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RESEARCH ARTICLE

Sex disparity in the burden of NCDs and its four main subgroups in Iran 1990–2019: a systematic analysis from the global burden of disease study 2019

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Abstract

Objectives The significant health differences between sexes in Iran in terms of burden of non-communicable diseases (NCDs) point to the urgency of developing policies. We aim to explore sex disparities in NCDs.

Methods We used Global Burden of Disease 2019 study to compare estimates of incidence, prevalence, disability-adjusted life years (DALYs), years lived with disabilities (YLDs), years of life lost (YLLs), and deaths among sexes for NCDs, and their main subgroups; neoplasms, cardiovascular diseases (CVDs), chronic respiratory diseases (CRDs), diabetes mellitus (DM) during 1990–2019.

Results In 2019, there were 62,476,274 (59517167.5, 65759931) incident NCDs in men and 78758640.6 (75222093.7, 82272935.8) in women. There were 7734064.3 (6744951.2, 8846192) DALYs in men and 7760484.2 (6496609, 9218299.9) in women. Fatal estimates (deaths and YLLs) of NCDs were higher for men, while non-fatal estimates (prevalence, YLDs) were higher for women. Men were superior in all burden indices of NCDs subgroups, except for all indices of DM and YLDs in CVDs. Compared to 1990–2010, the period 2010–2019 confirmed a marked stagnation in decline rates of burden indices, as well as an increase in incidence and prevalence which was more pronounced among men. Despite shrinking sex gaps in NCDs subgroups since 1990, sex gap in DM is widening in 2019.

Conclusions There is a notable sex disparity in NCDs prevalence in Iran, which has become increasingly evident in DM burden. It will be imperative to continue monitoring sexual differences in NCDs burden to determine if disease rates between sexes continue to diverge in the future.

Keywords Sex · Non-communicable diseases · Iran · Global burden of Disease Study · Diabetes · Neoplasm

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Abbreviations

ASDR	Age-standardized Death Rate
ASIR	Age-standardized Incidence Rate
ASPR	Age-standardized Prevalence Rate
ASR-DALYs	Age-standardized Rate of DALYs
BMI	Body Mass Index
BP	Blood Pressure
CODEm	Cause of Death Ensemble model
COPD	Chronic Obstructive Pulmonary Disease
CRD	Chronic Respiratory Disease
CVD	Cardiovascular Disease
DALYs	Disability-adjusted Life Years
DM	Diabetes mellitus
GBD	Global Burden of Disease
MDG	Millennium Development Goal
MI	Myocardial Infarction
MIR	Mortality to Incidence Ratio
MWR	Men to Women Ratio
NCD	Non-communicable Disease
SDG	Sustainable Development Goal
SDI	Socio-demographic Index
STEPS	STEPwise Approach to NCD Risk Factor Surveillance
UI	Uncertainty Interval
YLDs	Years Lived with Disability
YLLs	Years of Life Lost

Introduction

Non-communicable diseases (NCDs) accounted for approximately 300 thousand deaths in Iran in 2019, with cardiovascular diseases (CVDs), diabetes mellitus (DM), chronic respiratory diseases (CRDs), and cancers being the primary causes [1]. Managing such diseases poses significant challenges, not only in terms of healthcare management but also in terms of the disparities between men and women [2–4]. Cardiometabolic disorders and malignancies demonstrate marked sex disparities in prevalence, and respiratory diseases exhibit sex differences in incidence and outcomes, influencing the focus of health interventions and policy initiatives aimed at addressing these disparities [5–8].

Cohort studies conducted within the country provide insightful data illustrating these disparities. According to the Tehran Lipid and Glucose Study [9] and the Golestan Cohort Study [10], there are considerable differences in risk factors and disease prevalence between men and women, indicating that women may face greater barriers to healthcare access and worse outcomes due to NCDs. Inequities in access to healthcare and socioeconomic determinants of health often contribute to disparities in health [11]. Various factors can influence women's health conditions in Iran, such as lifestyle, employment status, and cultural norms, which can alter exposure and susceptibility to multiple diseases [3].

Understanding these differences at a national and subnational level is essential to develop tailored interventions to address specific local health needs and allocate resources accordingly. Furthermore, the evolution of Iran's health system post-revolution presents an exceptional case for studying the intersection of policy and sex in the context of NCDs. Global initiatives such as the Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs) have developed policies to address sex disparities in NCDs. Despite being designed to eliminate sex disparities in education and increase women's political participation, the MDGs failed to achieve their goals, with limited progress in areas such as employment and health [12]. In light of commitments to the SDGs, these disparities must be addressed immediately, particularly Goal 3, which seeks to ensure the health and well-being of all people of all ages, and Goal 5, which strives to achieve sex equality and empower all women and girls [12].

By utilizing the Global Burden of Disease (GBD) Study 2019, this study integrated Iranian health system data with global health analyses. This provides an unprecedented opportunity to examine the impacts of such disparities on both national and subnational health policy frameworks. By aligning the study of sex disparities in NCDs with international health goals, this paper elucidates the current development and drives forward the necessary policy modifications and interventions. This study aims to contribute substantively to the discourse concerning achieving equitable health outcomes in Iran by providing a comprehensive review and using robust study data.

Methods

Overview

GBD is a multinational effort that assesses the burden of 369 diseases and injuries in 204 countries and territories [13]. Using GBD data, this study provides population and subpopulation estimates at national and subnational levels in Iran using all-age numbers and age-standardized rates for 1990 to 2019 among women, men, and both sexes.

Case definition and their metrics

Standard definitions of the causes of death and their detailed methodology have been reported elsewhere (13–15). Here, we report the burden indices of NCDs and their subgroups, including neoplasms, CVDs, CRDs, and DM. The

incidence, prevalence, and death related to each cause were reported. The burden of disease has been measured by metrics including years of life lost (YLLs), which is calculated by multiplying the number of deaths in each category and life expectancy in that category. Years lived with disability (YLDs), which is calculated by multiplying the number of prevalence of causes in each category and disability weights for that condition [12]. Disability-adjusted life year (DALYs) was also obtained from the sum of YLLs and YLDs.

Estimation framework

The Estimation framework begins with the collection of raw data from a variety of sources, including vital registration systems, household surveys, censuses, hospital records, and disease registries. This diverse data foundation is crucial for ensuring a comprehensive understanding of health outcomes across different regions and populations. These sources undergo rigorous validation and adjustments to correct for biases such as underreporting, misclassification, and data gaps.

To synthesize the vast array of data, the GBD study employs sophisticated modeling techniques. One of the core tools used is DisMod-MR, a Bayesian meta-regression tool designed to integrate data from different studies and correct for discrepancies [13]. DisMod-MR leverages a hierarchical modeling approach, allowing for the incorporation of data from multiple sources and adjusting for potential biases and uncertainties. This model synthesizes information about disease incidence, prevalence, and mortality, providing consistent and comparable estimates across different populations and time periods. By accounting for the uncertainty and variability in the data, DisMod-MR ensures that the estimates are robust and reliable.

For mortality estimation, the GBD study employs the Cause of Death Ensemble model (CODEm) [13, 14]. CODEm is a highly advanced, ensemble modeling approach that evaluates numerous models and combinations of models to determine the most accurate estimates of cause-specific mortality. It incorporates a variety of potential predictors and data sources, using techniques such as machine learning to systematically evaluate and combine different models. This allows CODEm to produce estimates of cause-specific mortality that are highly accurate and reflective of the complex interplay of factors influencing death rates. By integrating multiple models, CODEm ensures that the estimates are not overly dependent on any single data source or methodological approach.

The Mortality to Incidence Ratio (MIR) methodology is a crucial analytical tool used in the GBD study to evaluate the severity and management outcomes of NCDs across diverse populations [15]. This ratio is derived by dividing the number of deaths caused by a specific NCD by the number of new cases diagnosed within a given period. The MIR helps to highlight disparities in health outcomes and the effectiveness of healthcare systems in managing NCDs. A lower MIR indicates better survival rates, suggesting more effective disease management and healthcare interventions. By employing this methodology, the GBD study assists in pinpointing regions and populations that require targeted healthcare improvements and resource allocation, thereby guiding global health policies and strategies to combat NCDs more effectively.

This integrated framework facilitates direct comparisons of health outcomes over time, across different populations, and across various health conditions, thereby informing targeted public health interventions and resource allocation.

Sociodemographic index

The Socio-Demographic Index (SDI) used in the GBD studies is a composite measure reflecting the level of sociodemographic development of a country or region by incorporating geometric mean education for the population aged 15 and older, income per capita adjusted for purchasing power parity, and the total fertility rate under age 25 [16]. Each of these indicators is standardized to a scale from 0 to 1, where 0 denotes the lowest socio-demographic development and 1 denotes the highest. The SDI score is calculated by averaging the standardized scores of these three indicators, allowing for the classification of countries or regions into quintiles (low, low-middle, middle, high-middle, and high SDI). This index enables comparison of health outcomes and disease burdens across different levels of sociodemographic development, aiding in more precise and effective public health interventions.

Statistical analysis

To present all-age numbers and age-standardized rates, we utilized an uncertainty interval (UI) of 95% for each quantity included in the study [13]. These UIs were determined by sampling 1000 samples from each quantity's posterior distribution of each quantity and selecting the 25th and 975th ranked draws from the uncertainty distribution [17]. We used Python version 3.11.4 for tabulation and visualization of the data.

