	Skin (0.95)	Migraine (1.27)	Diabetes (1.15)	Sense (1.01)	NN Preterm (1.01)
Turkey	Back & Neck (1.13)	IHD (0.53)	Diabetes (0.97)	Congenital (0.97)	Sense (0.85)	Stroke (0.40)	Depression (0.92)	NN Preterm (0.82)	Lung C (1.18)	Road (0.51)
Turkmenistan	IHD (2.96)	LRI (6.42)	Stroke (2.21)	Congenital (1.76)	Back & Neck (0.94)	NN Preterm (2.59)	NN Enceph (5.53)	Diabetes (1.56)	Depression (1.00)	Sense (1.06)
United Arab Emirates	IHD (2.63)	Road (3.09)	Back & Neck (0.99)	Diabetes (3.48)	Stroke (2.11)	Depression (1.18)	Other MSK (1.90)	Migraine (1.14)	Skin (0.93)	Drugs (1.93)

The ratio of observed DALYs to DALYs expected based on SDI is provided in brackets for each cause and cells are color coded by ratio ranges (calculated to place a roughly equal number of cells into each bin). Shades of velvet, blue and green represent much lower observed DALYs than expected levels based on SDI, whereas yellow, orange, and red show observed DALYs that exceed expected levels.

IHD: ischemic heart disease; Back & neck: low back and neck pain; Diabetes: diabetes mellitus; Stroke: Cerebrovascular disease; Lung C: lung, bronchus, and trachea cancers; Sense: sense organ diseases; Depression: depressive disorders; Oth MSK: other musculoskeletal disorders; COPD: chronic obstructive pulmonary disease; NN Preterm: neonatal preterm birth complications; Diarrhea: diarrheal diseases; Skin: skin and subcutaneous diseases; NN Enceph: neonatal encephalopathy due to birth asphyxia and trauma; Drugs: drug use disorders; Congenital: congenital anomalies; Anxiety: anxiety disorders; Iron: iron-deficiency anemia; LRI: lower respiratory infections; CMP: cardiomyopathy and myocarditis; Other Cardio: other cardiovascular and circulatory diseases; Alcohol: alcohol use disorders; Violence: interpersonal violence; TB: tuberculosis; War: collective violence and legal intervention; Other Unint: other unintentional injuries; Road: road injuries.

GBD: Global Burden of Disease. SDI: Socio-demographic Index. DALYs: disability-adjusted life-years.

Kazakhstan, Turkmenistan, and Armenia. The smallest gaps were observed in Afghanistan and Pakistan. The pattern of gaps between LE and HALE at birth in 2015 was almost similar to 2005, with greatest gaps in Russia, Kazakhstan, Turkmenistan, and Armenia, and the smallest gaps in Afghanistan and Pakistan. As for LE and HALE at age 65 years in 2015, the greatest gaps were observed in Russia, Turkey, Kazakhstan, Armenia, and Turkmenistan. The smallest gaps were observed in Afghanistan, Kuwait, and Pakistan. In Iran, the gap between women and men in LE and HALE at birth increased from 4.9 and 3.3 years in 2005, to 6.1 and 4.1 years in 2015. The gap in LE and HALE at age 65 years were 2.8 and 1.9 years, respectively, in 2015.

## Discussion

The GBD 2015 provides several summary measures that help assess the overall performance of the health systems in the past decades. Many measures have improved in Iran; however, the

pattern of disease burden shows significant changes. The results of GBD 2015 showed that all-age number of DALYs have remained stable during the last decade in Iran, despite decreasing rates. The share of NCDs caused DALYs has increased throughout the evident epidemiologic transition in Iran. The decreases in rates of communicable, maternal, neonatal, and nutritional diseases as well as injuries were much steeper than the decrease in rate of NCDs. Ten out of 20 leading causes of DALYs were among NCDs, which is in line with reports of previous iterations of the GBD<sup>28,29</sup> and previous burden of disease studies in Iran.<sup>30,31</sup> CVDs were the leading cause of DALYs and there was substantial increase in DALYs due to musculoskeletal disorders, diabetes, neoplasms, and mental disorders and substance use. Transport injuries ranked second in men in Iran. The high rank of transport injuries in men in Iran is alarming and needs specific attention by health authorities as well as other organizations out of the health sector, such as the transportation industry, that should be involved in adopting effective strategies to tackle this challenge in Iran.<sup>32,33</sup>

