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A 30-year trend of ischemic heart disease burden in a developing country; a systematic analysis of the global burden of disease study 2019 in Iran

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ABSTRACT

Background: Evaluating the burden of ischemic heart disease (IHD) as the first cause of mortality worldwide is necessary to develop healthcare policies. This study aimed to report the national and subnational IHD burden and risk factors in Iran according to the Global Burden of Disease (GBD) study 2019.

Methods: We extracted, processed, and presented the results of the GBD 2019 study regarding incidence, prevalence, deaths, years lived with disability (YLDs), years of life lost (YLLs), disability-adjusted life years (DALYs), and attributable burden to risk factors of IHD in Iran during 1990–2019.

Results: Age-standardized death and DALY rates decreased by 42.7% (95% uncertainty interval, 38.1–47.9) and 47.7% (43.6–52.9) during 1990–2019, slower since 2011 and reached 163.6 deaths (149.0–176.2), 2842.7 DALYs (2657.0–3103.1) per 100,000 persons in 2019. Meanwhile, with a lower reduction of 7.7% (6.0–9.5), the incidence rate reached 829.1 new cases (719.9–945.2) per 100,000 persons in 2019. High systolic blood pressure and elevated low-density lipoprotein cholesterol (LDL-C) contributed to the highest deaths, and DALYs age-standardized rates in 1990 and 2019. They followed by high fasting plasma glucose (FPG), and high body-mass index (BMI) with an upward trend of contribution from 1990 to 2019. A convergence pattern in the provincial death age-standardized rate was observed, with the lowest rate in Iran's capital city; 84.7 deaths per 100,000 (70.6–99.4) in 2019.

Conclusion: The incidence rate reduced remarkably lower than the mortality rate, which necessitates promoting primary prevention strategies. Also, interventions should be adopted to control growing risk factors like high FPG, and high BMI.

1. Introduction

Ischemic heart disease (IHD), or coronary heart disease, lies in the first rank of worldwide mortality causes in 2019, >9 million deaths [1]. Given that the sustainable development goal 3.4 (SDG 3.4) is proposed to reduce the one-third of pre-mature mortality of non-communicable diseases (NCDs) by 2030 [2], monitoring IHD burden as the first rank of mortality rate among NCDs is crucial for each country. Iran, a country located in the North Africa and Middle East region, with >80 million people, encompasses about 2% of global IHD prevalence, and lies in the second rank of global IHD incidence rate in 2019 [1]. This country is facing an emerging threat of NCDs, including IHD; total deaths caused by IHD has raised from 15% to 26% over 1990–2019 [1].

The current health system structure in Iran has been shaped by multiple health sector reforms and programs launched by the Ministry of Health and Medical Education (MoHME) in recent decades, which resulted in a shift from the significant burden of communicable diseases toward NCDs [3]..Furthermore, Iran's remarkable political,

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environmental, and cultural changes might have affected the health system and IHD burden. For instance, we have experienced sanctions and economic pressures since 2011 that could affect socioeconomic status (SES) and IHD burden [4]. Moreover, IHD imposes acute and chronic costs through revascularization and hospitalization and lifelong costs [5]. Therefore, a precise monitoring and evaluation of the IHD burden is mandatory to adopt health policies and reduce the cost of illness appropriately.

Considering the abovementioned situation, it is necessary to evaluate Iran's IHD burden and its changes in recent decades. To the best of our knowledge, no study reported the national and subnational records during 1990–2019. This study aimed to provide a comprehensive image of the national and subnational IHD burden in Iran, its changes, and risk factors from 1990 to 2019, based on the estimation of the Global Burden of Disease (GBD) Study in 2019.

2. Method

The 2019 version of GBD provides an annual burden estimation of 369 diseases and injuries and 87 risk factors for 204 countries, including IHD in Iran, and subnational regions. The processed data is categorized into two 4-leveled hierarchies, one regarding causes and the other risk factors. The details of data collection, updating, processing, modeling, and statistical methodologies have been discussed comprehensively elsewhere [6,7].

We presented the estimations for burden of IHD and its risk factors. IHD in GBD 2019 represents acute myocardial infarction, chronic stable angina, chronic IHD, and heart failure due to IHD for over 15-year-old people [8]. Records of the following measurements were extracted and reported for all-age numbers and both sexes, besides the age-standardized rates; incidence, prevalence, deaths, years lived with disability (YLDs), years of life lost (YLLs), and disability-adjusted life years (DALYs). Finally, to interpret risk factors, we used attributable deaths, DALYs, YLLs, and YLDs for IHD. Moreover, subnational records from 1990 to 2019 were processed and presented.

In GBD 2019, International Classification of Diseases (ICD)-10 codes I20-I25.9 were mapped to define IHD mortality [7], and I20-I21.6, I21.9-I25.9, Z82.4-Z82.49 codes were mapped to define non-fatal outcomes of IHD [9]. Furthermore, to estimate IHD mortality, data were gathered through vital registration and verbal autopsy data, and for non-fatal outcomes, surveillance, survey data, claim data-inpatient visits, and inpatient hospital data were applied [9]. Age-standardized rates were calculated using the standard GBD world population [7].

Percent changes were calculated as the difference between burden in 1990 and 2019 divided by 1990. After modeling the data and weighting the models, 1000 draws are created, proportionally contributed to each model based on its weight. The mean of the draws is used as the final estimate for this model, and a 95% uncertainty interval (UI) is calculated as the 0·025 and 0·975 quantiles of the draws. The validity of the UI is its coverage of the out-of-sample data; the most ideal 95% UI is the one that captures 95% of these data [7].

The socio-demographic index (SDI) is calculated from the geometric mean of total fertility rate in women younger than 25 years, lag-distributed income per capita, and average educational years [7]. In addition, decomposition analysis of incidence number was performed regarding alteration in age structure change, population growth, and cause-specific incidence rates [10].