Results

Overall burden of NCDs

In 2019, there were 141234914.6 (95%UI, 134968873.0 to 147641977) incident cases of NCDs, with an age-standardized incidence rate (ASIR) of 165910.6 (158062.6 to 173639.3) per 100,000. There were 62,476,274 (59517167.5 to 65759931) cases in men and 78758640.6 (75222093.7 to 82272935.8) in women in 2019. The ASIR 2019 were 147213.4 (140038.1 to 154816.9) and 185206.5 (176449 to 193860) in men and women, respectively. A 2% increase in ASIR was observed between 1990 and 2019 (1–2%) (Table 1).

In 2019, women had a higher incidence of NCDs in all provinces. The highest and lowest men-to-women ratio (MWR) was recorded in Fars (0.81) and Mazandaran (0.78). The most significant increase in ASIR during 1990–2019 among men and women was observed in Khuzestan (2.1% [-0.2–4.5%]) and Chahar Mahaal and Bakhtiari (2.3% [0.2–4.6%]), respectively (Table S1).

In 2019, there were 78855189.4 (78135532 to 79453190.7) prevalent cases of NCDs, with an age-standardized prevalence rate (ASPR) of 92646.5 (91678.3 to 93466.6) per 100,000. There were 39177162.4 (38731987.6 to 39571760.1) cases in men and 39,678,027 (39419842.3 to 39896839.7) cases in women in 2019. The ASPR in 2019 was 90536.3 (89363.9 to 91577.3) and 94854.3 (94115.6 to 95486.1) in men and women, respectively. A 1% increase in ASPR was observed between 1990 and 2019 (0–1%) (Table 1).

In 2019, women had a higher prevalence of NCDs in all provinces. The highest and lowest MWR were observed in Tehran (0.96) and Mazandaran (0.95). The highest increase in ASPR during 1990–2019 among men and women was observed in Tehran (0.3% [-0.1–0.8%]) and Khuzestan (1.1% [0.7–1.4%]), respectively (Table S1).

NCDs were responsible for 15494548.5 (13229362.6 to 18078885.3) DALYs in 2019, with an age-standardized rate of DALYs (ASR-DALYs) of 19632.9 (17000.1 to 22614.3) per 100,000. There were 7734064.3 (6744951.2 to 8846192) DALYs in men and 7760484.2 (6496609 to 9218299.9) in women in 2019. The ASR-DALYs 2019 were 19625.6 (17282.4 to 22198.7) and 19685.5 (16706.5 to 23100.9) in men and women, respectively. A 26% decrease in ASR-DALYs was observed between 1990 and 2019 (-31% to -20%) (Table 1).

In 2019, men had higher DALYs in most provinces, and MWR ranged from 1.2 in Lorestan to 0.9 in Tehran. The most significant decrease in ASR-DALYs during 1990–2019 among men and women was observed in Kurdistan (-37.1% [-48.5% to -23.3%]) and Ardebil (-32.2% [-41.7% to -20.9%]), respectively (Table S1).

NCDs resulted in 326507.8 (318267.7 to 335734.2) deaths in 2019, with an age-standardized death rate (ASDR) of 508.9 (496.5 to 522.7). There were 180005.1 (173339.4 to 187658.1) deaths in men and 146502.7 (141464.2 to 151659.4) deaths in women in 2019. The ASDR in 2019 was 544.3 (524.8 to 566.4) and 475.4 (459.6 to 491.6) in men and women, respectively. A 32% decrease in ASR-DALYs was observed between 1990 and 2019 (-35% to -28%) (Table 1).

In 2019, men had higher deaths in all of the provinces except for Qom and Tehran. MWR ranged from 1.65 in Lorestan to 0.92 in Tehran. The most significant decrease in ASDR during 1990–2019 among men and women was recorded in Kurdistan (-42.1% [-54.8% to -27%]) and Chahar Mahaal and Bakhtiari (-41% [-53.7% to -23.1%]), respectively (Table S1).

Measures of YLDs and YLLs and a sex-specific assessment of provincial burden are reported in Table 1 and Table S1, respectively. The comparison between 1990 and 2010 and 2010–2019 revealed a significant stagnation in the decline rates of DALYs, YLLs, and deaths from NCDs in most provinces(Fig. 1). Additionally, we have seen an increase in burden indices in some provinces. Regarding incidence and prevalence, the increase in rates was higher in 2010–2019 than in 1990–2010. Furthermore, the stagnation in decline, along with increasing in incidence and prevalence, was more pronounced among men than women. Concerning YLDs, the rate of change declined among women and stabilized among men in 2010–2019 compared to 1990–2010. Detailed information on the change rates of NCD subgroups can be found in supplementary Figs. 1, 2, 3, and 4. Furthermore, our time trend analysis confirmed our previous finding regarding the reversal of NCDs burden as their declining behavior is slowed down in the last decade (Fig. 2). A comparison of the times between 1990 and 2010 and 2010–2019 among NCDs subgroups including neoplasms, CRDs, CVDs, and DM shows a considerable increase, especially among men and a marked slowdown in declines over time (Figure S5, S6, S7, and S8).

Age groups

The burden indices of NCDs rise continuously with age, and older age groups suffer the greatest burden. YLDs were consistently elevated in women (except for the 5–9 age group), and this provided the basis for higher DALYs among women up to 45–49, excluding the 5–9 age group. In 2019, the surge in YLLs began in the 50–54 age group, resulting in higher DALYs among men from this age group to 75–79. Eventually, in the 80 + group, women had higher

Table 1 All-age number and age-standardized rate of deaths, disability-adjusted life years (DALYs), years of life lost (YLLs), years lived with disability (YLDs), prevalence, and incidence of non-communicable diseases and their groups by sex in 1990 and 2019 and overall percent change over 1990–2019 in Iran

Cause	Measure	Metric	Year						Annual rate of change (1990 to 2019)		
			1990			2019					
			Both	Women	Men	Both	Women	Men	Both	Women	Men
Non-communicable diseases	Deaths	All ages Number	173709.85 (159459.6 to 187265.87)	74521.98 (68097.58 to 81354.98)	99187.86 (90009.07 to 108141.75)	326507.75 (318267.74 to 335734.18)	146502.67 (141464.19 to 151659.42)	180005.09 (173339.38 to 187658.09)	0.88 (0.73 to 1.07)	0.97 (0.79 to 1.18)	0.81 (0.65 to 1.03)
		Age-standardized Rate	747.88 (718.89 to 775.14)	674.87 (646.2 to 705.42)	814.57 (771.97 to 856.89)	508.93 (496.46 to 522.71)	475.41 (459.64 to 491.55)	544.29 (524.78 to 566.43)	-0.32 (-0.35 to -0.28)	-0.3 (-0.33 to -0.25)	-0.33 (-0.37 to -0.28)
	DALYs	All ages Number	10743718.4 (9053265.64 to 12338035.78)	5125496.2 (4264107.91 to 5931058.88)	5618222.2 (4735970.47 to 6413178.54)	15494548.48 (13229362.62 to 18078885.25)	7760484.18 (6496608.97 to 9218299.93)	7734064.31 (6744951.16 to 8846192.02)	0.44 (0.29 to 0.62)	0.51 (0.34 to 0.69)	0.38 (0.22 to 0.58)
		Age-standardized Rate	26480.25 (23371.64 to 29475.7)	25644.07 (22329.74 to 29019.81)	27169.58 (24164.56 to 29934.57)	19632.9 (17000.07 to 22614.3)	19685.49 (16706.46 to 23100.9)	19625.56 (17282.44 to 22198.67)	-0.26 (-0.31 to -0.2)	-0.23 (-0.29 to -0.18)	-0.28 (-0.34 to -0.21)
	YLDs	All ages Number	4163697.1 (3047940.93 to 5471247.46)	2314448.51 (1680959.32 to 3028622.13)	1849248.59 (1350274.27 to 2421059.07)	8299279.89 (6107865.56 to 10838701.75)	4697119.4 (3443243.36 to 6134980.75)	3602160.49 (2655457.36 to 4682721.06)	0.99 (0.95 to 1.04)	1.03 (0.98 to 1.07)	0.95 (0.9 to 1.0)
		Age-standardized Rate	9579.49 (7074.3 to 12484.25)	10896.41 (8006.52 to 14193.84)	8316.26 (6131.38 to 10792.42)	9709.0 (7136.75 to 12623.22)	10979.78 (8057.71 to 14296.85)	8471.26 (6269.02 to 10993.02)	0.01 (0.0 to 0.02)	0.01 (-0.0 to 0.02)	0.02 (0.01 to 0.03)
	YLLs	All ages Number	6580021.3 (5491058.4 to 7634732.18)	2811047.69 (2323065.4 to 3316307.7)	3768973.61 (3118507.47 to 4387690.03)	7195268.59 (6943678.19 to 7476119.83)	3063364.77 (2926659.19 to 3196962.22)	4131903.82 (3944778.86 to 4343249.52)	0.09 (-0.07 to 0.33)	0.09 (-0.09 to 0.34)	0.1 (-0.08 to 0.35)
		Age-standardized Rate	16900.76 (15474.94 to 18258.14)	14747.67 (13430.13 to 16141.99)	18853.32 (17080.81 to 20584.56)	9923.9 (9580.32 to 10317.61)	8705.71 (8322.17 to 9079.79)	11154.29 (10668.34 to 11723.79)	-0.41 (-0.46 to -0.35)	-0.41 (-0.47 to -0.34)	-0.41 (-0.46 to -0.33)
	Prevalence	All ages Number	51980232.19 (51100708.45 to 52743757.58)	26026305.12 (25647037.85 to 26355094.97)	25953927.07 (25455320.22 to 26409595.83)	78855189.38 (78135532.04 to 79453190.67)	39678027.0 (39419842.34 to 39896839.71)	39177162.39 (38731987.61 to 39571760.08)	0.52 (0.51 to 0.53)	0.52 (0.51 to 0.54)	0.51 (0.5 to 0.52)
		Age-standardized Rate	92163.9 (91179.77 to 93039.76)	93949.67 (93084.47 to 94695.72)	90441.58 (89294.97 to 91479.02)	92646.45 (91678.34 to 93466.63)	94854.34 (94115.64 to 95486.12)	90536.25 (89363.93 to 91577.25)	0.01 (0.0 to 0.01)	0.01 (0.01 to 0.01)	0.0 (-0.0 to 0.0)
	Incidence	All ages Number	92089480.36 (85858347.69 to 98160149.34)	49568216.85 (46294534.4 to 52646095.39)	42521263.51 (39485617.05 to 45663507.87)	141234914.57 (134968873.0 to 147641976.93)	78758640.58 (75222093.67 to 82272935.8)	62476273.99 (59517167.46 to 65759930.97)	0.53 (0.48 to 0.59)	0.59 (0.53 to 0.64)	0.47 (0.42 to 0.53)
		Age-standardized Rate	163407.77 (155422.89 to 171220.58)	182443.72 (173759.85 to 190958.25)	145113.89 (137741.41 to 153108.96)	165910.59 (158062.61 to 173639.27)	185206.54 (176448.96 to 193859.95)	147213.43 (140038.14 to 154816.86)	0.02 (0.01 to 0.02)	0.02 (0.01 to 0.02)	0.01 (0.01 to 0.02)

