Original Article

Burden of Malaria in Iran, 1990–2010: Findings from the Global Burden of Disease Study 2010

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Abstract

Background: Malaria is a major public health challenge in tropical and semi-tropical countries in terms of high morbidity and mortality. The present study aimed to report the burden of malaria in Iran, extracted from the global burden of disease 2010 study (GBD 2010) covering the period 1990 to 2010, to compare these findings with similar results, and to present some recommendations as potential solutions for gaining more accurate estimations regarding the burden of the disease in Iran.

Methods: Data covering the period from 1990 to 2010 were derived from the GBD 2010, which is published by the Institute for Health Metrics and Evaluation (IHME). The findings were used to estimate the years lived with disability (YLDs), the years of life lost (YLLs), the disability-adjusted life-years (DALYs), and the death rate of malaria in Iran.

Results: The GBD 2010 estimated that there was a sharp declining death trend with regard to DALYs and death rate, showing that 4,647.63 DALYs were due to malaria in Iranian people of all ages and both genders, and that DALYs per 100,000 individuals declined from 37.15 in 1990 to 5.87 in 2010. The total number of malaria deaths over the 20 years was 73.37.

Conclusion: The findings revealed that the burden of malaria decreased remarkably between 1990 and 2010. The explanation for this decrease is the establishment of a malaria surveillance system in various parts of Iran, and utilization of proper intervention and the improvement of infrastructures, which play a role in disease transmission, especially in endemic areas.

Keywords: DALY, Global Burden of Disease (GBD), Iran, malaria, mortality, YLL, YLD

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Introduction

Malaria is a tropical, and semi-tropical, vector-borne parasitic disease caused by the unicellular protozoan parasites of the genus *Plasmodium*. It is considered a major public health problem with high morbidity and mortality. According to the World Health Organization (WHO) report of 2014, there are over 200 million annual cases of malaria, and the disease claims over half a million lives every year, mainly those of young children (i.e., younger than 5 years). It is transmitted in 108 countries, and makes a profound impact on the socioeconomic status of the nations in which it is endemic.[1–3] Approximately 90% of malaria deaths, and 85% of malaria cases occur in sub-Saharan Africa,[3] and although five *Plasmodium* species are known to infect human beings, all deaths are caused by *P. falciparum*.[2]

Iran is one of the main endemic foci of malaria, but the annual number of reported cases has fallen from 66,075 to 3,200 between 1995 and 2011, illustrating the sharp decrease of incidence of this disease. However, malaria is still considered an acute health problem, especially in south and southeast Iran, particularly in Kerman, Sistan-va-Baluchestan, and Hormozgan provinces, and the total number of people at risk in these areas is 2,714,648.[4,5] Therefore, malaria has always been a health priority in these regions (Figure 1).[6]

Iran has recently achieved notable success in improving health.[7] From 1990 to 2010, life expectancy has increased from 64.6 to 71.6 years for males, and from 71 to 77.8 years for females.[8] Furthermore, important advances have been made in the control of infectious diseases, such as dracunculiasis (no reported cases), and schistosomiasis.[9] However, malaria remains a major health obstacle in Iran, with increased concerns in recent years. Consequently, measurement of health metrics, including disability and death rates, using well-known criteria is essential in an at-risk population.[6]

To date, the Global Burden of Diseases, Injuries, and Risk Factors Study 2010 study (The GBD 2010) is the largest, and most