3. Results

3.1. National IHD burden and trend from 1990 to 2019

Overall, death, DALY and YLL age-standardized rates declined by >40% during 1990–2019. In 2019, 163.6 IHD deaths (95%UI, 149.0–176.2) were reported per 100,000 persons, 42.7% (38.1–47.9) lower than 1990. All-ages number of deaths was 55,668 in 1990 (51,802-60,039), and 102,799 in 2019 (94,455-111,215). The age-standardized death rate was higher in males; 177.2 and 150.9 deaths per 100,000 males and females in 2019 (161.5–192.5, and 133.8–164.0, respectively). This pattern was observed throughout the study period despite greater reduction in males; 45.0% and 38.5% age-standardized death rate reduction in males and females over 1990–2019, respectively (39.9–51.8, and 30.4–44.7, respectively) (Table 1, Fig. 1, Fig. 1 appendix).

Age-standardized DALY rate reduced by 47.7% (95%UI, 43.6–52.9) and reached 2842.7 per 100,000 persons in 2019 (2657.0–3103.1). In contrast, YLD age-standardized rate had an insignificant change from 81.5 per 100,000 in 1990 to 81.0 in 2019 (55.4–114.5, and 55.0–113.8, respectively). Furthermore, 3393.6 and 100.6 age-standardized DALYs and YLDs were observed per 100,000 males in 2019 (3160.6–3734.0, and 67.9–141.3, respectively), which are >2298.4 (2100.5–2484.0) and 61.4 (41.4–86.1) in the female group, respectively. Moreover, YLD age-standardized rate showed a different direction of change between sexes, where females showed a significant decline by 4.1% (2.1–6.2), while males had an insignificant change during 1990–2019 (1.9% [−0.8,4.6]) (Table 1, Fig. 1, Fig. 1 appendix).

Age-standardized incidence rate decreased by 7.7% (95%UI, 6.0–9.5) during 1990–2019, and reached 829.1 IHD new cases per 100,000 persons in 2019 (719.9–945.2) (Table 1). Regarding sex groups, this rate was 1007.8 and 625.0 per 100,000 males and females in 2019, with 6.5% (4.3–8.9) and 7.7% (5.8–9.8) reduction since 1990, respectively (Table 1, Fig. 1, Fig. 1 appendix). IHD new cases significantly raised from 218,181 in 1990 to 593,001 in 2019, a 171.8% rise. Decomposition analysis of incidence number showed that age structure changes and population growth contributed to 149.8% and 44.0% rise in incidence number (Table 1 appendix). Females had significantly greater incidence number growth (190.3%) than males (161.5%) (Table 2 appendix).

The age-standardized prevalence rate showed an insignificant change from 6250.6 per 100,000 persons in 1990 (95%UI, 5678.7, 6852.2) to 6198.5 in 2019 (5644.4–6814.6). The rate was significantly greater in males during 1990–2019; in 2019, 7597.1 per 100,000 males reported to have IHD, versus 4815.8 per 100,000 females (6922.8–8329.1, and 4354.0–5316.4, respectively). Moreover, prevalence rate increased significantly by 1.9% (0.7–3.0) in males from 1990 to 2019, while decreased in females (3.3% reduction [2.1–4.4]) (Table 1, Fig. 1, Fig. 1 appendix).

A closer look reveals that changes in the all-ages number and age-standardized rates of DALY and death did not follow a linear pattern. The all-age number of DALYs and deaths rapidly increased over 1990–2002, and 2011–2019, while it slowed down during 2002–2011. Similarly, the age-standardized rate of death and DALY decreased significantly steeper during 2002–2011 than 1990–2002 and 2011–2019. However, incidence and prevalence rate changing trends did not remarkably follow this pattern (Fig. 1). In this order, Fig. 2 indicates that age-standardized rates of DALY and death declined by about 40% during 1990–2010, significantly higher than near 10% during 2010–2019 (Fig. 2).

3.2. Mortality to incidence ratio

Overall, age-standardized mortality to incidence ratio (MIR) was higher in females over the study period; about 0.35 in 1990, and 0.25 in 2019 in females versus near 0.3 and below 0.2 in males for 1990 and 2019, respectively. Moreover, similar to the trend of changes in mortality rates in Fig. 1, MIR decreased rapidly between 2002 and 2011, followed by a slight increase from 2011 to 2016 (Fig. 2 appendix).

3.3. IHD burden in different age groups

IHD incidence, prevalence, death, and DALY rates significantly increased by age in 1990 and 2019. Moreover, males illustrated greater

Table 1
All-ages number and age-standardized rates of IHD burden and their percent changes by measure, and sex in 1990 and 2019.