Table 1 (continued)

Cause	Measure	Metric	Year						Annual rate of change (1990 to 2019)		
			1990			2019					
			Both	Women	Men	Both	Women	Men	Both	Women	Men
Neoplasms	Deaths	All ages Number	26646.75 (23901.37 to 29005.21)	10735.87 (9479.76 to 11936.62)	15910.87 (13786.19 to 17680.41)	66792.3 (61592.26 to 71948.68)	27814.54 (25668.07 to 29951.48)	38977.76 (35413.15 to 42374.64)	1.51 (1.29 to 1.96)	1.59 (1.28 to 1.99)	1.45 (1.18 to 2.03)
		Age-standardized Rate	102.35 (91.28 to 110.79)	81.76 (72.21 to 93.11)	123.73 (105.33 to 135.94)	95.78 (88.23 to 103.1)	78.2 (71.53 to 84.44)	113.24 (102.81 to 122.81)	-0.06 (-0.14 to 0.12)	-0.04 (-0.17 to 0.1)	-0.08 (-0.17 to 0.15)
	DALYs	All ages Number	930393.29 (826199.71 to 1041492.57)	402723.19 (336614.86 to 459985.5)	527670.1 (446468.0 to 605518.31)	1801835.27 (1644788.02 to 1941130.7)	799680.26 (734094.82 to 855769.94)	1002155.0 (891125.44 to 1100990.97)	0.94 (0.72 to 1.25)	0.99 (0.71 to 1.33)	0.9 (0.64 to 1.3)
		Age-standardized Rate	2618.93 (2356.59 to 2851.68)	2236.9 (1977.36 to 2479.06)	2983.76 (2590.05 to 3312.38)	2320.58 (2116.05 to 2497.06)	2013.79 (1849.42 to 2159.97)	2632.51 (2353.6 to 2885.87)	-0.11 (-0.19 to 0.04)	-0.1 (-0.2 to 0.03)	-0.12 (-0.22 to 0.09)
	YLDs	All ages Number	15559.12 (10868.92 to 20882.78)	7707.58 (5440.91 to 10400.38)	7851.54 (5477.45 to 10541.63)	53852.59 (38373.22 to 70898.93)	26576.51 (19204.34 to 35006.8)	27276.08 (19236.57 to 36576.49)	2.46 (2.11 to 3.01)	2.45 (1.97 to 3.0)	2.47 (2.0 to 3.21)
		Age-standardized Rate	45.81 (32.66 to 60.09)	44.14 (31.26 to 58.94)	47.58 (33.77 to 62.74)	69.04 (49.39 to 90.64)	65.72 (47.82 to 86.74)	72.68 (51.52 to 96.69)	0.51 (0.37 to 0.73)	0.49 (0.31 to 0.7)	0.53 (0.34 to 0.86)
	YLLs	All ages Number	914834.17 (812004.51 to 1023769.79)	395015.61 (331353.1 to 452055.66)	519818.56 (439172.82 to 596471.82)	1747982.67 (1595732.38 to 1887477.63)	773103.75 (710619.96 to 827774.04)	974878.92 (868402.47 to 1070800.63)	0.91 (0.7 to 1.22)	0.96 (0.68 to 1.3)	0.88 (0.62 to 1.28)
		Age-standardized Rate	2573.13 (2313.47 to 2803.26)	2192.76 (1939.91 to 2433.24)	2936.18 (2546.07 to 3263.49)	2251.55 (2059.22 to 2431.24)	1948.08 (1793.42 to 2087.29)	2559.83 (2286.43 to 2804.83)	-0.12 (-0.2 to 0.03)	-0.11 (-0.22 to 0.02)	-0.13 (-0.22 to 0.08)
	Prevalence	All ages Number	3796712.41 (3115219.22 to 4662223.44)	1843666.87 (1494925.78 to 2265488.76)	1953045.54 (1587952.08 to 2408447.83)	7714726.78 (6262068.88 to 9539185.7)	3689932.5 (2990737.04 to 4553253.08)	4024794.28 (3283856.62 to 5046133.78)	1.03 (0.85 to 1.2)	1.0 (0.81 to 1.19)	1.06 (0.89 to 1.22)
		Age-standardized Rate	8688.92 (7068.73 to 10629.96)	8257.51 (6738.6 to 10188.99)	9092.39 (7422.39 to 11276.67)	8929.36 (7333.19 to 10869.87)	8510.18 (6999.99 to 10435.73)	9376.66 (7702.41 to 11539.03)	0.03 (0.02 to 0.04)	0.03 (0.02 to 0.04)	0.03 (0.02 to 0.04)
	Incidence	All ages Number	2739667.61 (2221891.13 to 3381818.19)	1332885.52 (1082311.79 to 1643391.0)	1406782.08 (1128789.9 to 1731393.66)	5346531.33 (4322337.72 to 6595814.89)	2559377.43 (2061736.79 to 3160894.38)	2787153.9 (2246161.27 to 3487129.74)	0.95 (0.79 to 1.11)	0.92 (0.74 to 1.11)	0.98 (0.84 to 1.13)
		Age-standardized Rate	6154.02 (5037.27 to 7505.42)	5863.92 (4794.91 to 7162.42)	6422.64 (5250.64 to 7895.97)	6166.28 (5052.8 to 7505.88)	5895.41 (4820.29 to 7191.73)	6454.76 (5282.12 to 7917.82)	0.0 (-0.0 to 0.01)	0.01 (0.0 to 0.01)	0.01 (0.0 to 0.01)

Table 1 (continued)