**Table 3.** National life expectancy and HALE at birth, by sex, in 2005 and 2015, and at age 65, by sex, in 2015

	2005 at birth						2015 at birth						2015 at age 65 years						
	Female			Male			Female			Male			Female			Male			
	LE	HALE	LE	HALE	LE	HALE	LE	HALE	LE	HALE	LE	HALE	LE	HALE	LE	HALE	LE	HALE	
<b>Afghanistan</b>	51.40 (47.39-55.64)	44.45 (40.62-48.10)	52.67 (48.93-56.74)	45.55 (42.13-49.21)	54.46 (50.19-58.82)	47.11 (43.28-51.24)	53.34 (49.22-57.70)	46.27 (42.42-50.19)	9.41 (8.21-10.93)	6.91 (5.82-8.22)	10.57 (9.49-12.37)	7.68 (6.52-9.09)							
<b>Armenia</b>	75.32 (74.82-75.77)	65.81 (63.07-68.24)	68.18 (67.64-68.75)	60.65 (58.47-62.68)	78.37 (77.89-78.95)	68.40 (65.51-70.99)	70.75 (70.05-71.47)	62.84 (60.47-65.01)	18.06 (17.85-18.44)	13.83 (12.63-14.95)	14.37 (14.13-14.66)	10.99 (9.99-11.87)							
<b>Azerbaijan</b>	71.39 (70.61-72.13)	62.63 (59.91-65.16)	65.10 (64.27-65.92)	58.10 (55.95-60.12)	76.32 (75.59-77.07)	66.67 (63.73-69.41)	69.57 (68.51-70.58)	61.78 (59.33-63.98)	17.57 (17.25-17.90)	13.56 (12.32-14.64)	14.46 (13.77-14.96)	11.12 (10.05-12.10)							
<b>Bahrain</b>	78.06 (77.24-78.93)	66.10 (62.55-69.30)	74.63 (73.80-75.59)	64.92 (62.04-67.48)	80.34 (78.92-81.83)	67.98 (64.36-71.35)	78.21 (76.45-79.99)	67.89 (64.67-71.12)	19.23 (18.60-20.06)	14.00 (12.51-15.46)	17.76 (16.79-18.90)	13.22 (11.71-14.75)							
<b>Iran</b>	74.58 (72.51-76.50)	64.28 (61.12-67.51)	69.64 (67.24-71.98)	60.98 (57.86-64.21)	77.98 (75.87-80.02)	67.13 (63.56-70.62)	71.85 (69.18-74.18)	62.99 (59.82-66.40)	17.85 (16.78-19.04)	13.34 (11.86-14.92)	15.06 (14.08-16.17)	11.40 (10.11-12.80)							
<b>Iraq</b>	68.24 (65.65-70.65)	58.57 (55.18-61.60)	63.26 (59.95-66.53)	54.71 (51.15-58.09)	70.66 (67.52-73.64)	60.53 (56.47-63.92)	64.33 (60.79-68.46)	55.65 (51.90-59.50)	14.80 (13.47-16.11)	10.88 (9.40-12.25)	13.05 (11.96-15.04)	9.55 (8.38-10.94)							
<b>Kazakhstan</b>	71.06 (70.70-71.40)	62.23 (59.70-64.57)	59.79 (59.41-60.14)	53.24 (51.28-54.98)	75.03 (74.05-75.95)	65.52 (62.54-68.31)	65.29 (64.11-66.49)	57.91 (55.58-60.11)	16.49 (16.00-16.99)	12.70 (11.53-13.82)	12.66 (12.21-13.13)	9.60 (8.68-10.47)							