Measure	Metric	Year						% Change (1990 to 2019)		
		1990			2019					
		Both	Female	Male	Both	Female	Male	Both	Female	Male
Incidence	All ages number	218,181 (187,231 to 250,909)	78,076 (68,043 to 89,474)	140,104 (119,779 to 162,184)	593,001 (515,830 to 676,050)	226,652 (197,595 to 258,247)	366,349 (317,515 to 418,667)	171.8 (163.7 to 180.4)	190.3 (182.1 to 198.9)	161.5 (152.9 to 171.1)
	Age-standardized rate (per 100,000)	898.3 (784 to 1026.5)	706.3 (614.5 to 807.6)	1077.5 (935.5 to 1233.3)	829.1 (719.9 to 945.2)	652 (568.7 to 743.2)	1007.8 (876.1 to 1147.1)	−7.7 (−9.5 to −6)	−7.7 (−9.8 to −5.8)	−6.5 (−8.9 to −4.3)
Prevalence	All ages number	1,489,114 (1,340,079 to 1,647,733)	547,770 (493,328 to 605,681)	941,344 (844,849 to 1,043,645)	4,335,510 (3,950,113 to 4,761,788)	1,661,183 (1,507,054 to 1,835,044)	2,674,327 (2,431,911 to 2,929,213)	191.1 (186.1 to 196.8)	203.3 (198.4 to 208.4)	184.1 (178.7 to 190.4)
	Age-standardized rate (per 100,000)	6250.6 (5678.7 to 6852.2)	4978.1 (4489.4 to 5479.1)	7457.3 (6801.2 to 8162.3)	6198.5 (5644.4 to 6814.6)	4815.8 (4354 to 5316.4)	7597.1 (6922.8 to 8329.1)	−0.8 (−1.7 to 0.1)	−3.3 (−4.4 to −2.1)	1.9 (0.7 to 3)
Deaths	All ages number	55,668 (51,802 to 60,039)	21,630 (19,335 to 23,582)	34,038 (31,468 to 37,505)	102,799 (94,455 to 111,215)	44,479 (39,745 to 48,195)	58,320 (53,654 to 63,323)	84.7 (65.3 to 100)	105.6 (82 to 130.9)	71.3 (50.1 to 87.9)
	Age-standardized rate (per 100,000)	285.7 (260.8 to 307.1)	245.6 (213.6 to 269.1)	322.1 (295.4 to 352.9)	163.6 (149 to 176.2)	150.9 (133.8 to 164)	177.2 (161.5 to 192.5)	−42.7 (−47.9 to −38.1)	−38.5 (−44.7 to −30.4)	−45 (−51.8 to −39.9)
DALYs	All ages number	1,392,859 (1,303,028 to 1,515,545)	491,487 (451,951 to 537,892)	901,372 (830,023 to 995,658)	2,025,424 (1,898,318 to 2,228,261)	768,825 (709,374 to 825,789)	1,256,599 (1,175,477 to 1,399,982)	45.4 (30.2 to 57.9)	56.4 (37.7 to 73.1)	39.4 (23.7 to 53.2)
	Age-standardized rate (per 100,000)	5437.6 (5060.9 to 5851)	4260.8 (3841.2 to 4634.4)	6502 (6020.9 to 7142.4)	2842.7 (2657 to 3103.1)	2298.4 (2100.5 to 2484)	3393.6 (3160.6 to 3734)	−47.7 (−52.9 to −43.6)	−46.1 (−51.7 to −40)	−47.8 (−53.8 to −43)
YLLs	All ages number	1,373,051 (1,283,296 to 1,496,037)	484,162 (445,612 to 529,496)	888,889 (819,897 to 982,352)	1,967,791 (1,837,841 to 2,166,855)	747,114 (686,472 to 806,710)	1,220,677 (1,139,254 to 1,366,412)	43.3 (27.4 to 55.6)	54.3 (35.3 to 71.4)	37.3 (20.6 to 51.5)
	Age-standardized rate (per 100,000)	5356.1 (4983 to 5775.2)	4196.7 (3773.5 to 4567.2)	6403.3 (5920.8 to 7033.2)	2761.7 (2570.4 to 3020.8)	2237 (2040.5 to 2411.6)	3293 (3063.6 to 3638.8)	−48.4 (−53.6 to −44.2)	−46.7 (−52.3 to −40.6)	−48.6 (−54.7 to −43.5)
YLDs	All ages number	19,808 (12,988 to 27,511)	7325 (4831 to 10,304)	12,483 (8196 to 17,354)	57,633 (38,662 to 81,196)	21,712 (14,579 to 30,527)	35,921 (24,274 to 50,664)	191 (178.5 to 203.9)	196.4 (185.7 to 207.2)	187.8 (173.1 to 203.6)
	Age-standardized rate (per 100,000)	81.5 (55.4 to 114.5)	64.1 (43.4 to 90.3)	98.7 (67.4 to 137.8)	81 (55 to 113.8)	61.4 (41.4 to 86.1)	100.6 (67.9 to 141.3)	−0.6 (−2.7 to 1.2)	−4.1 (−6.2 to −2.1)	1.9 (−0.8 to 4.6)

Data in parentheses are 95% Uncertainty Intervals (95% UIs); DALYs = Disability-Adjusted Life Years; YLLs = Years of Life Lost; YLDs = Years Lived with Disability.

rates than females, except for over 80-year-old death and DALY rates in 2019 (Fig. 3 appendix). The greatest all-age number of deaths was observed in 50–69-year-old in 1990, while in over 70-year-old people in 2019; 26,065 deaths (95%UI, 24,329-28,396), and 67,109 (59,744-72,711), respectively. The greatest reduction in death, DALY, and incidence rates were observed in 50–69-year-old by 56.6% (52.4–61.6), 55.7% (51.5–60.7), and 7.2% (5.3–9.1), respectively. However, the incidence rate of 15–49-year-old people increased by 48.8% (42.4–54.5) (Table 3 appendix).

3.4. Modifiable risk factors

Among level 2 of risk factors, dietary risks earned the first rank of total attributable age-standardized death, DALY, and YLL rates, followed by metabolic risk factors including high systolic blood pressure (SBP), high LDL-C, high fasting plasma glucose (FPG), and high body-mass index (BMI) in order in 2019 (Fig. 4 appendix, Fig. 5 appendix). Going through the 4th level of risk factors, high SBP, high LDL-C, and high FPG in order were observed in the first ranks of all attributable measures in 2019 (Fig. 3, Fig. 6 appendix). >2500 age-standardized DALYs per 100,000 persons were attributed to high SBP, and high LDL-C in 1990, which reached below 1500 in 2019. Smoking, and ambient particular matter pollution as the fourth and fifth ranks of attributable DALYs per 100,000 in 1990, illustrated a significant reduction from near 1300, and 1100 to about 600 in 2019, respectively (Fig. 7 appendix). Despite the reduction in age-standardized death and DALY rates attributed to high SBP, and high LDL-C, Fig. 8, and 9 appendix demonstrated a minimal change in their percentage contribution to these rates during 1990–2019. This contribution increased regarding high FPG, and high BMI over the study period.