Cause	Measure	Metric	Year						Annual rate of change (1990 to 2019)		
			1990			2019					
			Both	Women	Men	Both	Women	Men	Both	Women	Men
Chronic respiratory diseases	Deaths	All ages Number	8206.72 (7168.93 to 9874.04)	3361.6 (2545.14 to 4272.47)	4845.12 (4272.34 to 6048.27)	16834.62 (14588.04 to 18193.27)	6763.59 (5355.93 to 7882.95)	10071.03 (8774.83 to 10864.8)	1.05 (0.67 to 1.37)	1.01 (0.55 to 2.02)	1.08 (0.61 to 1.4)
		Age-standardized Rate	42.64 (36.06 to 52.57)	36.15 (27.19 to 47.85)	49.39 (42.91 to 62.69)	26.93 (23.24 to 29.14)	22.39 (17.47 to 26.11)	31.42 (27.59 to 33.98)	-0.37 (-0.49 to -0.27)	-0.38 (-0.55 to -0.1)	-0.36 (-0.51 to -0.27)
	DALYs	All ages Number	365428.54 (315782.94 to 425585.21)	159387.73 (129921.45 to 190367.22)	206040.82 (178518.97 to 241937.53)	587911.35 (521418.31 to 661391.85)	252948.54 (219783.79 to 289415.53)	334962.82 (296527.44 to 374789.21)	0.61 (0.42 to 0.77)	0.59 (0.37 to 1.03)	0.63 (0.38 to 0.81)
		Age-standardized Rate	1113.2 (983.72 to 1275.37)	979.11 (792.26 to 1180.87)	1241.64 (1100.77 to 1472.08)	794.09 (705.19 to 886.5)	690.45 (600.6 to 784.4)	898.61 (801.82 to 997.75)	-0.29 (-0.38 to -0.21)	-0.29 (-0.4 to -0.1)	-0.28 (-0.4 to -0.2)
	YLDs	All ages Number	145147.4 (105334.3 to 194582.49)	69469.24 (50893.55 to 92922.8)	75678.16 (54579.42 to 102578.81)	266779.06 (206943.79 to 330855.43)	128280.25 (100302.53 to 159559.89)	138498.82 (106121.84 to 174294.25)	0.84 (0.65 to 1.06)	0.85 (0.67 to 1.06)	0.83 (0.64 to 1.07)
		Age-standardized Rate	326.96 (247.15 to 419.31)	323.32 (248.1 to 410.67)	330.28 (246.92 to 424.54)	338.06 (262.69 to 420.17)	327.95 (255.12 to 408.55)	348.54 (267.76 to 437.61)	0.03 (-0.01 to 0.09)	0.01 (-0.04 to 0.07)	0.06 (0.0 to 0.12)
	YLLs	All ages Number	220281.14 (194885.24 to 259952.78)	89918.49 (64688.93 to 111291.54)	130362.65 (115385.56 to 161137.16)	321132.29 (283708.74 to 347041.47)	124668.29 (103502.38 to 147168.31)	196464.0 (174268.9 to 210647.24)	0.46 (0.19 to 0.7)	0.39 (0.07 to 1.22)	0.51 (0.17 to 0.75)
		Age-standardized Rate	786.25 (687.2 to 946.77)	655.79 (496.04 to 828.4)	911.35 (804.52 to 1136.21)	456.03 (405.19 to 492.82)	362.5 (295.29 to 426.8)	550.07 (492.9 to 589.85)	-0.42 (-0.53 to -0.33)	-0.45 (-0.57 to -0.17)	-0.4 (-0.53 to -0.31)
	Prevalence	All ages Number	2737620.45 (2317641.38 to 3270975.87)	1283937.22 (1093691.69 to 1514275.86)	1453683.23 (1220040.17 to 1760773.2)	4076809.86 (3634958.58 to 4620503.23)	1926746.78 (1716073.01 to 2197384.24)	2150063.08 (1912497.38 to 2434524.98)	0.49 (0.38 to 0.61)	0.5 (0.4 to 0.62)	0.48 (0.37 to 0.61)
		Age-standardized Rate	5670.25 (5033.62 to 6394.6)	5519.23 (4881.72 to 6239.11)	5818.19 (5150.75 to 6548.88)	5155.4 (4567.16 to 5859.61)	4908.39 (4353.4 to 5582.1)	5400.49 (4774.53 to 6134.03)	-0.09 (-0.12 to -0.06)	-0.11 (-0.14 to -0.08)	-0.07 (-0.11 to -0.04)
	Incidence	All ages Number	545475.36 (438127.35 to 678388.54)	255143.84 (208070.15 to 314014.0)	290331.52 (230056.26 to 365900.9)	731231.27 (633930.96 to 845833.04)	355020.08 (309913.14 to 411175.8)	376211.19 (324274.35 to 438955.12)	0.34 (0.22 to 0.49)	0.39 (0.26 to 0.54)	0.3 (0.18 to 0.44)
		Age-standardized Rate	948.83 (820.19 to 1108.5)	924.3 (805.01 to 1073.87)	972.37 (829.59 to 1133.83)	932.07 (799.65 to 1091.46)	915.39 (797.94 to 1063.45)	947.98 (805.01 to 1112.07)	-0.02 (-0.05 to 0.01)	-0.01 (-0.04 to 0.02)	-0.03 (-0.06 to 0.01)

Table 1 (continued)

Cause	Measure	Metric	Year						Annual rate of change (1990 to 2019)		
			1990			2019					
			Both	Women	Men	Both	Women	Men	Both	Women	Men
Cardio-vascular diseases	Deaths	All ages Number	89210.68 (83564.08 to 95792.65)	37852.3 (34656.0 to 41084.23)	51358.38 (47759.72 to 55784.14)	173600.57 (159444.82 to 183900.94)	79484.71 (71330.95 to 85147.63)	94115.87 (86700.0 to 100155.93)	0.95 (0.74 to 1.08)	1.1 (0.85 to 1.31)	0.83 (0.65 to 0.99)
		Age-standardized Rate	464.78 (426.09 to 498.2)	425.97 (383.63 to 462.12)	496.98 (455.02 to 536.46)	277.73 (252.82 to 294.81)	268.73 (239.02 to 288.46)	288.58 (264.18 to 306.61)	-0.4 (-0.46 to -0.36)	-0.37 (-0.44 to -0.3)	-0.42 (-0.48 to -0.37)
	DALYs	All ages Number	2419826.1 (2283426.24 to 2599478.41)	975030.16 (907245.21 to 1052150.63)	1444795.94 (1345516.98 to 1576556.83)	3603911.62 (3393352.78 to 3847274.27)	1519187.35 (1403019.73 to 1623566.67)	2084724.27 (1965318.17 to 2229440.47)	0.49 (0.35 to 0.59)	0.56 (0.4 to 0.69)	0.44 (0.31 to 0.56)
		Age-standardized Rate	9052.62 (8471.3 to 9688.68)	7826.65 (7203.93 to 8452.82)	10128.29 (9409.11 to 10980.8)	5077.28 (4759.72 to 5382.5)	4483.12 (4116.33 to 4796.38)	5683.59 (5331.25 to 6069.64)	-0.44 (-0.49 to -0.4)	-0.43 (-0.49 to -0.37)	-0.44 (-0.49 to -0.39)
	YLDs	All ages Number	135878.39 (97798.1 to 173681.04)	68016.96 (49371.01 to 85963.78)	67861.43 (48737.46 to 87723.76)	319096.01 (229793.48 to 405500.41)	162531.25 (117440.45 to 204967.18)	156564.75 (112185.28 to 201279.84)	1.35 (1.27 to 1.43)	1.39 (1.31 to 1.47)	1.31 (1.22 to 1.39)
		Age-standardized Rate	454.28 (328.07 to 575.56)	473.8 (344.81 to 598.21)	435.29 (313.75 to 558.77)	425.41 (307.9 to 543.21)	433.19 (315.3 to 550.79)	417.87 (301.26 to 539.48)	-0.06 (-0.08 to -0.05)	-0.09 (-0.11 to -0.06)	-0.04 (-0.06 to -0.02)
	YLLs	All ages Number	2283947.71 (2154600.77 to 2464135.4)	907013.2 (842426.51 to 985770.23)	1376934.51 (1279715.92 to 1509909.02)	3284815.62 (3087688.89 to 3503551.59)	1356656.1 (1246378.42 to 1447497.06)	1928159.51 (1813742.63 to 2073622.51)	0.44 (0.3 to 0.54)	0.5 (0.33 to 0.64)	0.4 (0.27 to 0.53)
		Age-standardized Rate	8598.35 (8057.33 to 9234.73)	7352.85 (6752.36 to 7979.99)	9693.0 (9010.25 to 10532.57)	4651.88 (4335.34 to 4928.81)	4049.92 (3688.25 to 4316.9)	5265.72 (4942.26 to 5625.94)	-0.46 (-0.51 to -0.42)	-0.45 (-0.51 to -0.4)	-0.46 (-0.51 to -0.41)
	Prevalence	All ages Number	2648751.07 (2459866.75 to 2840026.84)	1165432.31 (1087832.36 to 1243382.63)	1483318.76 (1372832.21 to 1599088.92)	6765927.27 (6363046.25 to 7168742.45)	3072779.02 (2884235.99 to 3255642.78)	3693148.25 (3465142.9 to 3925652.62)	1.55 (1.49 to 1.61)	1.64 (1.57 to 1.7)	1.49 (1.42 to 1.55)
		Age-standardized Rate	9237.67 (8707.53 to 9754.99)	8546.88 (8078.07 to 9023.27)	9871.62 (9279.7 to 10473.31)	9117.99 (8588.81 to 9652.52)	8286.55 (7810.18 to 8753.92)	9961.92 (9369.65 to 10573.07)	-0.01 (-0.02 to -0.01)	-0.03 (-0.04 to -0.02)	0.01 (0.0 to 0.02)
	Incidence	All ages Number	337812.16 (305625.27 to 371699.08)	139180.33 (127768.06 to 151728.1)	198631.84 (177154.91 to 220837.29)	856813.1 (777244.64 to 940229.64)	367319.35 (336629.02 to 399359.21)	489493.75 (439423.37 to 541595.73)	1.54 (1.48 to 1.6)	1.64 (1.58 to 1.7)	1.46 (1.4 to 1.53)
		Age-standardized Rate	1271.1 (1150.81 to 1398.13)	1104.12 (1008.16 to 1204.0)	1427.49 (1281.73 to 1574.59)	1183.71 (1072.72 to 1298.04)	1033.66 (945.53 to 1124.43)	1334.91 (1199.49 to 1477.04)	-0.07 (-0.08 to -0.06)	-0.06 (-0.08 to -0.05)	-0.06 (-0.08 to -0.05)

Table 1 (continued)

