Journal of Biostatistics and Epidemiology

J Biostat Epidemiol. 2023;9(3):312-324

Original Article

Geographical Disparities in Hypertension Incidence Rate in Iran 2004-2016: Bayesian Spatial Analysis

Roghaye Zare[1], Erfan Ghasemi[2], Shirin Djalalinia[3,4], Masoud Alimardi[1], Moein Yoosefi[5], Abbas Rahimi-Foroushani[1*]

[1]Department of Epidemiology and Biostatistics, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran.
[2]Non-Communicable Diseases Research Center, Endocrinology and Metabolism Population Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran.
[3]Development of Research and Technology Center, Deputy of Research and Technology Ministry of Health and Medical Education, Tehran, Iran.
[4]Non-Communicable Diseases Research Center, Endocrinology and Metabolism Population Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran.
[5]Department of Mathematics and Statistics, Memorial University of Newfoundland, NL, Canada.

ARTICLE INFO

Received 09.02.2023
Revised 28.02.2023
Accepted 04.04.2023
Published 15.09.2023

Key words:
Hypertension;
Incidence rate;
Bayesian spatial analysis.

ABSTRACT

Introduction: Cardiovascular diseases such as coronary heart disease, heart failure, arrhythmia, and cardiomyopathy all include hypertension as a key risk factor. Research has shown that the early detection and treatment of hypertension and its risk factors, as well as public health policies to reduce behavioral risk factors, have led to a gradual reduction in mortality caused by heart disease and stroke in high-income countries in the past three decades. Trends in hypertension incidence have been monitored at the national level in Iran. The aim of this study examine province-level disparities in Hypertension incidence from 2004 to 2016.

Methods: Use the Non-Communicable Diseases Risk-Factors Surveillance in the Islamic Republic of Iran STEPs registry data. to estimate the incidence rate of hypertension for all provinces in 2004, 2006-2009, 2011, and 2016 using a Bayesian spatial model with Markov chain Monte Carlo algorithm in OpenBUGS version 3.2.3 and R version 4.2.2.

Results: The estimated Hypertension incidence rate in total increased from 19.87 per 1000 people (95% credible interval 14.28, 25.48) in 2004 to 193.02 (171.92, 220.48) in 2016. According to the estimates of 2016, we found that the provinces of Markazi, Ardabil, and Semnan had the highest rate of hypertension, and the provinces of Hormozgan, and Sistan-Baluchistan had the lowest rate. Our findings show that Khorasan, North, Alborz, and Semnan have the most significant percentage change in incidence rate from 2004-2016.

Conclusion: To reduce the prevalence of hypertension in Iranian regions, it is crucial to develop regular hypertension screening programs, especially among the elderly.

*.Corresponding Author: ahimifo@tums.ac.ir

Introduction

Non-Communicable Diseases (NCDs) are a growing concern worldwide, accounting for approximately 71% of all deaths globally. In low- and middle-income countries (LMICs), NCDs represent a significant health issue, with around 85% of NCDs and 78% of related deaths occurring in these regions. Among NCDs, cardiovascular diseases (CVDs) have the highest mortality rate globally and are a significant public health issue in LMICs.[1,2] One of the key risk factors for various CVDs is hypertension, which has become increasingly prevalent worldwide, especially in LMICs. Hypertension is a chronic medical condition characterized by elevated blood pressure levels, and if left untreated, can lead to significant health complications such as stroke, heart failure, and chronic kidney disease.[3]

Various risk factors contribute to the incidence of hypertension and CVDs, including smoking, excessive alcohol use, poor diet, physical inactivity, overweight and obesity, elevated blood sugar, and abnormal blood lipids. Addressing these risk factors through public health policies and interventions is essential to reduce the burden of hypertension and CVDs.[3]

In Iran, with its diverse population and varying lifestyles and socioeconomic statuses, hypertension has become a growing concern. The latest population census report in 2016 shows that 75% of the population lives in urban areas, which are associated with higher CVD risk factors such as hypertension.[4,5] Research has shown that the early detection and treatment of hypertension and its risk factors, as well as public health policies to reduce behavioral risk factors, have led to a gradual reduction in mortality caused by heart disease and stroke in high-income countries in the past three decades.[6]

As part of the National and Subnational Burden of Disease, Injuries, and Risk Factors (NASBOD) project in Iran,[7] we used Non-Communicable Diseases Risk-Factors Surveillance in the Islamic Republic of Iran STEPs registry data to assess levels of hypertension across the 31 Iranian provinces from 2004 to 2016. Our study employed Bayesian spatial analysis to explore the geographical disparities in the hypertension incidence rate in Iran.