3.5. Subnational IHD burden and trend from 1990 to 2019

A disparity was observed among provinces regarding age-standardized incidence, prevalence, death, and DALY rates in 1990 and 2019, while a convergence can be seen regarding death and DALY (Fig. 10 appendix, Table 4 appendix). The details of subnational results are presented in the Supplementary File.

4. Discussion

We illustrated that the IHD death rate in Iran declined near six times greater than the incidence rate (about 40% reduction in mortality rate and 7% in incidence rate) during 1990–2019. The downward trend of IHD mortality burden was not steady and a considerable more rapid decline was observed between 2002 and 2011 than after 2011.

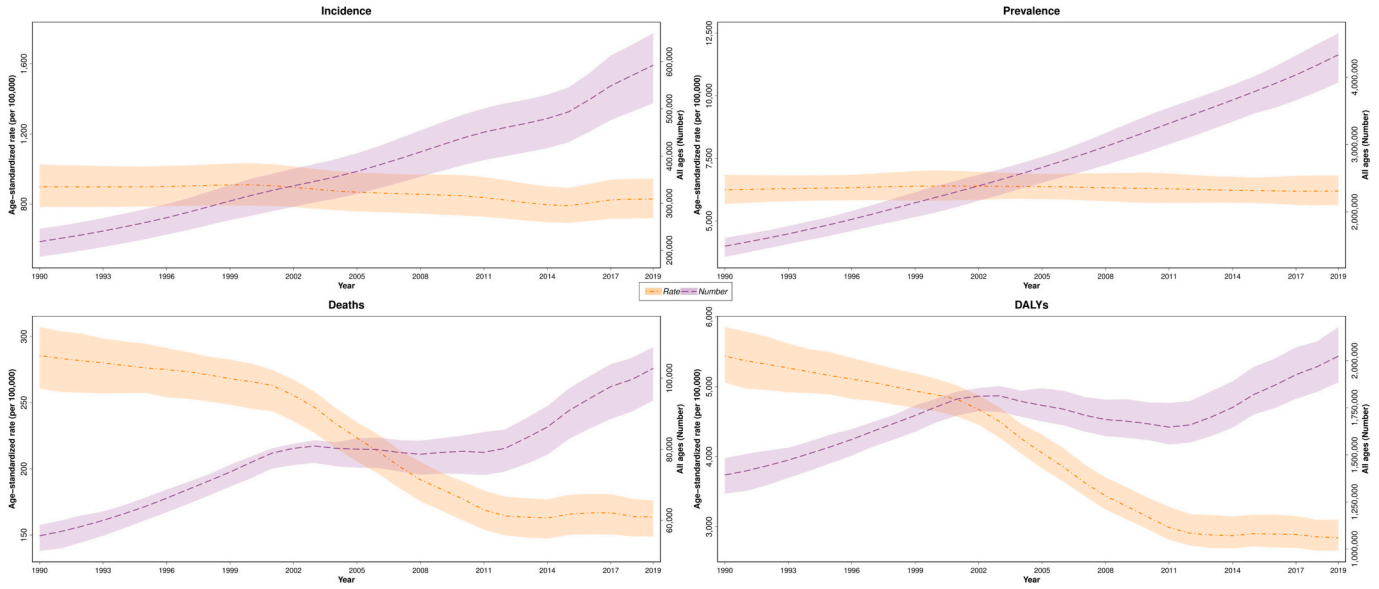

Fig. 1. Time trend of IHD burden age-standardized rates versus all-ages number by measure from 1990 to 2019.