Cause	Measure	Metric	Year						Annual rate of change (1990 to 2019)		
			1990			2019					
			Both	Women	Men	Both	Women	Men	Both	Women	Men
Diabetes mellitus	Deaths	All ages Number	2764.7 (2454.09 to 3140.5)	1472.58 (1210.19 to 1763.44)	1292.12 (1111.18 to 1518.31)	14738.27 (12478.54 to 15876.24)	7922.34 (5502.23 to 8793.22)	6815.93 (6161.56 to 7488.46)	4.33 (3.27 to 5.19)	4.38 (2.44 to 5.99)	4.27 (3.34 to 5.35)
		Age-standardized Rate	13.6 (11.8 to 15.64)	15.01 (11.9 to 18.12)	12.04 (10.24 to 14.28)	22.72 (19.06 to 24.54)	24.95 (17.79 to 27.8)	20.6 (18.49 to 22.68)	0.67 (0.33 to 0.98)	0.66 (0.06 to 1.25)	0.71 (0.39 to 1.06)
	DALYs	All ages Number	160375.6 (131622.55 to 194501.13)	78651.57 (64396.24 to 94967.09)	81724.02 (66085.92 to 100417.12)	760542.62 (613583.83 to 932942.81)	393388.23 (313632.14 to 484473.37)	367154.39 (296416.17 to 447858.8)	3.74 (3.32 to 4.05)	4.0 (3.34 to 4.48)	3.49 (3.08 to 3.86)
		Age-standardized Rate	565.89 (466.26 to 681.79)	583.33 (482.55 to 699.79)	547.36 (442.75 to 667.39)	1009.8 (821.64 to 1231.8)	1052.28 (845.48 to 1286.36)	967.47 (785.89 to 1176.5)	0.78 (0.61 to 0.91)	0.8 (0.52 to 1.03)	0.77 (0.6 to 0.92)
	YLDs	All ages Number	88595.18 (60785.33 to 121405.98)	41693.23 (28650.42 to 57042.75)	46901.95 (32032.19 to 64380.95)	456904.57 (313637.98 to 623429.01)	236268.74 (163087.12 to 321870.87)	220635.82 (151459.04 to 299684.51)	4.16 (3.98 to 4.36)	4.67 (4.45 to 4.92)	3.7 (3.51 to 3.92)
		Age-standardized Rate	302.77 (208.51 to 414.66)	297.03 (204.91 to 408.46)	308.15 (212.24 to 421.58)	583.38 (400.61 to 791.36)	603.9 (416.44 to 823.87)	562.72 (387.49 to 764.06)	0.93 (0.86 to 1.0)	1.03 (0.95 to 1.12)	0.83 (0.75 to 0.91)
	YLLs	All ages Number	71780.41 (64271.9 to 80743.96)	36958.34 (31450.27 to 43787.57)	34822.07 (30257.77 to 40778.01)	303638.05 (254938.55 to 325373.2)	157119.48 (106344.9 to 172978.01)	146518.57 (133693.68 to 159834.79)	3.23 (2.33 to 3.8)	3.25 (1.65 to 4.22)	3.21 (2.45 to 4.0)
		Age-standardized Rate	263.12 (233.6 to 297.94)	286.3 (237.72 to 343.31)	239.21 (205.93 to 281.28)	426.42 (356.13 to 457.61)	448.38 (306.01 to 495.66)	404.75 (369.3 to 442.65)	0.62 (0.29 to 0.88)	0.57 (-0.03 to 1.02)	0.69 (0.38 to 1.03)
	Prevalence	All ages Number	1065190.57 (955486.45 to 1179390.92)	503481.56 (450824.52 to 558066.82)	561709.02 (504068.65 to 624138.66)	5379253.31 (4859918.79 to 5910718.54)	2766481.0 (2493760.45 to 3055187.84)	2612772.31 (2355045.69 to 2870407.08)	4.05 (3.89 to 4.23)	4.49 (4.3 to 4.74)	3.65 (3.46 to 3.85)
		Age-standardized Rate	3485.12 (3142.16 to 3850.07)	3434.41 (3095.17 to 3792.93)	3531.22 (3189.38 to 3913.85)	6701.72 (6079.41 to 7360.76)	6935.61 (6288.43 to 7630.45)	6464.01 (5848.57 to 7072.43)	0.92 (0.86 to 0.99)	1.02 (0.94 to 1.11)	0.83 (0.76 to 0.91)
	Incidence	All ages Number	65469.24 (59664.61 to 72216.7)	30792.72 (27918.16 to 33949.34)	34676.52 (31591.8 to 38307.87)	300262.18 (273940.59 to 328969.01)	155075.57 (141270.5 to 170683.61)	145186.61 (132384.28 to 158545.23)	3.59 (3.39 to 3.81)	4.04 (3.79 to 4.32)	3.19 (2.98 to 3.41)
		Age-standardized Rate	176.31 (161.04 to 194.15)	171.81 (155.93 to 189.01)	179.77 (164.21 to 198.52)	334.29 (306.82 to 364.97)	348.88 (319.16 to 382.64)	319.69 (293.27 to 348.94)	0.9 (0.83 to 0.97)	1.03 (0.95 to 1.13)	0.78 (0.71 to 0.86)

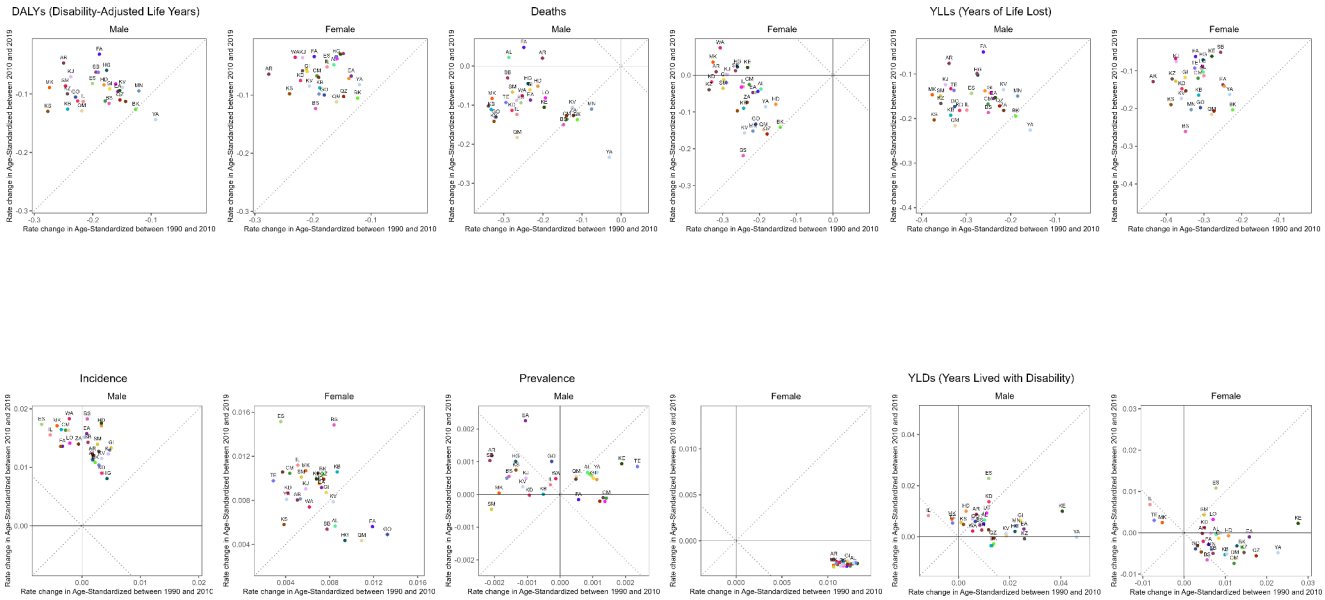

Fig. 1 Rate of change in age-standardized rate of deaths, disability-adjusted life years (DALYs), years of life lost (YLLs), years lived with disability (YLDs), prevalence, and incidence of non-communicable diseases among men and women in 1990–2010 and 2010–2019 in Iran

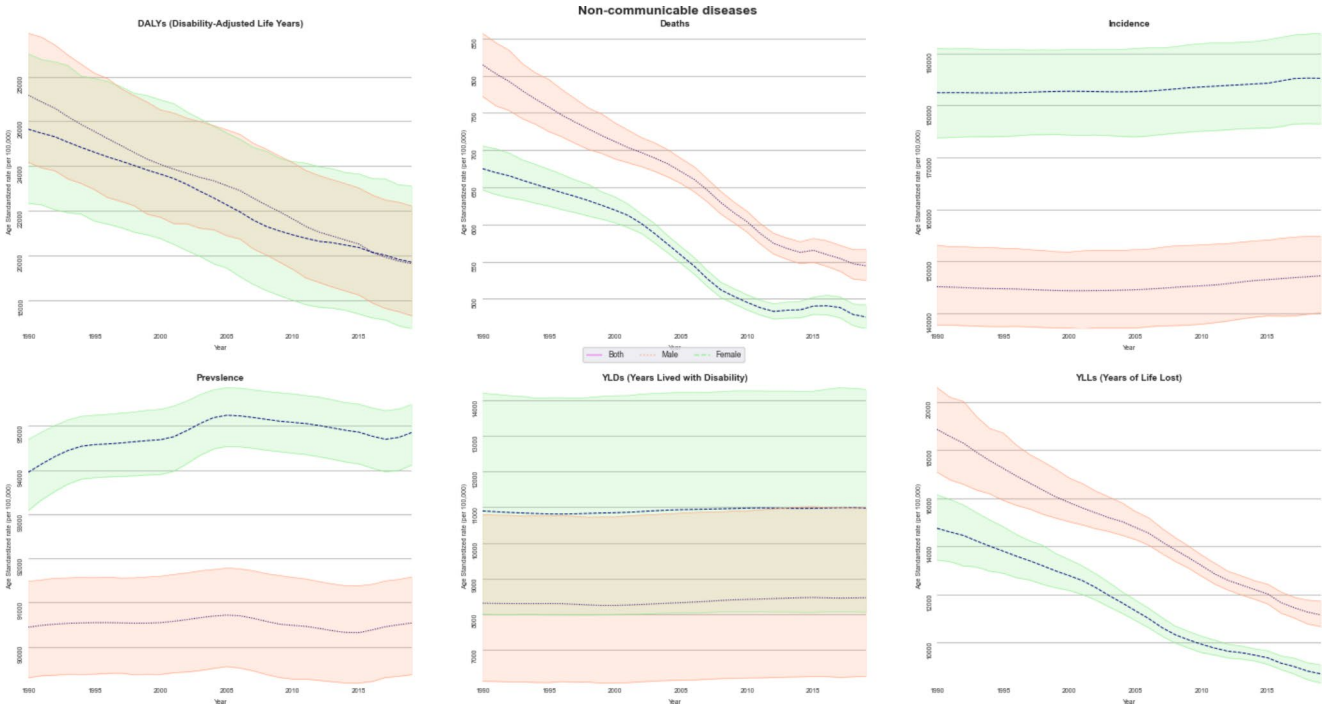

Fig. 2 Time trend of age-standardized rate of deaths, disability-adjusted life years (DALYs), years of life lost (YLLs), years lived with disability (YLDs), prevalence, and incidence of non-communicable diseases by sex in from 1990 to 2019 in Iran