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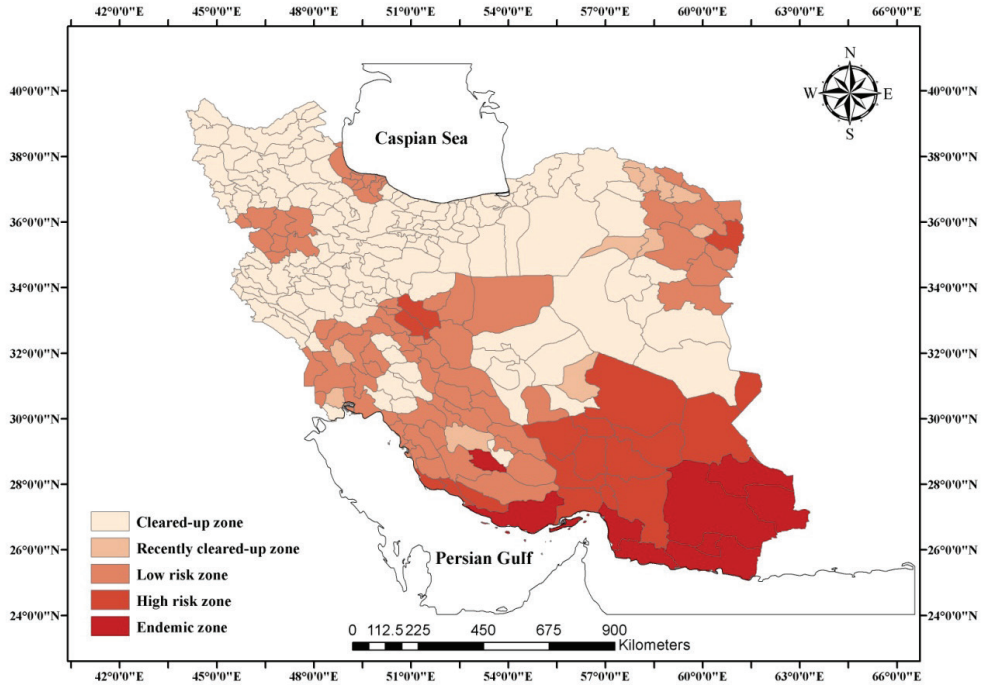

Figure 1. Distribution of Malaria in Iran according to the districts classification, 2013. (Created by Arc GIS version 10.2**).**

comprehensive, scientific effort that has been undertaken to measure disease incidence and prevalence, as well as to make comprehensive, regional, and global assessments of mortality, morbidity, and disability resulting from major diseases, injuries, and risk factors worldwide.[10]

Malaria has placed an enormous burden on the health, lifetime, and general prosperity of vast sections of the population of Iran.[11] Therefore, knowledge of the epidemiology of malaria is invaluable in assessing the burden of disease. We believe that the latter has been underestimated in Iran, and that its epidemiology has not been broadly verified. Moreover, few studies have examined the burden of disease in the general population. Therefore, the present study reports the burden of malaria in Iran from 1990 to 2010, by acquiring data from the GBD 2010, and also introduces the GBD 2010 method, which was recently developed by the Institute for Health Metrics and Evaluation (IHME).[12]

Materials and Methods

We used the data obtained in the GBD 2010 and published by the IHME in December 2012, which was conducted in 187 countries and includes 291 diseases and injuries in males and females in 20 age groups. A complete explanation and estimation of the data, statistical modeling, and metrics are described in detail elsewhere.[10,13–16]

In the GBD 2010, numerous measures have been used to assess the outcomes of health loss, including deaths and death rates, YLLs, YLDs, and DALYs.[17,18] The YLLs were basically computed through multiplying the number of deaths (N) in each age group by a standard life expectancy (LE) at the age of death in years (d). Therefore, the main formula for calculating YLLs is as follows: (YLLs = N × (LE-d)).The YLDs were calculated by multiplying the incident cases (I) by the disability weight (DW) by the average duration of the case until remission or death (years) (L), using the following formula: (YLD = I × L × DW). The DW was scaled from zero to one, where zero indicated a healthy state corresponding to full health, and a value of one signified a state that is equivalent to death. DW was calculated for 220 unique health conditions in the GBD 2010, which covered 1,160 diseases and injuries.[14,19]

DALYs are a measure of overall disease burden, shown as the number of years lost due to ill-health, disability, or early death. Therefore, DALYs were calculated by the sum of YLLs and YLDs (DALY = YLLs + YLDs). In addition, the level of uncertainty for each cause-specific DALY was computed through combining uncertainty at the levels of all-cause mortality, cause-specific mortality, prevalence, and DW.[20,21]

Estimation of most diseases was carried out on the basis of a database that covered all age-gender-country year groups, and via the utilization of a Bayesian meta-regression method that was established for the GBD 2010 (Dis Mod-MR).[22] Estimation of each disease was attained through a systematic analysis of published, and accessible unpublished, data sources on prevalence and incidence, remission, and mortality.[23] Causes of death were estimated by utilizing a detailed database of vital registration, verbal autopsy, surveillance, and other sources, covering almost 187 countries over 20 years. The Cause of Death Ensemble Modeling was used for all causes of death, worldwide.[15] Malaria was one of the most considerable items within the neglected tropical diseases category that were measured using DALYs in the GBD 2010. Data were analyzed using graph Pad-Prism-5 software.

Results

In the following, we report noticeable findings from the GBD 2010 with regard to the burden of malaria in Iran: (DALYs), the

Table 1. DALYs and Death Rates per 100,000 attributable to Malaria by all ages and both sexes, Iran 1990 to 2010.