<b>Kuwait</b>	80.19 (79.91-80.52)	68.91 (65.71-71.77)	76.27 (75.99-76.54)	66.90 (64.25-69.36)	81.55 (80.47-82.71)	70.19 (66.81-73.29)	79.43 (77.94-80.67)	69.56 (66.56-72.40)	19.18 (18.38-20.06)	14.41 (12.88-15.84)	18.94 (18.09-19.69)	14.40 (12.97-15.80)							
<b>Oman</b>	78.38 (77.34-79.32)	66.81 (63.47-69.91)	74.07 (72.92-75.18)	64.15 (61.29-66.85)	79.64 (78.29-81.14)	67.75 (64.31-71.05)	75.71 (74.05-77.69)	65.38 (62.24-68.65)	18.79 (18.11-19.71)	13.71 (12.25-15.17)	16.32 (15.48-17.55)	12.03 (10.70-13.57)							
<b>Pakistan</b>	63.24 (61.42-65.05)	54.31 (51.48-57.18)	61.29 (59.54-63.19)	53.51 (50.86-55.94)	67.32 (65.22-69.82)	57.93 (54.76-61.01)	64.54 (62.22-66.49)	56.40 (53.59-59.28)	14.39 (13.34-15.78)	10.73 (9.41-12.06)	13.59 (12.72-14.32)	10.21 (9.14-11.34)							
<b>Qatar</b>	78.31 (77.49-79.11)	67.01 (63.71-70.07)	75.24 (73.63-76.87)	65.43 (62.30-68.46)	81.20 (79.43-82.88)	69.31 (65.82-72.71)	79.11 (76.93-81.25)	68.57 (64.92-71.83)	19.76 (18.65-20.98)	14.58 (12.92-16.27)	18.59 (17.07-19.91)	13.80 (12.07-15.51)							
<b>Russia</b>	72.21 (72.11-72.30)	62.43 (59.56-64.98)	58.71 (58.54-58.87)	52.21 (50.31-53.88)	76.57 (76.22-76.90)	66.02 (62.89-68.71)	65.30 (64.85-65.77)	57.71 (55.43-59.76)	17.48 (17.29-17.64)	13.26 (12.03-14.31)	13.12 (12.95-13.30)	9.83 (8.86-10.68)							
<b>Saudi Arabia</b>	80.00 (79.43-80.55)	68.99 (65.85-71.89)	75.95 (75.29-76.58)	66.78 (64.09-69.25)	82.21 (81.29-83.09)	70.87 (67.53-74.08)	77.45 (76.34-78.53)	68.15 (65.33-70.73)	20.68 (19.98-21.46)	15.72 (14.25-17.18)	17.77 (16.98-18.51)	13.67 (12.41-14.90)							
<b>Turkey</b>	79.52 (78.90-80.10)	68.04 (64.90-70.99)	72.91 (72.25-73.57)	64.01 (61.39-66.35)	82.37 (81.82-82.94)	70.49 (66.94-73.59)	75.90 (75.25-76.55)	66.61 (63.86-69.04)	21.21 (20.91-21.55)	15.75 (14.19-17.16)	17.35 (16.89-17.67)	13.17 (11.92-14.27)							
<b>Turkmenistan</b>	69.51 (68.21-70.74)	61.31 (58.75-63.67)	62.12 (60.77-63.27)	55.49 (53.35-57.52)	73.69 (72.71-74.46)	64.83 (62.09-67.28)	66.33 (65.35-67.15)	59.11 (56.86-61.15)	16.78 (16.53-17.01)	13.09 (11.99-14.06)	13.57 (13.32-13.79)	10.47 (9.58-11.31)							
<b>United Arab Emirates</b>	77.32 (76.47-78.00)	66.22 (63.07-69.16)	74.16 (73.26-74.93)	64.47 (61.53-67.14)	78.02 (75.54-79.89)	67.00 (63.40-70.34)	74.52 (71.82-77.08)	65.04 (61.38-68.31)	17.99 (16.84-18.95)	13.46 (11.93-14.80)	15.92 (14.70-17.04)	11.98 (10.50-13.33)							