DALYs than men due to their higher YLDs, along with narrowed gaps in YLLs in the mentioned age group. Generally, the gap between men and women is more comprehensive in younger age groups and diminishes in older age groups. No general pattern regarding sex gaps was related to 1990 or 2019. NCDs deaths were higher for men in all age groups in 1990 and 2019, except for the 10–14 and 80 + age groups in 2019 (Fig. 3).

Concerning neoplasms and CRDs, men had a higher rate of burden indices in 1990 and 2019, except for YLDs of CRDs in 2019. In terms of CVDs and DM, the gap between men and women started to narrow in the middle age group, and women took over men in older age groups. Eventually,

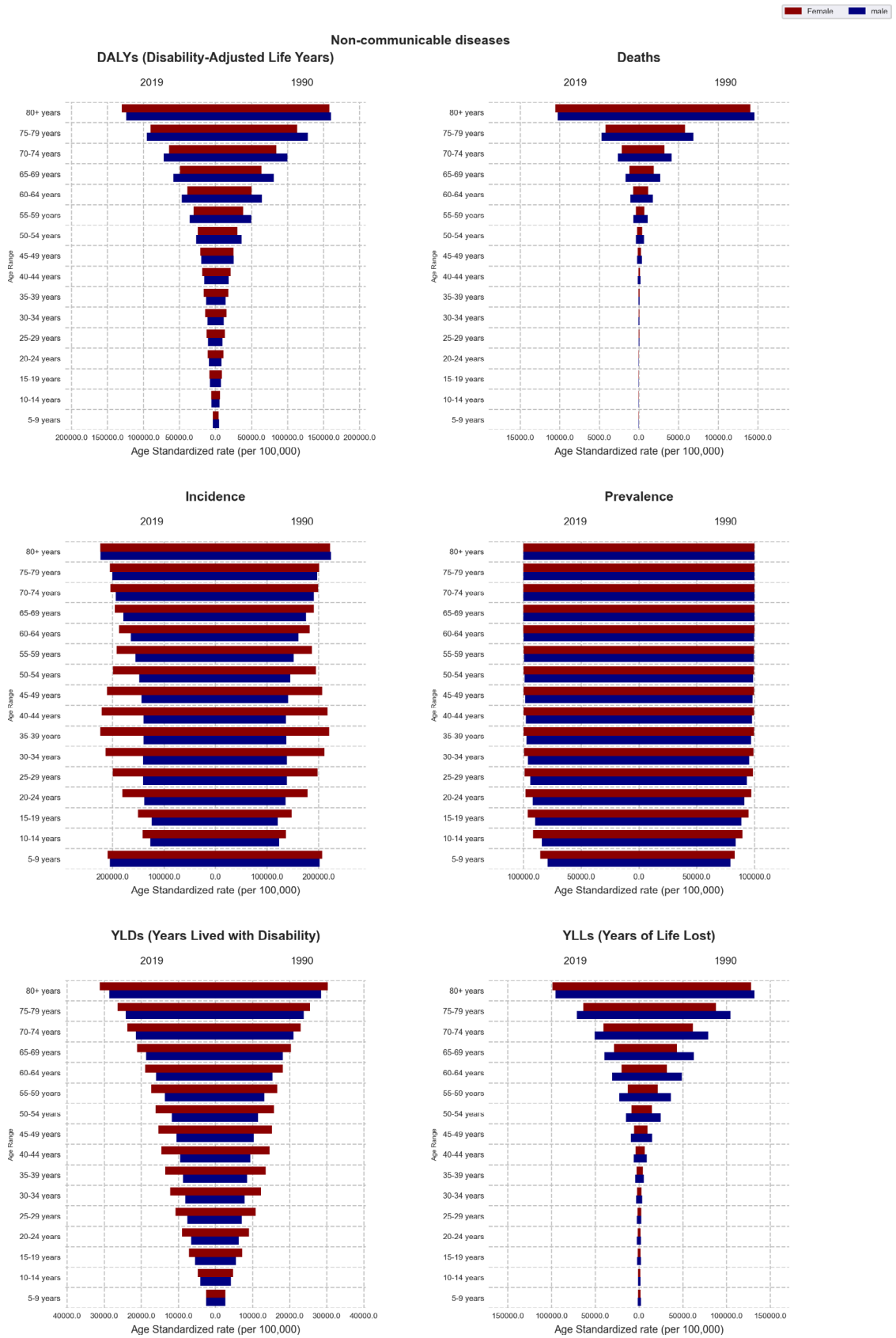

Fig. 3 Rate of deaths, disability-adjusted life years (DALYs), years of life lost (YLLs), years lived with disability (YLDs), prevalence, and incidence of non-communicable disease by age and sex in 1990 and 2019 in Iran

the sex gap widens, which was more noticeable in 2019 (Figure S9, S10, S11, and S12).

Incidence and prevalence of NCDs were consistently higher among women except for incidence in the 80 + age group in 1990 (Fig. 3). Moreover, incidence and prevalence of CVDs and neoplasms were consistently greater among men in all age groups except for 5–9 and 10–14 in 1990 and 5–9 years in 2019. Sex differences in CRDs and DM patterns were heterogeneous. Regarding Neoplasms, men outnumbered women in the 50–54 age groups, and this trend persists in older age groups (Figure S9, S10, S11, and S12).

SDI

In 2019, similar incidence, prevalence, deaths, DAYLs, YLDs, and YLLs regarding NCDs and their subgroups were observed in countries with different SDI levels (Fig. 4). For example, in 2019, both Fars (1137.2 [1034.3 to 1250.6]), a high SDI province and Sistan and Baluchistan (1147.5 [1037.1 to 1269.7]), a low SDI province, showed comparable CVD incidence rates. In contrast, Chahar Mahaal and Bakhtiari (1934.8 [1656.9 to 2285.5]) and West Azerbaijan (3060 [2631.9 to 3463]) with similar SDI levels (low SDI) were far from each other in ASR-DALYs attributed to neoplasms (Figure S13, S14, S15, and S16).

NCDs subgroups

Neoplasms

The ASIR of neoplasms increased by 1% (0–1%) among men and women in 2019, reaching 6454.8 (5282.1 to 7917.8) and 5895.4 (4820.3 to 7191.7), respectively. As of 2019, ASR-DALYs of men with neoplasms decreased by 12% (-22–9%) and reached 2632.5 (2353.6 to 2885.9). Conversely, women's ASR-DALYs decreased by -10% (-20–3%) and went to 2013.8 (1849.4 to 2160) (Table 1).

In 2019, men had a higher incidence of neoplasms in all provinces. The highest and lowest MWR were observed in Lorestan (1.1) and Tehran (1.09). The most significant increase in ASIR during 1990–2019 among men and women was observed in Qazvin (1.2% [0.6–2%]) and Yazd (0.9% [0.3–1.7%]), respectively (Table S1).

In 2019, men had higher DALYs of neoplasms in all provinces. MWR ranged from 1.74 in Lorestan to 1 in Tehran. The largest increase in ASR-DALYs during 1990–2019 among men and women was observed in Qazvin (12.4% [-15.3–56.2%]) and Sistan and Baluchistan (11% [-21.9–68.2%]), respectively (Table S1).