Age groups	Sex	DALY/ 100,000					Death/ 100,000				
		1990	1995	2000	2005	2010	1990	1995	2000	2005	2010
< 5 years	Male	10.08	7.07	4.12	2.72	1.47	0.113	0.077	0.043	0.027	0.013
	Female	10.65	7.11	3.61	2.17	0.81	0.119	0.078	0.037	0.020	0.005
	Both	10.36	7.09	3.87	2.45	1.15	0.116	0.077	0.040	0.023	0.009
5–14 years	Male	1.51	1.31	0.98	0.67	0.41	0.015	0.013	0.009	0.005	0.002
	Female	1.41	1.04	0.71	0.47	0.26	0.014	0.010	0.006	0.004	0.001
	Both	1.46	1.17	0.84	0.57	0.34	0.014	0.011	0.007	0.004	0.002
15–49 years	Male	1.80	1.70	1.21	0.73	0.34	0.029	0.028	0.020	0.012	0.005
	Female	1.13	0.91	0.62	0.38	0.20	0.017	0.014	0.009	0.005	0.002
	Both	1.47	1.30	0.92	0.56	0.28	0.023	0.021	0.015	0.009	0.004
50–69 years	Male	3.02	3.00	2.38	1.43	0.65	0.097	0.102	0.082	0.048	0.021
	Female	1.74	1.49	1.03	0.60	0.31	0.055	0.050	0.033	0.019	0.009
	Both	2.40	2.26	1.71	1.02	0.48	0.076	0.076	0.058	0.033	0.015
>70 years	Male	3.24	3.18	2.51	1.53	0.70	0.183	0.191	0.159	0.100	0.046
	Female	2.54	1.91	1.32	0.85	0.42	0.143	0.120	0.092	0.065	0.034
	Both	2.40	2.58	1.94	1.22	0.57	0.163	0.155	0.126	0.082	0.040
All Ages	Male	3.25	2.44	1.58	0.99	0.50	0.048	0.040	0.029	0.019	0.009
	Female	2.86	1.81	0.99	0.58	0.28	0.039	0.026	0.015	0.009	0.004
	Both	3.06	2.13	1.28	0.79	0.39	0.043	0.033	0.022	0.014	0.006

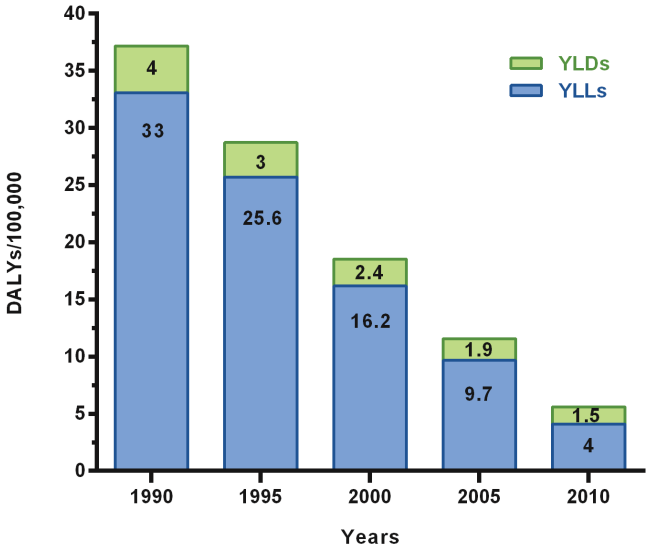

Figure 2. Total YLDs and YLLs rates per 100,000 (DALYs) of malaria, Iran 1990 to 2010.

burden of mortality due to premature deaths (YLLs), and the burden of disability due to nonfatal health outcomes (YLDs), in addition to disease death rates.

Leading causes of DALYs

Table 1 shows the rates of DALYs per 100,000 regarding malaria in Iran from 1990 to 2010, classified by age and gender. In both genders, the burden of malaria caused by deaths and disability per 100,000 was estimated as a total of 101.533 DALYs, which consisted of 12.89 YLD sand 88.64 YLLs (Figure 2). Number of DALYs per 100,000 decreased significantly from 37.15 in 1990 to 5.87 in 2010. Furthermore, the maximum and minimum numbers of DALYs per 100,000 were calculated as 37.15 for 1990 and 5.87 for 2010, which has reduced by seven-fold (Figure 2). The total number of DALYs was calculated as 4647.63 years (Table 2).