LE: Life Expectancy. HALE: Healthy Life Expectancy. Figures in parentheses show the 95% uncertainty interval.

The distribution of causes across age groups also showed that neonatal disorders are still the main causes of burden in infants, indicating that the efforts of the health system have not been adequate for preventing this group of diseases. Middle-aged groups are mainly affected by mental and substance use disorders and injuries while older age groups suffer from CVDs. The burden of diabetes and musculoskeletal disorders is higher on women than men. The observed rate of DALYs caused by IHD and other cardiovascular diseases, road injuries, substance use, and diabetes were significantly higher than expected levels, while those for stroke and sense organ diseases were lower. These findings illustrate the importance of developing policies that are tailored to specific needs and priorities of every nation based on the distribution of main causes of burden across sex and age sub-groups.

Life expectancy and HALE increased steadily in Iran between 1990 and 2015. The observed levels were higher than expected levels at most time points from 1990 to 2015. Women lived longer than men at all time points. The significant increase in life expectancy and HALE are good proxies for improvement of overall health status and living standards in Iran. The gap in LE and HALE between men and women has remained constant in Iran while in many countries, men have shown larger improvements in their LE and HALE in recent years.

From 1990 to 2015, among all 16 countries, DALY rates were the highest in Afghanistan and the number of DALYs were the highest in Pakistan and Russia, mostly due to their larger population size. The least rates were observed in Kuwait, while the steepest decrease occurred in Turkey and Iran. Overall, it seems that the performance of the health system has substantially improved in Turkey and Iran among other countries, while there was almost no improvement in Iraq and Russia. The rather slow improvement in Iraq can be attributable to the long-term political instability, while there is no such clear justification for Russia. Afghanistan and Pakistan suffer from the triple burden of NCDs and Group 1 diseases, as well as injuries. Apart from Afghanistan, Iraq, and Pakistan, the overall pattern of causes of DALYs were almost similar across countries, with CVDs occupying the highest ranks followed by neoplasms, mental disorders and substance use, and diabetes and endocrine diseases. Exceptions were the high rank of transport injuries in Iran and musculoskeletal disorders in women in most high-income countries of the region.

The observed to expected ratio was higher than 1.00 for most causes in Afghanistan, Iraq, Kazakhstan, Russia, and Turkmenistan, while the ratio was below 1.00 for most causes in Saudi Arabia and Turkey. LE and HALE were the lowest in Afghanistan and Pakistan, the highest in Qatar, Kuwait, and Saudi Arabia, and substantially improved in Iran and Turkey. In order to improve further, policies should be developed and specifically tailored for countries for causes whose observed DALYs are higher than expected values.

Overall, the health status has substantially improved in almost all 16 countries since 1990 and particularly during the past decade. The change in burden due to causes from Group 1 diseases to NCDs is also consistent across countries. Life expectancy has increased in all countries. The longer life expectancy means better health status, but it also means that more years are lived with functional health loss.

Despite similarities, there were also great differences in major causes of DALYs between Iran and its neighboring countries.

The observed differences between countries can be attributed to a myriad of determinants, including social, cultural, ethnic, religious, political, economic, and environmental factors as well as the performance of the health systems.<sup>34</sup> Equal access to health care is a major determinant of health system performance. Investigating the differences in health status as well as causes of death and disability between neighboring countries and countries with similar socio-economic, cultural, and political characteristics can inform more effective policy making and resource allocation in countries with inadequate performance. Indeed, a great portion of the variability between these 16 countries is attributable to political instabilities.

GBD results showed the rising share of NCDs in DALYs in almost all countries across the world. In 2015, the United Nations called for a one-third reduction in NCD premature mortality by 2030.<sup>8</sup> Following the call, the Iranian Non-Communicable Disease Committee (INCDC) was formed in the Ministry of Health in Iran and is directly headed by the Minister of Health.<sup>35</sup> Controlling NCDs requires a coordinated health care system with effective and transparent funding.<sup>36</sup> Several challenges should be overcome, including high level of out-of-pocket payment, insufficient health insurance plans, poor inter-sectoral collaborations, poor partnership between public and private sectors, and low general awareness about NCDs and injuries. Part of these challenges will be overcome upon implementation of a universal health care system. The extensive primary health care system in Iran is a major point of strength as it provides an ideal setting for integration of comprehensive and equitable health care services into existing care. The actual integration of these services into the health care system requires the commitment of policy makers in the highest levels of the health sector and collaboration of non-health sectors that are somehow involved in this concerted effort at the national level.

#### Limitations

While GBD has many strengths, the methodology has several limitations, as well. First, the limitations of all previous analytical steps in the GBD are inherent in calculating DALYs and HALE. These steps include calculation of all-cause and cause-specific mortality, prevalence, incidence, disability weight, and comorbidities. Second, limitations in availability and quality of data are among major contributors to uncertainties in GBD estimates for data-poor times and places. Third, although the correlation of DALYs and HALE with SDI was often observed to be strong, the relationship cannot be considered as causal. In cases when the components of SDI were used as covariates in models, the association of health indicators with SDI could be considered as a confounder. In future iterations of GBD, other components of development (such as inequality) may be added to SDI. Fourth, the uncertainty of YLDs has been assumed to be independent of the uncertainty in YLLs and life expectancy. Fifth, due to time lag in data capture, all aspects of health loss due recent mass migration in Syria and Libya have not been covered in our estimates. Finally, as expected estimates of burden are only based on average SDI in each level, the observed to expected ratios for endemic diseases will be high in endemic countries and low in non-endemic countries.

In conclusion, in this paper, we presented the main drivers of DALYs in Iran and its neighboring countries as well as the trends in life expectancy and HALE as main summary measures

for monitoring progress of nations towards SDGs. We showed the change in the pattern of diseases in line with epidemiologic transition in Iran and the relatively substantial improvement in health status in Iran compared with its neighbors. Universal and comprehensive action plans are required to tackle the emerging epidemic of NCDs and injuries in Iran. Lessons can be learned from best-performing countries with socio-economic status similar to Iran.

## Competing interest

The authors declare no competing interests.

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