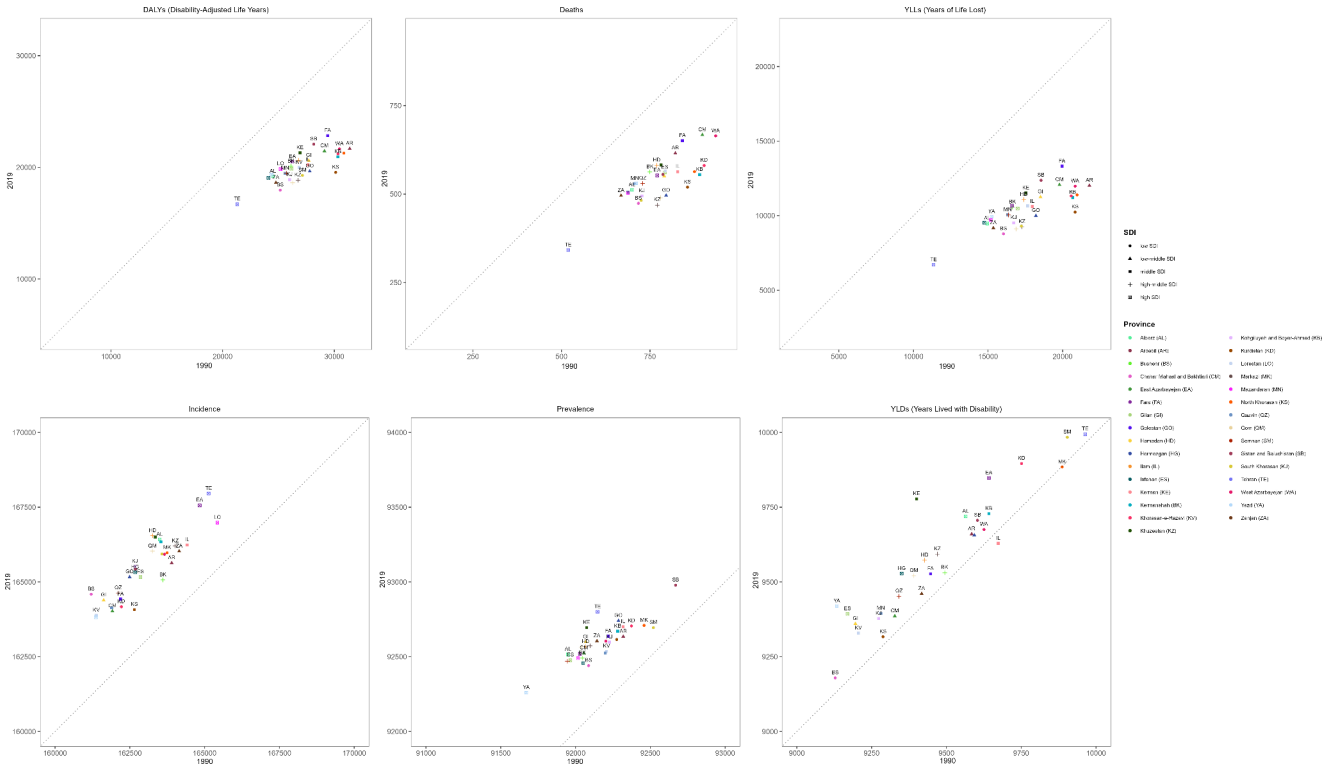

Fig. 4 Age-standardized rate of deaths, disability-adjusted life years (DALYs), years of life lost (YLLs), years lived with disability (YLDs), prevalence, and incidence of non-communicable disease by sociodemographic index (SDI) quintiles among both sexes in 1990 and 2019 in Iran

CRDs

The ASIR of CRDs decreased by 3% in 2019 (-6–1%) among men, reaching 948 (805 to 1112.1). Conversely, ASIR among women dropped by 1% (-4–2%) and reached 915.4 (797.9 to 1063.5). ASR-DALYs of CRDs declined by 28% (-40% to -20%) among men and amounted to 898.61 (801.8 to 997.8) in 2019. Conversely, women's ASR-DALYs decreased by -29% (-40% to -10%) and stood at 690.45 (600.6 to 784.4) (Table 1).

In 2019, men had a higher incidence of CRDs in all provinces except North Khorasan. MWR ranged from 1.07 in South Khorasan to 1 in North Khorasan. The greatest decrease in ASIR during 1990–2019 among men and women was observed in Sistan and Baluchistan by -9.6% (-15.6% to -3.9%) and − 7.8% (-12.6% to -2.1%), respectively (Table S1).

In 2019, men had a higher DALYs of CRDs in all provinces. MWR ranged from 1.58 in Qazvin to 1.13 in North Khorasan. The largest decrease in ASR-DALYs during 1990–2019 among men and women was observed in Sistan and Baluchistan by 42% (-57.3% to -14.4%) and 42.2% (-57.8% to -17.4%), respectively (Table S1).

CVDs

In 2019, the ASIR of CVDs decreased by 6% (-8% to -5%) for men and women, reaching 1334.9 (1199.5 to 1477) and 1033.7 (945.5 to 1124.4), respectively. In 2019, the ASR-DALYs of CVDs decreased by 44% (-49% to -39%) among men and reached 5683.6 (5331.3 to 6069.6). Conversely, women's ASR-DALYs dropped by -43% (-49% to -37%) and fell to 4483.1 (4116.3 to 4796.4) (Table 1).

In 2019, men had a higher incidence of CVDs in all provinces. MWR ranged from 1.33 in Yazd to 1.24 in Fars. The greatest decrease in ASIR during 1990–2019 among men and women was observed in Khorasan-e-Razavi by -11.8% (-16.2% to -7%) and − 11.1% (-14.5% to -7%), respectively (Table S1).

In 2019, men had a higher DALYs of CVDs in all provinces. MWR ranged from 1.76 in Lorestan to 1.03 in Qom. The highest decrease in ASR-DALYs during 1990–2019 among men and women was observed in Kerman (-50.7% [-61.9% to -35.9%]) and Chahar Mahaal and Bakhtiari (-48.7% [-60.7% to -32.6%]), respectively (Table S1).

DM

ASIR of DM increased by 78% (71–86%) among men and reached 319.7 (293.3 to 348.9) in 2019. Conversely, ASIR among women increased by 103% (95–113%) and grew to 348.9 (319.5 to 382.6). ASR-DALYs of DM grew by 77% (60–92%) among men and reached 967.5 (785.9 to 1176.5) in 2019. Conversely, women's ASR-DALYs increased by 80% (52–103%) and amounted to 1052.3 (845.5 to 1286.4) (Table 1).

In 2019, women had a higher incidence of DM in the majority of provinces. MWR ranged from 1.09 in Khorasan-e-Razavi to 0.83 in South Khorasan. The highest increase in ASIR during 1990–2019 among men and women was observed in Gilan at 121.9% (103.1–143%) and 166.9% (142–195%), respectively (Table S1).

In 2019, women had a higher DALYs of DM in the majority of provinces. MWR ranged from 1.16 in Chahar Mahaal and Bakhtiari to 0.83 in Mazandaran. The highest increase in ASR-DALYs during 1990–2019 among men and women was observed in Gilan at 144.7% (113.2–184.5%) and 194.4% (88–252%), respectively (Table S1).

MIR

Age-standardized rates of MIR for NCDs and their subgroups declined between 1990 and 2019. However, women consistently have higher rates of CVDs (0.39 in 1990 and 0.26 in 2019) and DM (0.87 in 1990 and 0.07 in 2019). Table S2 provides year-by-year estimates of the age-standardized rate of MIR for NCDs and their subgroups.

Other burden measures of NCDs subgroups at national and subnational levels are presented in Table 1 and Table S1, respectively. Generally, except for DM, whose burden measures were higher in women, men have higher values than women. Compared to 1990, the sex gaps in NCDs subgroups are shrinking. Despite this, the sex gap in DM is widening in 2019. This indicates that this subgroup is mainly responsible for the overall sex gap in NCDs.

Discussion

In this study, the state of sex disparities in NCDs in Iran over the past three decades was comprehensively assessed. CRDs, CVDs, DM, and neoplasms comprise the majority of NCDs in Iran and are associated with considerable sexual disparities, which can negatively affect morbidity and mortality rates. Several studies indicate that these disparities are driven by biological, socioeconomic, education level, and cultural factors that have an impact on disease outcomes differently for men and women [1, 18].

Our study highlighted significant sex-based differences in the burden of NCDs in Iran. Among NCDs in 2019, fatal estimates (deaths and YLLs) were higher for men, while non-fatal estimates (incidence, prevalence, YLDs) were higher for women. DALYs, a measure of both estimates, are higher in women, resulting in a higher YLDs to YLLs ratio.

Our findings are consistent with the Ravansar Cohort study, which reported a higher prevalence of NCDs in women than in men, except for kidney stones [19].

In terms of NCD subgroups, men were superior in all burden indices except for DM and YLDs in CVDs. These findings were in line with the higher prevalence of diabetes among women in the Shahrekord Cohort study and the higher prevalence of CVDs and kidney stones in men [20].

Similar to our findings, there is an increasing trend in NCD risk factors, particularly highlighting that men are at greater risk due to the high burden of risk factors and hazardous exposures. By 2030, there is expected to be a significant increase in mortality rates, especially among men, due to increased exposure to behavioral risk factors [21, 22]. Moreover, higher mortality rates among men are attributed to the life expectancy gap [3].

In contrast, Rafsanjan Cohort study revealed that women were more likely to have cardiometabolic risk factors, including body mass index (BMI), low-density lipoprotein, and total cholesterol. However, self-reported myocardial infarctions (MIs) and cardiac disease were significantly higher in men [23]. It is possible that this state of high-risk exposure could be compensated for by the presence of sex hormones or overshadowed by the high prevalence of other risk factors among men.

There are significant differences in the burden of cancer among women and men in Iran. It is evident that both the onset and outcomes associated with these conditions are more severe in men. The findings of our study are consistent with the findings of the U.S. pan-cancer study, which also showed higher occurrence and deteriorating survival rates for men [24]. Additionally, almost all non-sex-specific cancers are reported to have lower mortality rates among women than among men [25].

Excluding sex-specific cancers, men are more than twice as likely to suffer from most cancers than women at shared anatomic sites [26]. This disparity has been attributed to differences in occupational exposures, smoking, drinking, diet, health care access, and cancer screening [27, 28]. It is noteworthy that carcinogenic exposures differ between the sexes, but their impact on men's predominance was modest (11.2–49.5%). Therefore, our collective priority should be on examining how sex-related biological mechanisms may play a major role in gender variations in risk of cancer rather than variations in carcinogenic exposures [6]. Progesterone and estrogen levels differ in women, contributing to lower cancer rates [29, 30]. Conversely, men with high testosterone levels may be at a higher risk for liver, prostate, and skin cancer due to its ability to promote cell growth [31, 32].