Sex and age patterns for DALYs

The acquired data show that the burden of DALYs was higher for males (58.17 %) than females (41.83 %); 57.73% of YLLs and 51.55% of YLDs were in males, while 42.27% of YLLs and 48.45% of YLDs were in females. DALY rates per 100,000 were 57.82 years for males and 43.71 years for females. YLLs rates were 37.47 years per 100,000 females and 51.17 years per 100,000 males. YLDs rates were 6.25 and 6.64 years per 100,000 people for females and males, respectively. In males, the burden of premature death or YLLs was higher than females, but the burden of disability or YLDs was almost identical in both genders, which resulted in a greater total burden of disease and mortality for males compared with females (Figures 3 and 4).

In 1990, the highest burden of disability per 100,000 was in females aged 70 years and above at 0.77, and the highest burden of

Table 2. The Death and DALYs number of malaria in different age groups, Iran 1990 to 2010.

Age groups	DALYs number			Death number		
	Female	Male	Total	Female	Male	Total
Under 5	950.54	1019.33	1969.87	10.25	11.04	21.30
5–14 years	299.03	390.69	689.72	2.81	3.60	6.42
15–49 years	500.80	899.28	1400.08	7.42	14.64	22.06
50–69 years	144.44	304.17	448.61	4.57	10.19	14.76
70+ years	49.25	90.09	139.34	3.23	5.60	8.83
Total	**1944.07**	**2703.56**	**4647.63**	**28.29**	**45.08**	**73.37**

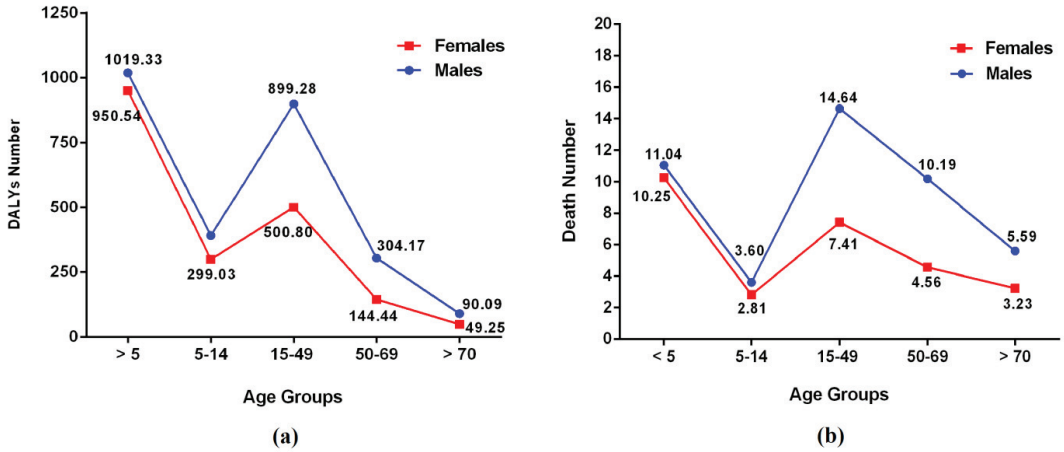

Figure 3. **(a)** DALYs and **(b)** Death numbers of malaria in different age groups by sex, Iran 1990 to 2010.

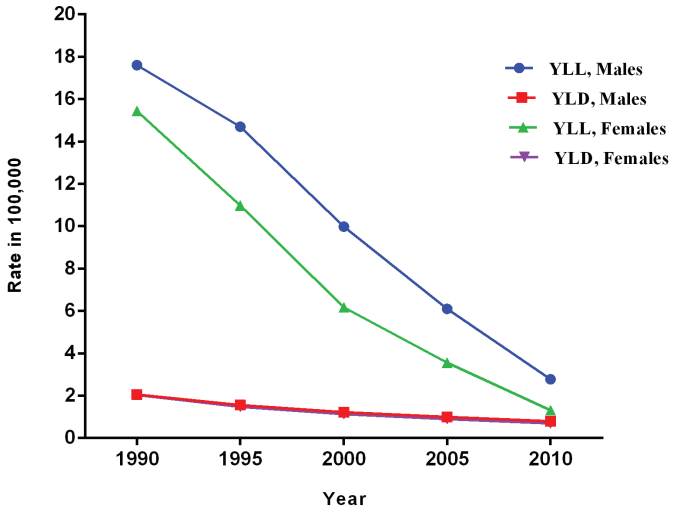

Figure 4. Sex differentials in burden of leishmaniasis by years, Iran 1990 to 2010.

death was in females aged under 5 years at 10.13. The age patterns of deaths and YLLs were very similar: the number of deaths decreased with age, and the burden of death (YLLs) was greater for children (Figure 4 and Table 3).