By identifying areas with a higher incidence rate of hypertension, our study can help inform public health policies and interventions to reduce the burden of hypertension in Iran. Targeted screening programs, education and awareness campaigns, and interventions promoting healthy lifestyle behaviors can all help reduce hypertension incidence rates and improve cardiovascular health in the country.

Overall, our study highlights the importance of spatial analysis to identify geographical disparities in hypertension incidence rates. This analytical approach allows us to uncover spatial patterns and distributions of this health issue in Iran between 2004 and 2016. Such insights are crucial and can inform initiatives aimed at enhancing cardiovascular health not only in Iran but also in other low- and middle-income countries (LMICs).

Methods

Hypertension incidence data

Hypertension incidence data were collected between 2004 and 2016 by the Non-Communicable Diseases Risk-Factors Surveillance in the Islamic Republic of Iran

STEPs registry. The STEPS Noncommunicable Disease Risk Factors Survey uses a survey methodology developed by the World Health Organization (WHO) to help countries establish noncommunicable disease surveillance systems. Some surveys are conducted at the country level, and others at the subnational level. The methodology prescribes three steps-questionnaire, physical measurements, and biochemical measurements. Core topics covered by most surveys are demographics, health status, and health behaviors. The STEPS survey in Iran was a population-based survey of adults aged 15-64. A cluster sampling approach was employed to generate representative data within the specified age range in Iran,[8] with sampling weights meticulously calculated to account for diverse factors. For an in-depth understanding of the study design, refer to the comprehensive study protocol.[9]

According to the steps study information, for people who were present in all three blood pressure measurements, the initial systolic and diastolic blood pressure values were discarded, and the average of the values measured in the second and third times as the systolic and diastolic blood pressure values in We comment. Although a person was not present on the third time of measurement, the importance of that person's first and second times will be used, and if a person was present only one time, we will use the values of the same time. After that, we consider people who have a systolic blood pressure of more than 140 and diastolic blood pressure of more than 90, or if the person has stated that he is taking blood pressure medicine, as a person with high blood pressure. After identifying the people with hypertension, we will calculate the number of these people, along with some other characteristics for each province separately. Finally, we have used the obtained data to fit the considered model.

Covariates

For each year and province, the following covariates were included: urbanization rate (URB), calculated as the proportion of the population living in urban areas divided by the total population, body mass index (BMI), and Age of people (AGE).

Statistical analysis

To analyze geographical inequalities, we estimated hypertension incidence for the 31 provinces and seven-years: 2004, 2006, 2007, 2008, 2009, 2011, and 2016. This research used a Bayesian Poisson spatial model with covariates, which prevented imbalanced estimates and produced reliable data for each province. By utilizing data from neighboring areas, spatial modeling enables estimation for regions with little.[10] Observed similarities between neighboring provinces and how stable or unreliable the estimated impacts are in each province determine how dependent estimations are on data for nearby provinces. Applying the Besag, York, and Mollie model, cross-province variance is empirically divided into a spatial component fitted using a conditional autoregressive prior, and a non-spatial component fitted using a prior with a Gaussian and gamma distribution.[11] In this study, based on previous studies designed to select the suitable gamma distribution,[12] we used 0.5 and 0.005 for spatially and non-spatially structured random effects.

$$Y_i \sim Poisson\left(E_i \lambda_i\right) \quad (1)$$

$$\log(\lambda_i) = \alpha + \beta_{Age} Age_i + \beta_{URB} URB_i + \beta_{BMI} BMI_i + U_i + \varepsilon_i \quad (2)$$

Let Y_i represent the number of individuals with high blood pressure in the i-th province. E_i denotes the expected value of high blood pressure cases in the *i*-th province. We estimated this value by utilizing the mean national rate for Iran in 2021 for each province and multiplying it by the sample size of each province.[13] The parameter λ_i represents the relative risk of high blood pressure in the *i*-th province, estimated through a hierarchical Bayesian model. The constant α is a fixed value, U_i is the spatially structured random term obtained from the Bayesian model in the i-th province, and ε_i represents the error term of the model.