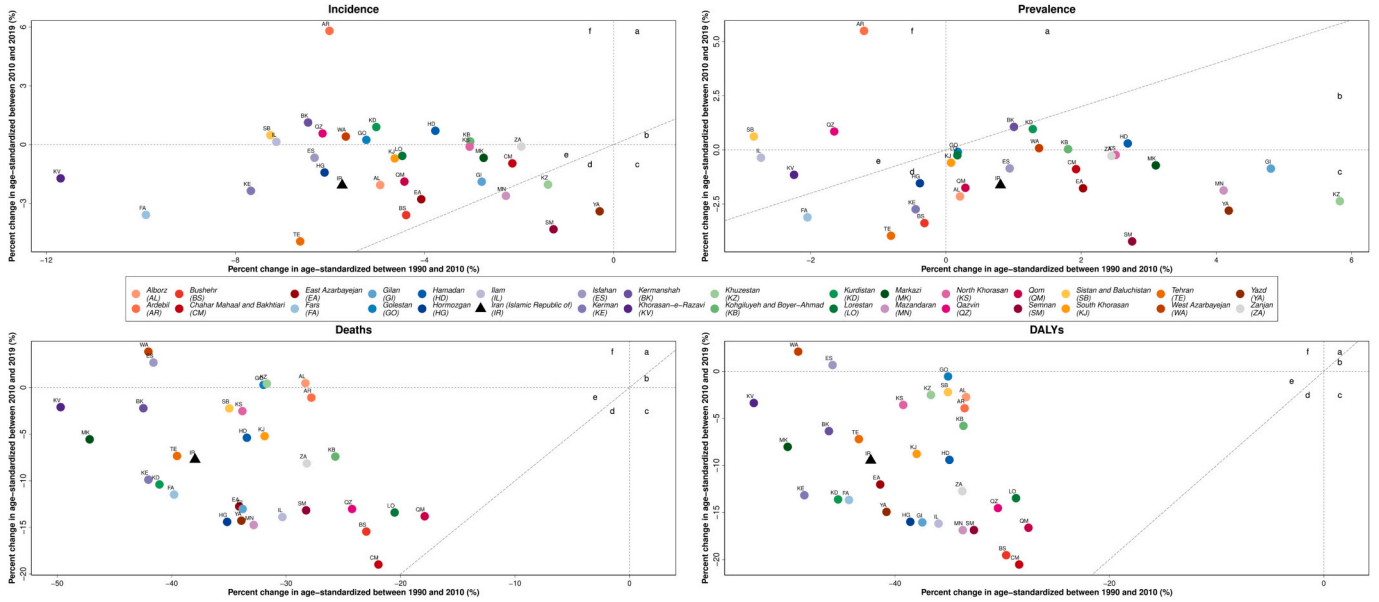

Fig. 2. Percent change of IHD burden age-standardized rates at the national and subnational levels during 1990–2010 versus 2010–2019, by measure. (a), rates increased more rapidly after vs. before 2010, (b), rates increased more slowly after vs. before 2010, (c), rates increased before 2010 but decreased after 2010, (d), rates decreased more rapidly after than before 2010, (e), rates decreased more slowly after than before 2010, (f), rates decreased before 2010 but increased after 2010.

Moreover, a provincial disparity exists in provincial mortality records despite a convergence that observed over the study period, where Tehran, the capital city of Iran, had the lowest rate, near one-third of Golestan province with the greatest rate.

Our finding illustrated near 7% reduction in age-standardized incidence rate during 1990–2019, which resulted in descending Iran's position to the second level of global rate in 2019 [11]. This decline was in-line with the regional (EMRO) records but lower than the on-average 17% global rate reduction [11]. Given that population growth and aging resulted in a remarkable rise in global IHD prevalence and incidence number, to reduce the incidence rate, improvement in primary prevention and better management of IHD is mandatory [8,12]. A previous GBD study on the global burden of IHD demonstrated that high SDI countries had the greatest reduction in IHD incidence rate (>40%) by adopting various primary prevention programs [12]. Iran also experienced considerable population growth and aging due to the rise in life expectancy at birth from about 68 in 1990 to 78 years in 2019 [1], which might resulted in increment of IHD new cases. However, the age-standardized incidence rate decreased in line with similar studies on other NCDs like stroke [13]. Furthermore, fundamental health system reforms such as the primary healthcare (PHC) system were implemented in the 1980s to increase the primary and secondary healthcare coverage in Iran particularly in deprived areas of the country that might have played a role in IHD incidence rate reduction [3]. Overall, Iran' health system includes public and private sectors and NGOs, like most of the Western countries. There are some differences like the costs cost of public sector services which varies depending on the insurance in Iran but is free in some Western countries. However, the efficacy of the health

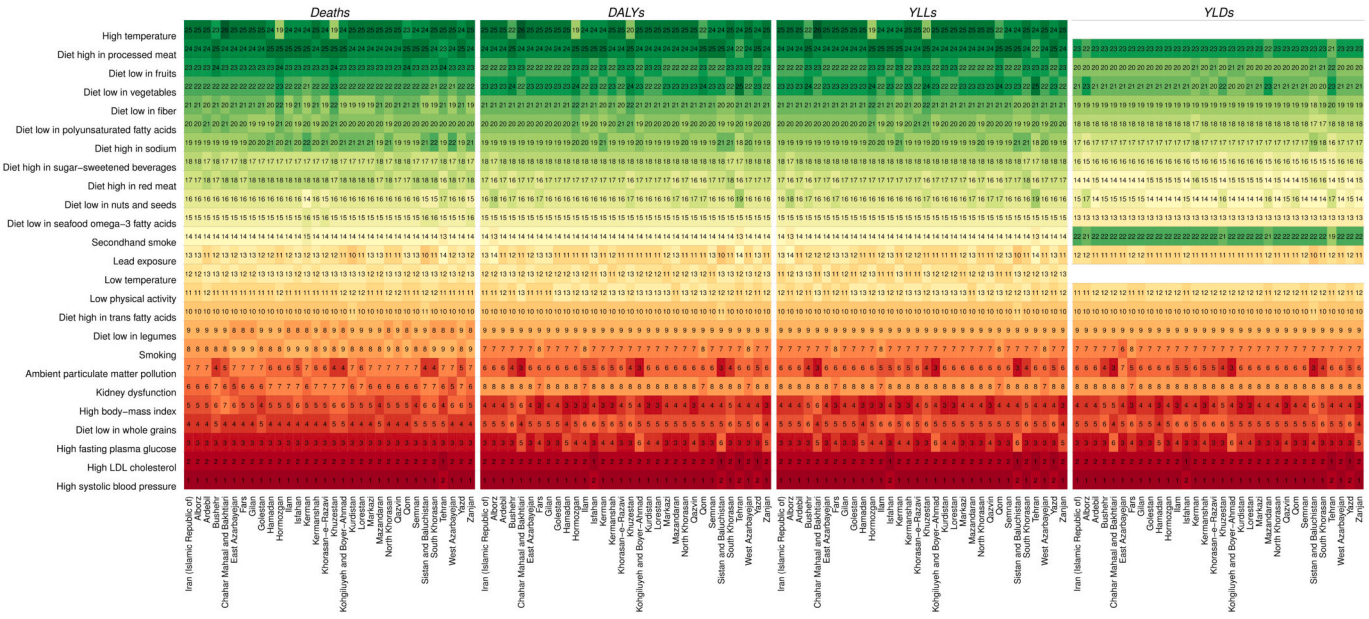

Fig. 3. Ranking of 4th level of risk factors attributable age-standardized rates at the national and subnational levels in 2019, by measure.

system and PHC is not well compared with the Western countries, and there is much room remaining for it to improve and decrease the incidence rate.