Figure 5 shows the number of DALYs across different age groups. The findings show that the minimum and maximum rates of DALYs between 1990 and 2010 were associated with ages above 70 years and under 5 years in 1990. However, after 2000, the highest rate of DALYs was found in the 15-49 years age group, in which the DALYs rate was approximately equal across all 20 years of study. Figure 3 illustrates the fact that males had a higher DALYs rate than females in all age groups.

Death and fatality rates

The GBD 2010 showed that 73.37 people in Iran died as a result of malaria between 1990 and 2010. Table 1 presents a detailed comparative view of deaths per 100,000, and shows that the death rate in all ages and both genders decreased by 82%, which is a significant change. The highest death rate was observed in 1995 in males aged 70 years and above, at 0.191 per 100,000, and the lowest rate was found in 2010 in females aged 5–14 years, at 0.001727 per 100,000. Moreover, Table 1 indicates the higher prevalence

Table 3. YLLs and YLDs of malaria in different age groups, Iran 1990 to 2010.

Age	Year	YLLs per 100,000		YLDs per 100,000	
		Female	Male	Female	Male
Under 5	1990	10.13	9.58	0.52	0.50
5–14 years	1990	1.09	1.14	0.32	0.37
15–49 years	1990	0.97	1.61	0.16	0.19
50–69 years	1990	1.47	2.70	0.26	0.32
70+ years	1990	1.76	2.57	0.77	0.66
Under 5	1995	6.62	6.59	0.49	0.47
5–14 years	1995	0.77	0.98	0.26	0.33
15–49 years	1995	0.78	1.55	0.13	0.15
50–69 years	1995	1.31	2.78	0.18	0.22
70+ years	1995	1.49	2.79	0.42	0.39
Under 5	2000	3.15	3.67	0.46	0.45
5–14 years	2000	0.50	0.69	0.21	0.29
15–49 years	2000	0.52	1.10	0.10	0.11
50–69 years	2000	0.91	2.23	0.12	0.15
70+ years	2000	1.10	2.29	0.22	0.22
Under 5	2005	1.73	2.29	0.43	0.42
5–14 years	2005	0.29	0.42	0.18	0.25
15–49 years	2005	0.29	0.65	0.08	0.08
50–69 years	2005	0.52	1.33	0.08	0.10
70+ years	2005	0.72	1.40	0.12	0.13
Under 5	2010	0.43	1.11	0.38	0.35
5–14 years	2010	0.13	0.17	0.13	0.24
15–49 years	2010	0.13	0.29	0.08	0.06
50–69 years	2010	0.26	0.59	0.05	0.06
70+ years	2010	0.36	0.61	0.06	0.09

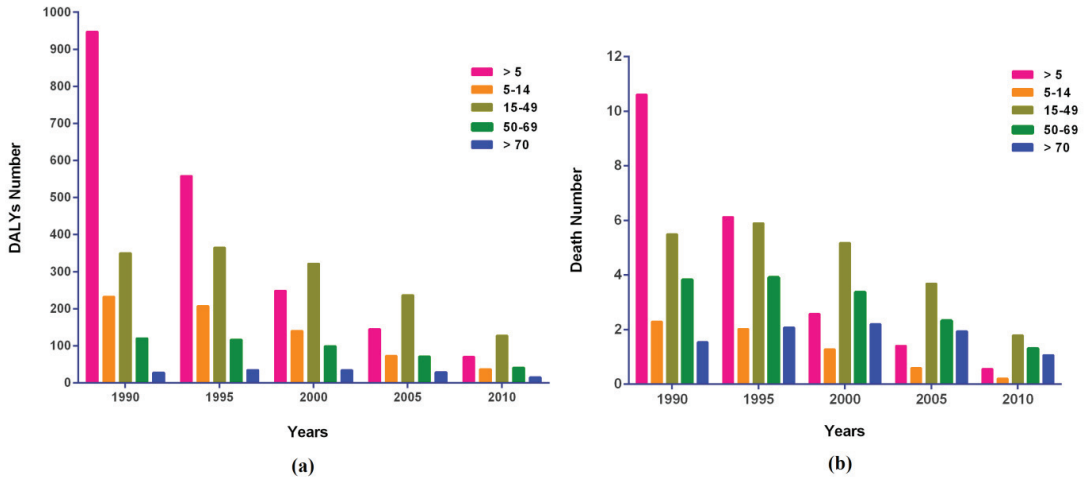

Figure 5. **(a)** DALYs and **(b)** Death numbers of malaria in different age groups by years, Iran 1990 to 2010.