Women's adaptive and innate immune responses may reduce their cancer risk. Women's immune systems can better fight infections caused by oncogenic agents such as hepatitis B and C viruses and human papillomaviruses [33]. Different genes on the X-chromosome related to immunity and tumor suppression may explain sex differences in cancer risk [29]. Also, the loss of the Y-chromosome in men and epigenetic inactivation of X-chromosome genes contribute to gender disparities [30, 34].

Among Iranian men, CVDs remain the leading cause of death. Our findings are consistent with the higher prevalence of coronary heart disease among men in Tehran compared to women, particularly pronounced in patients with diabetes [35]. This is also aligns with higher CVDs mortality rates among men in Tehran lipid and glucose study, especially in those over 50 years of age [2].

Smoking and high-cholesterol diets contribute to CVDs in men at a young age. Furthermore, the metabolism of men undergoes unfavorable changes during their early adulthood, setting the stage for premature CVDs among them [5]. Women, however, often show atypical symptoms, leading to underdiagnosis or delayed treatment, which complicates outcomes [18]. The Hoveyzeh Cohort Study reported that diabetes and hypertension exhibited a higher correlation with CVDs in men than in women [36]. This is echoed by a disproportionate rise in ischemic heart disease rates among men if current trends continue [37].

Nevertheless, the sex gap between men and women is narrowing, especially among women who have reached menopause. Isfahan Cohort study reported that the 10-year difference in CVDs incidence between men and women has decreased [38]. Accordingly, CVDs prevalence is higher among women in older age groups, which is consistent with a higher stroke prevalence among Iranian women than men as a result of their longer life expectancy [39].

CVDs morbidity and mortality are substantially influenced by hypertension [40, 41]. Women are less likely to have hypertension and high blood pressure (BP) than men of similar age at a young age [42]. However, the sex gap narrows as one age, with both sexes showing almost similar prevalence rates between 65 and 84 years of age [43]. This is consistent with the narrowed sex gap in CVD burden as a result of aging in our study.

At an older age, women with hypertension are more likely to develop heart failure than men [42, 44]. women with hypertension had a 50% and 36% higher probability of suffering a MI and stroke, respectively, compared to men [45, 46]. Furthermore, studies revealed that women with hypertension have an excess risk of 7% of stroke and an excess risk of 27% in MI [47, 48].

The relationship between obesity and BP is stronger in women. Thus, women with a similar BMI increase have a greater systolic BP [11]. Moreover, compared to men, women showed a steeper increase in BP measures that were initiated in the third decade and persisted throughout life

[49]. The early onset and elevated BP profile coupled with higher BMI exposure in women contribute to the more severe manifestations of hypertension on CVDs in women than men [5, 45].

Iranian women are more likely to develop diabetes and die from it, due to a variety of factors. According to the STEPwise Approach to NCD Risk Factor Surveillance (STEPS), 41% and 57% of men and women had low physical activity, respectively. Furthermore, a significant difference ($p < 0.001$) was observed between obesity prevalence among men (15.3%) and women (29.8%) [50]. A higher proportion of fat and less muscle tissue contributes to obesity in women. Furthermore, hormones during puberty, contraceptives, pregnancy weight gain, hormonal disorders during menopause, and inactivity can contribute to obesity [51]. Obesity can have extensive effects on women's reproductive system, especially on gestational diabetes [52].

As a consequence, gestational diabetes is associated with a higher incidence of diabetes among women, illustrating the importance of providing high-quality prenatal care to detect and manage gestational diabetes during pregnancy [53]. Based on these risk factors, diabetes is projected to increase by 11.2% and 9.5% in women and men, respectively, in 2030 [4].

The burden of CRDs is higher among Iranian men. However, women often experience more severe outcomes due to later diagnoses and less aggressive treatment approaches [54]. This study showed that men had a higher burden of CRDs than women, in accordance with the worldwide trend [55]. However, this finding contrasts with the higher prevalence of CRDs among women in the Azar [56] and Hoveyzeh [36] Cohort studies.

Globally, smoking was the primary risk factor for CRD-related disability for men [55]. The STEPS [57] and Hoveyzeh [36] studies reported that in terms of smoking prevalence, men and women have a huge discrepancy with men smoking about 6 times more than women. Moreover, due to differences in job distribution, men are more exposed to occupational pollutants [57]. The Rafsanjan Cohort study indicated that more than 16% of its participants (33.47%), mostly men, are pistachio farmers or copper miners, likely to be exposed to toxic chemicals or dust. Although both groups have healthy lipid profiles, their BP is higher than in other occupations. Consequently increasing their risk of CVDs and CRDs [23].

Globally, chronic obstructive pulmonary disease (COPD) remains the most prevalent CRDs among men and women [55]. Evidently, it is now more common among women than men to die from COPD; for instance, COPD-related deaths among American women outnumber those of men [58, 59]. As smoking patterns evolve and women take on traditionally male occupations, COPD prevalence in women is on the rise [60]. Women are exposed to toxic substances for longer periods due to dissimilar metabolisms of tobacco components [59]. Moreover, CRDs are prevalent among women due to household air pollution resulting from the indoor combustion of solid fuels [57].

CRDs are more common among women than men in older age groups because of menopause-associated alveolar loss [61]. Furthermore, The physiology of women makes them more vulnerable to lung function decline when adjusted for the number of cigarettes smoked [62]. It is also known that men and women react differently to nicotine and the sensory effects of smoking. Therefore, nicotine patches are more effective in quitting smoking in men than in women [63].

In analyzing the NCDs subgroups, it is essential to consider the co-existence of NCDs, also called multimorbidity [64]. A significant proportion of NCDs mortality can be attributed to their multimorbidity in the eastern Mediterranean region [65], and this phenomenon affects more than half of adults with NCDs [66].

In the Persian cohort study, multimorbidity prevalence was higher in women (39.1%) than men (24.9%) [20]. Furthermore, women are at higher risk of multimorbidity (OR = 1.49) in the Kurdish population [67]. In the Golestan cohort study, multimorbidity prevalence was 19.4%, with CVDs (72.7%), diabetes (25.3%), and COPD (21.9%) being the most common diseases [10]. Women were 2.11-fold more likely to have multimorbidity than men [10]. The high prevalence of multimorbidity in these studies further confirms the high prevalence of NCDs among women in our study.

Genetic, hormonal, behavioral, and social factors may explain concurrent morbid conditions. Different sexes have also been cited for health-seeking behaviors [3]. In addition, women are more likely to mention their conditions in self-reports [68]. A higher prevalence of hypertension, obesity, and physical inactivity makes women more likely to suffer from multimorbidity [64]. Also, due to their longer life expectancy and greater hazardous exposure, women will suffer greater losses due to longer exposure to risk factors [10, 69].

This study underscores the significant sex disparities in the burden of NCDs in Iran, noting that men generally face higher mortality rates while women experience higher prevalence and disability from these conditions. These findings emphasize the critical need for sex-sensitive health interventions and policies that address disease outcomes for men and women. Improving healthcare access, promoting preventive measures, and ensuring representation of women in health research and policymaking are essential steps towards reducing these disparities and enhancing overall health equity.

Addressing sex disparities in NCDs in Iran requires specific, culturally tailored strategies that consider the unique socio-political and economic landscape of the country. Iranian women are faced with distinct challenges that affect their health outcomes, including cultural norms, legal restrictions, and varying levels of access to healthcare and education. There is a need to adopt a multifaceted approach incorporating policy reform, community engagement, and health system improvement to address these disparities effectively.

Our study comprehensively assessed NCD health outcomes through a sex lens, arguing against the current established indicators of progress that have primarily focused on burden over the last three decades. There are several limitations associated with the use of GBD data. In particular, the estimates are predominantly based on models, which are relied upon when highly accurate, comprehensive, and medically certified vital registration systems are not available [13]. As a result, the quality of estimates regarding death rates and other vital statistics is significantly compromised. The GBD study employs 95% UIs to address this limitation. These UIs use the best available information on causes of death, population, and life expectancy, allowing the GBD to make more accurate estimates of death and disability burden.

Conclusion

Our study highlighted significant sex-based differences in the burden of NCDs in Iran. Compared to 1990, the sex gaps in NCD subgroups are shrinking. Despite this, the sex gap in DM is widening in 2019, indicating that this subgroup is primarily responsible for the overall sex gap in NCDs. To achieve equitable improvement in NCD morbidity and mortality globally, it is imperative to identify and address sex differences in populations for targeted interventions.

Considering sex intersections with other sociodemographic health factors is crucial for formulating effective interventions. Additionally, the focus should be on morbidity rather than merely on mortality, as concentrating only on mortality may obscure the impact of NCDs on women. It is imperative to enhance the quality of research on NCDs by increasing the number of women participating in research and empowering more women in leadership roles. This approach ensures that policies, agendas, and research projects are more representative of women's concerns.

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Data availability The data supporting this study's findings are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate The proposal of the current study was approved by the Research Ethics Committee of Endocrinology and Metabolism Research Institute, Tehran University of Medical Sciences, Tehran, Iran (IR.TUMS.EMRI.REC.1402.059).

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