Apart from providing better primary healthcare coverage to reduce the IHD incidence, other successful preventive strategies such as lifestyle modification, hypertension and diabetes treatment, lowering cholesterol, and antithrombotic therapy should be adopted and improved [4]. It is noteworthy that Iran reported higher diabetes and hypertension prevalence (as the two major IHD risk factors) compared with some Western countries like European area [14,15], which emphasize on the importance of tackling these risk factors. In this regard, multiple programs were established, like the rural PHC system and the National Program for Prevention and Control of Diabetes (NPPCD) in 2004 [16]. The presence of rural PHC workers (known as Behvarz) was associated with significantly lower FPG and high SBP [17]. However, the initial report of NPPCD illustrated that despite the widespread availability of glucose-lowering drugs and insulin, diabetes control in Iran was unsatisfactory [18]. Therefore, to better tackle the growing NCD burden, the National Action Plan to Prevent and Control NCDs was developed by the Iranian Non-Communicable Diseases Committee (INCDC) in 2015. It is in line with the Global Monitoring Framework on the Prevention and Control of NCDs (GMF) [19] and includes multiple goals and programs across the country such as levying tax on tobacco products, promoting physical activity, reduction of alcohol consumption, decreasing high SBP prevalence and changing in regulations of food industries to reduce free fatty acid, sugar, and salt in processed foods until 2025 [20]. Although it might be early to evaluate the effect of this program, our findings did not reveal a significant change in the trend of IHD incidence rate since 2015.

We illustrated that dietary risks, high SBP, and high LDL-C were the top three contributors to DALY and death rate in 1990 and 2019, which is in line with global records [12]. A closer look revealed that high SBP and high LDL-C, high FPG, diet low in whole grains and high BMI were the top five in the 4th level of risk factors in 2019. Although reduction was observed in attributable measures of almost all risk factors, high FPG attributed rates increased over the study period. Moreover, the percentage contribution of major ones such as high SBP and high LDL-C remained somehow the same, while increased regarding high FPG and high BMI. Overall, the prevalence of obesity, diabetes, and hypertension increased in Iran in recent decades [21–23]. Furthermore, given that the Iranian population have high salt intake [24], and low hypertension awareness in youth, and control among elderlies [25], as well as the upward trend of urbanization, low physical activity, and sedentary lifestyle [26], a multi-dimensional approach is necessary to focus not only on lifestyle modification but also on better management of these risk factors with shared basis, as suggested by the global pandemic of obesity, under-nutrition, and climate change [27]. Regarding smoking that showed a significant reduction in attributable IHD burden, the establishment of Framework Convention on Tobacco Control (FTCT) in 2005 and the GMF-based programs might have been effective [16,19].

Death and DALY rates declined by >40%, which if continue to decline similarly, can result in achieving SDG 3.4 target by 2030 (reducing one-third of NCDs mortality) [2]. However, we illustrated that the rate reduction was not steady over the study period; near 40% rate reduction between 1990 and 2010, while slowed down to near 10% since 2010. Therefore, if the pattern of declining after 2010 continues, we probably will not be able to reach the SDG 3.4. Multiple factors influence the IHD mortality such as alternation in SES, political events, adopting lifesaving treatments, and improved educational level [28]. Low SES of the population is associated with 35% greater mortality risk of the IHD [4]. Accordingly, our findings showed a rapid reduction of mortality during 2002–2010, simultaneous with the sharp growth of GDP (about 129 to 644 billion US$), of which the healthcare expenditure had a proportion of 4.7 to 6.7% [29,30]. Afterward, imposing international sanctions against Iran in 2011 caused a rapid reduction of GDP from about 644 to 284 billion US$ in 2019, which could be one of the influential factor for the considerable slowing of mortality rate decline. Similarly, previous studies declared that higher SES is associated with better affordability and accessibility of primary and secondary healthcare services, and higher educational level, which results in lower mortality [4]. In this order, high SES countries despite great IHD risk factors prevalence demonstrated the lowest mortality rates [31]. Therefore, GPD seems to be a prominent contributor to the IHD mortality changes in Iran, and might have restricted the impact of multiple programs implemented during the study period to reduce the IHD burden. However, the role of risk factors management is yet prominent, like a previous study in Russia, that showed that the unhealthy lifestyle, and inadequate risk factor control could be the reasons for one of the highest mortality rate worldwide despite the technologies and policies that were implemented [32].

Lifesaving treatments like primary percutaneous coronary intervention, fibrinolytic therapy, and emergency surgeries that became more

extensively available in the country besides growth in hospital beds and adoption of modern facilities [33], probably led to mortality reduction. At the provincial level, the higher availability of these services in Tehran might be the reason for its lowest mortality rate. Furthermore, Iran experienced >70% and 60% growth in literacy rate of women and men during 1995–2015 [3], which is a contributor to healthier lifestyle choices, better health knowledge and awareness of diseases, and receiving early management [4] leading to mortality reduction.

Although reducing mortality is an important target, averting deaths might result in chronic conditions, like heart failure, which increases the disability rate and cost of illnesses [5]. Accordingly, our findings revealed that the YLD remained the same due to reducing mortality much more than the incidence rate. Therefore, the Iranian healthcare system must consider appropriate rehabilitation programs to deal with this emerging burden of morbidity, and improve the PHC system to accelerate incidence rate reduction.

Men had greater IHD burden in almost all ages; however, the sex differences decreased when age increased probably due to the reduction of estrogen in post-menopausal women, which plays significant role in vascular repair, and maintaining vascular health during stressful events [34]. On the other hand, we illustrated that MIR is higher in women than men. This sex difference has been attributed to older age, and higher prevalence of risk factors such as comorbidities in women with IHD compared with their counterpart men. Several conditions of females such as variation in estrogen and androgen level during life, use of contraceptives, and greater rate of vascular abnormalities could explain the worse outcomes of IHD among them [35]. Furthermore, women might receive lower aggressive management approaches than men with the same signs, symptoms, and non-invasive cardiac evaluations. One of the reasons for this phenomenon might be the physician's assumption that angina is more a benign symptom in women than men; angina in men is due to myocardial infarction in 45% of cases, compared with 15% regarding women [36]. Considering the greater MIR of females in Iran, it is vital to recognize and modify the influential factors and improve quality of care [37].