of malaria in males at all ages studied (Figure 3). Across all age groups, the highest (14.64) number of deaths was in males aged between 15 and 49 years, and the lowest (2.81) was in females aged between 5 and 14 years, (Table 2 and Figure 5). Surprisingly, death rates were higher in males at all ages (Figure 3).

Discussion

We believe this is the first comprehensive effort to report the burden of malaria in Iran. It uses data acquired from the GBD 2010 covering the period 1990–2010 across all age groups and both genders.

The current study clearly shows that DALYs and fatality rates, as well as the incidence rate of malaria, decreased significantly in both genders and all ages in Iran during the period studied. Our findings are consistent with those of Murray *et al.* (2012), although they observed a lower number of deaths (44) than our results (73.3).[24] The WHO (2014) has reported that the incidence of malaria declined between 1990 and 2010 in Iran, and the number of deaths from this disease is still decreasing gradually as of now. Moreover, a significant reduction has been shown in malaria burden and morbidity in the country.[2,25] However, our findings from the GBD 2010 revealed a greater number of deaths (73.37) across all age groups in Iran than did the World Malaria Report (2010

and 2014) which recorded 49 deaths.[2,26] Rezaei Hemami *et al.* have previously reported that there has been a remarkable decline in the number of malaria cases; therefore, the incidence rate per 100,000 decreased from 1.5 in 1990 to 0.24 in 2007.[6] Some factors, such as immunological and genetic properties, immigration, the population at risk, species of parasite, climate changes, vectors, utilization of anti-malaria drugs, and prevention measures, are influential in malaria mortality and, therefore, in the burden of the disease.

The major finding of the current study is a sharp decline in the burden of the disease, which has also been observed in previous studies.[24,27] One possible explanation for this interesting finding is that malaria control programs have been highly effective in improving malaria morbidity and mortality in Iran.[6]

Our results also showed that infection rates were lower in females than in males, which is most likely because females veil their bodies with the Islamic Hijab in the Islamic Republic of Iran, while males generally work in the fields, and are directly exposed to mosquito bites as a result.

The data indicate that those aged under 5 years had higher infection rates than the other age groups. Although the most probable explanation for this higher infection rate is the weaker immune system of children, the reasons why children are infected more than other groups remain poorly understood. However, it is most probable that a viable explanation will come as a result of studying the effects of natural host malaria-resistance factors.[28]

Despite the fact that GBD 2010 was efficient in estimating the global burden of diseases, it has some critical limitations. One is that it does not distinguish between the burden of malaria due to *Plasmodium falciparum* and that resulting from *P. vivax* in Iran. This may be a consideration for future studies, because both parasites are endemic in Iran, and each has its own burden of disease and death rate. Moreover, *P. vivax*, the second most widespread *Plasmodium* across the entire world, has a hypnozoite stage in the liver that causes multiple relapses, recrudescence, or reinfection after clearance of the blood-stage infection.[29]

According to WHO 2014, Iran is in the malaria elimination phase,[2] but the most important problems in this phase are Iran's extensive borders with malaria-endemic countries, such as Pakistan and Afghanistan, and illegal immigrants that come from these nations to Iran.[6] Therefore, it is recommended that DALYs and fatality rates of disease are estimated at national and sub-national levels in Iran, Afghanistan, and Pakistan to provide more effective public health strategies. In accordance with this recommendation, the health authorities of Iran decided to perform a study on the burden of diseases, injuries, and risk factors at both national and sub-national levels, namely the National and Subnational Burden of Diseases (NASBOD)[30] study that is a data-driven study and benefits from all published and unpublished data in Iran, and two advanced statistical methods.[31,32]

In summary, the outcome of this survey may aid policy-makers in determining the factors that can eradicate the burden of disease in Iran. Furthermore, the health sector can benefit through monitoring and surveillance strategies.

Authors' contributions

General designing of paper: Alireza Badirzadeh, Zahra Asadgol, Yaser Mokhayeri

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Approval

All authors have read and approved the content and the authorship of the final version of the submitted manuscript.

Competing interests

We declare that we have no conflict of interest.

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