Our model was fitted in open-source software OpenBUGS version 3.2.3 using the Markov chain Monte Carlo algorithm and R version 4.2.2. This made it possible for us to estimate incidence rates in each province by using data from the posterior distribution of the model parameters in each province, including the 2.5th and 97.5th percentiles of this distribution as estimates of the lower and upper bounds of credible intervals (CrI), respectively.

A credible interval is an interval within which an unobserved parameter value falls with a particular probability. It is an interval in the domain of a posterior probability distribution or a predictive distribution.[14]

Table1. Frequency and percentage of participants by gender, Residential area, and hypertension in each of the years and total

year	sex	n (%)	Residential area	n (%)	Hypertension Status	n (%)
2004	men	39369 (49.37)	urban	52003 (65.22)	No	78136(97.99)
	women	40367 (50.63)	rural	27733 (34.78)	Yes	1600(2.01)
2006	men	14524 (49.62)	urban	18184 (62.13)	No	28050(95.84)
	women	14745 (50.38)	rural	11085 (37.87)	Yes	1219(4.16)
2007	men	14519 (49.46)	urban	17344 (59.09)	No	24796(84.47)
	women	14835 (50.54)	rural	12010 (40.91)	Yes	4558(15.53)
2008	men	14218 (49.28)	urban	18626 (64.46)	No	24536(85.05)
	women	14631 (50.72)	rural	10223 (35.44)	Yes	4313(14.95)
2009	men	14373 (49.39)	urban	15847 (54.46)	No	25020(85.98)
	women	14727 (50.61)	rural	13253 (45.54)	Yes	4080(14.02)
2011	men	6837 (55.97)	urban	8203 (67.16)	No	10452(85.57)
	women	5378 (44.03)	rural	4012 (32.84)	Yes	1763(14.43)
2016	men	15900 (52.10)	urban	19133 (62.69)	No	24615(80.65)
	women	14619 (47.90)	rural	11386 (37.31)	Yes	5904(19.35)
Total	men	119740 (50.09)	urban	149340 (62.47)	No	215605(90.20)
	women	119302 (49.91)	rural	89702 (37.53)	Yes	23437(9.80)

Results

In the first phase, STEPS 2004 with 79736 participants, STEPS 2006 with 29269, STEPS 2007 with 29354, STEPS 2008 with 28849, STEPS 2009 with 29100, STEPS 2011 with 12215, and STEPS 2016 with 30519 were done. Province-year units summarized data for incidence. The Table1 shows the number of people by gender, Residential area, and hypertension status in each of the years under study.

We've calculated the residuals and conducted Moran's I test[15] to ensure there's no spatial autocorrelation among these residuals. The result of the Moran's I coefficient, which was close to zero, along with the associated p-value ($p>0.05$), suggests that there was no spatial autocorrelation detected. The inclusion of the three covariates leads to improved model specification according to the Deviance Information Criterion.[10, 16]

Table 2 indicates that, in 2016, no information is available from Qom province, considering this point, it can be seen that the density of the incidence rate for hypertension is located in the center of the country in provinces such as Markazi (Hypertension incidence rate, [(95% CrI)]) (238.93, [191.07-292.86]), Ardabil (236.88, [185.40-293.75]), and Semnan (236.67, [186.47-294.59]), while this density is much lower in the south and southeast. The provinces of Sistan and Baluchistan (157.48, [123.54-194.93]), and Hormozgan (157.82, [119.30-200.00]) have the lowest rates.

According to the data from 2011, the information of Alborz province is also available, according to this information, it can be seen that Sistan and Baluchistan province (89.67, [55.26-128.34]) has the lowest incidence of hypertension, while the semi-western provinces such as Lorestan (190.21, [126.22-261.22]) have the highest incidence this year. After that, we can mention the provinces of Gilan (189, [121.74-265.48]), and Ardabil (186.59, [115.43-267.69]).