4.1. Strengths and limitations

One of the strengths of this study was providing the subnational level estimations, which is invaluable for policymakers and the health system. Moreover, the GBD applied time covariates and regional data for estimation in the years that there were no data; thus, the estimations were not affected by the incompleteness of the data. On the other hand, the lack of estimations for IHD subtypes, such as myocardial infarction and stable angina, was a study limitation.

5. Conclusion

Despite the great reduction in mortality measures, the remarkable incidence of IHD enlightens the urgent need to improve primary prevention strategies. If this trend continues, a great amount of burden will be imposed on the therapeutic and the tertiary healthcare system. Regarding the mortality rate, it seems that SES is one of the prominent factors, which need political, and financial policies. Moreover, the increasing trend of high FPG and obesity is alarming; therefore, one of the major obstacles that should be tackled through primary and secondary prevention interventions is controlling the IHD risk factors.

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Authors' contributions

The authors confirm contribution to the paper as follows:

- SK, YST, SSM, MK, HT, NR, NR, BL, and FF designed the study. SK, YST, SSM, NA, NR, MK, FF, analyzed and interpreted the data. SK, YST, SA, FF, SSM, SS, MK, NA, SHG, MAK, BL, FF and NR drafted the manuscript. SK, NR, NR, FF, SA, SSM, AG, SS, SHG, MAK, and YST revised the manuscript critically for important intellectual content. All authors read and approved the final manuscript.

Declaration of Competing Interest

Authors declared no conflict of interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcard.2023.03.012.

References

[1] IHME, GBD Compare: Institute for Health Metrics and Evaluation, Available from: https://vizhub.healthdata.org/gbd-compare/, 2019.
[2] World Health Organization, Regional Office for the Western P. Sustainable Development Goals (SDGs) : Goal 3. Target 3.4 : By 2030, By 2030, Reduce by One Third Premature Mortality from Non-Communicable Diseases through Prevention and Treatment and Promote Mental Health and Well Being [Poster] 2016, WHO Regional Office for the Western Pacific, Manila, 2016.
[3] G. Danaei, F. Farzadfar, R. Kelishadi, A. Rashidian, O.M. Rouhani, S. Ahmadnia, et al., Iran in transition, Lancet 393 (10184) (2019) 1984–2005.
[4] D.P. Leong, P.G. Joseph, M. McKee, S.S. Anand, K.K. Teo, J.-D. Schwalm, et al., Reducing the global burden of cardiovascular disease, part 2: prevention and treatment of cardiovascular disease, Circ. Res. 121 (6) (2017) 695–710.
[5] B. Sagar, A.E.M. Dugani, Robert O. Bonow, Thomas A. Gaziano, Ischemic Heart Disease: Cost-Effective Acute Management and Secondary Prevention. Cardiovascular, Respiratory, and Related Disorders, 3rd edition, The International Bank for Reconstruction and Development: The World Bank, Washington (DC), 2017.
[6] C.J. Murray, A.Y. Aravkin, P. Zheng, C. Abbafati, K.M. Abbas, M. Abbasi-Kangevari, et al., Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the global burden of disease study 2019, Lancet 396 (10258) (2020) 1223–1249.
[7] T. Vos, S.S. Lim, C. Abbafati, K.M. Abbas, M. Abbasi, M. Abbasifard, et al., Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the global burden of disease study 2019, Lancet 396 (10258) (2020) 1204–1222.
[8] G.A. Roth, G.A. Mensah, C.O. Johnson, G. Addolorato, E. Ammirati, L.M. Baddour, et al., Global burden of cardiovascular diseases and risk factors, 1990-2019: update from the GBD 2019 study, J. Am. Coll. Cardiol. 76 (25) (2020) 2982–3021.
[9] Network, GBoDC. Global Burden of Disease Study 2019 (GBD 2019) Cause List Mapped to ICD Codes, Institute for Health Metrics and Evaluation (IHME), Seattle, United States of America, 2020. Available from: http://ghdx.healthdata.org/record/ihme-data/gbd-2019-cause-icd-code-mappings.
[10] F. Farzadfar, M. Naghavi, S.G. Sepanlou, S.S. Moghaddam, W.J. Dangel, N. D. Weaver, et al., Health system performance in Iran: a systematic analysis for the global burden of disease study 2019, Lancet 399 (10335) (2022) 1625–1645.
[11] IHME, Ischemic Heart Disease: IHME, Available from: https://collab2019.healthdata.org/gbd-compare/?utm_source=Active+Collaborators&utm_campaign=7b019ca2ad-EMAIL_CAMPAIGN_2020_04_24_06_07_COPY_01&utm_medium=email&utm_term=0_d65e2ca485-7b019ca2ad-422599137, 2019.
[12] H. Dai, A.A. Much, E. Maor, E. Asher, A. Younis, Y. Xu, et al., Global, regional, and national burden of ischemic heart disease and its attributable risk factors, 1990-2017: results from the global burden of disease study 2017, Eur. Heart J. Qual. Care Clin. Outcomes 8 (1) (2022) 50–60.
[13] A. Fallahzadeh, Z. Esfahani, A. Sheikhy, M. Keykhaei, S.S. Moghaddam, Y. S. Tehrani, et al., National and subnational burden of stroke in Iran from 1990 to 2019, Annals of clinical and translational, Neurology 9 (5) (2022) 669–683.
[14] International Diabetes Federation DA, Diabetes Prevalence (% of Population Ages 20 to 79): The World Bank, Available from: https://data.worldbank.org/indicator/SH.STA.DIAB.ZS?most_recent_value_desc=true, 2021.

[15] Organization TWH, Raised Blood Pressure (SBP ≥ 140 OR DBP ≥ 90), Age-Standardized (%), Available from: https://apps.who.int/gho/data/view.main.NCDBPAREGv?lang=en.
[16] S. Azadnajafabad, E. Mohammadi, A. Aminorroaya, N. Fattahi, S. Rezaei, R. Haghshenas, et al., Non-communicable diseases' risk factors in Iran; a review of the present status and action plans, J. Diabetes Metab. Disord. (2021) 1–9.
[17] F. Farzadfar, C.J.L. Murray, E. Gakidou, T. Bossert, H. Namdaritabar, S. Alikhani, et al., Effectiveness of diabetes and hypertension management by rural primary health-care workers (Behvarz workers) in Iran: a nationally representative observational study, Lancet 379 (9810) (2012) 47–54.
[18] A. Esteghamati, B. Larijani, M.H. Aghajani, F. Ghaemi, J. Kermanchi, A. Shahrami, et al., Diabetes in Iran: prospective analysis from first nationwide diabetes report of National Program for prevention and control of diabetes (NPPCD-2016), Sci. Rep. 7 (1) (2017) 1–10.
[19] World Health Organization, Surveillance MaRt. NCD Global Monitoring Framework: The World Health Organization, Available from: https://www.who.int/publications/i/item/ncd-surveillance-global-monitoring-framework, 2011.
[20] N. Peykari, H. Hashemi, R. Dinarvand, M. Haji-Aghajani, R. Malekzadeh, A. Sadrolsadat, et al., National action plan for non-communicable diseases prevention and control in Iran; a response to emerging epidemic, J. Diabetes Metab. Disord. 16 (1) (2017) 1–7.
[21] S.G. Sepanlou, P. Mehdipour, A. Ghanbari, S. Djalalinia, N. Peykari, A. Kasaeian, et al., Levels and trends of hypertension at national and subnational scale in Iran from 1990 to 2016: a systematic review and pooled analysis, Arch. Iran. Med. 24 (4) (2021).
[22] S. Djalalinia, P. Mehdipour, B. Mohajer, F. Mohebi, B. Larijani, S.G. Sepanlou, et al., Levels and trends of BMI, obesity, and overweight at national and sub-national levels in Iran from 1990 to 2016; A comprehensive pooled analysis of half a million individuals, Arch. Iran. Med. 24 (5) (2021).
[23] B. Zhou, Y. Lu, K. Hajifathalian, J. Bentham, M. Di Cesare, G. Danaei, et al., Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4· 4 million participants, Lancet 387 (10027) (2016) 1513–1530.
[24] S. Rezaei, Z. Mahmoudi, A. Sheidaei, Z. Aryan, N. Mahmoudi, K. Gohari, et al., Salt intake among Iranian population: the first national report on salt intake in Iran, J. Hypertens. 36 (12) (2018) 2380–2389.
[25] M. Mahdavi, M. Parsaeian, B. Mohajer, M. Modirian, N. Ahmadi, M. Yoosefi, et al., Insight into blood pressure targets for universal coverage of hypertension services in Iran: the 2017 ACC/AHA versus JNC 8 hypertension guidelines, BMC Public Health 20 (1) (2020) 347.
[26] F. Mohebi, B. Mohajer, M. Yoosefi, A. Sheidaei, H. Zokaei, B. Damerchilu, et al., Physical activity profile of the Iranian population: STEPS survey, 2016, BMC Public Health 19 (1) (2019) 1–17.
[27] B.A. Swinburn, V.I. Kraak, S. Allender, V.J. Atkins, P.I. Baker, J.R. Bogard, et al., The global Syndemic of obesity, undernutrition, and climate change: the lancet commission report, Lancet 393 (10173) (2019) 791–846.
[28] V. Fuster, B.B. Kelly, R. Vedanthan, Promoting global cardiovascular health: moving forward, Circulation. 123 (15) (2011) 1671–1678.
[29] BANK TW, GDP (Current US$) - Iran, Islamic Rep, Available from: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=IR, 2021.
[30] BANK TW, Current Health Expenditure (% of GDP) - Iran, Islamic Rep, Available from: https://data.worldbank.org/indicator/SH.XPD.CHEX.GD.ZS?locations=IR, 2022.
[31] M.A. Khan, M.J. Hashim, H. Mustafa, M.Y. Baniyas, S. Al Suwaidi, R. AlKatheeri, et al., Global epidemiology of ischemic heart disease: results from the global burden of disease study, Cureus. 12 (7) (2020), e9349.
[32] S. Matskeplishvili, A. Kontsevaya, Cardiovascular health, disease, and Care in Russia, Circulation. 144 (8) (2021) 586–588.
[33] S. Rezaei, M. Bazyar, R. Fallah, Y. Chavehpour, Rad E. Homaie, Assessment of need and access to physician and hospital beds: a cross sectional province based study in Iran, Shiraz E Med. J. 16 (6) (2015), e26351.
[34] C. Noel Bairey Merz, B.D. Johnson, B.L. Sharaf, V. Bittner, S.L. Berga, G. D. Braunstein, et al., Hypoestrogenemia of hypothalamic origin and coronary artery disease in premenopausal women: a report from the NHLBI-sponsored WISE study, J. Am. Coll. Cardiol. 41 (3) (2003) 413–419.
[35] V. Vaccarino, H.M. Krumholz, L.F. Berkman, R.I. Horwitz, Sex differences in mortality after myocardial infarction: is there evidence for an increased risk for women? Circulation. 91 (6) (1995) 1861–1871.
[36] W.B. Kannel, M. Feinleib, Natural history of angina pectoris in the Framingham study: prognosis and survival, Am. J. Cardiol. 29 (2) (1972) 154–163.
[37] A. Aminorroaya, M. Yoosefi, N. Rezaei, M. Shabani, E. Mohammadi, N. Fattahi, et al., Global, regional, and national quality of care of ischaemic heart disease from 1990 to 2017: a systematic analysis for the global burden of disease study 2017, Eur. J. Prev. Cardiol. 29 (2) (2021) 371–379.