Provinces with the greatest hypertension rates were Sistan-Baluchistan (175.91, [135.18-222.58]), Khorasan, South (173.3, [139.90-209.48]), and Kerman (165.4, [133.13-199.48]). Meanwhile, Kordestan (109.2, [84.89-134.97]), Ardabil (120.39, [92.69-149.95]), and Isfahan (120.91, [93.87-149.49]) the lowest rate in 2009.

in 2008, the prevalence of blood pressure is high in the rest of the country, except in the northwest and southwest, so the provinces of Gilan (187.72, [152.28-228.93]), Tehran (165.40, [132.96,20-199.69]), and Qom (163.05, [133.64-197.63]) have the highest rate and Hamadan (105.23, [78.19-134.36]), Lorestan (131.17, [101.76-160.27]), and Chahar Mahal and Bakhtiari (132.05, [102.10-161.93]) have the lowest rate.

The incidence rate for hypertension was highest in Yazd (191.15, [155.35-230.66]), Khorasan, South (184.00, [148.83-221.20]), and Gilan (177.09, [143.58-214.05]) in 2007. In contrast, Azerbaijan, West (128.80, [100.39-160.24]), Ilam (130.04, [100.85-161.00]), and Ardabil (133.63, [105.42-164.66]) were found to have the lowest rates in the same time.

According to the information related to 2006, it can be concluded that the incidence rate of hypertension is high in the southeastern part of the country, such as Kerman province (79.48, [56.35-104.65]), and the eastern and central provinces of the country such as Ilam (69.66, [48.01-93.97]) and Markazi (67.88, [(46.56-92.11]) province, while Golestan (11.88, [4.09-21.64]), Kermanshah (29.12, [16.26-44.72]),

Table 2. Hypertension incidence rates (per 1000) by province and year (with 95% CrI)

	Hypertension Incidence rate (95% CrI)						
	2004	2006	2007	2008	2009	2011	2016
Markazi	27.30 (20.02,35.68)	67.88 (46.56,92.11)	161.06 (129.25,193.78)	162.94 (132.44,196.92)	163.25 (131.07,197.56)	176.46 (113.92,248.23)	238.93 (191.07,292.86)
Gilan	26.78 (19.74,34.71)	60.80 (41.19,83.43)	177.09 (143.58,214.05)	187.72 (152.28,228.93)	148.05 (117.70,180.04)	189.00 (121.74,265.48)	220.12 (183.18,259.56)
Mazandaran	23.92 (15.82,32.96)	42.92 (26.94,62.18)	154.79 (124.12,187.79)	153.43 (125.08,187.31)	136.64 (109.01,167.91)	148.09 (107.35,195.25)	208.80 (176.56,242.60)
Azerbaijan, East	25.61 (18.59,33.53)	36.03 (21.34,53.86)	174.49 (140.95,211.01)	146.29 (116.49,177.32)	130.91 (101.11,162.53)	170.03 (129.29,215.22)	204.15 (173.75,235.64)
Azarbaijan, West	22.64 (14.81,31.37)	32.95 (18.37,50.64)	128.80 (100.39,160.24)	143.70 (114.67,173.97)	132.76 (104.08,163.47)	146.97 (103.14,195.09)	211.65 (177.39,248.70)
Kermanshah	11.24 (6.07,17.36)	29.12 (16.26,44.72)	148.42 (118.49,181.72)	153.31 (125.26,185.61)	127.51 (100.20,156.85)	153.40 (93.96,217.02)	193.01 (154.62,233.91)
Khuzestan	18.83 (15.07,22.68)	44.51 (27.38,63.89)	138.06 (108.30,168.52)	135.73 (108.40,165.69)	148.18 (118.32,180.16)	148.77 (112.88,189.00)	185.06 (157.99,213.78)
Fars	26.82 (17.87,36.54)	44.93 (28.68,63.78)	160.71 (129.59,194.08)	139.52 (109.65,171.27)	152.87 (119.60,185.61)	128.21 (94.71,165.14)	172.07 (147.03,197.85)
Kerman	26.78 (20.52,33.81)	79.48 (56.35,104.65)	163.46 (130.50,197.54)	157.79 (126.11,191.85)	165.43 (133.13,199.48)	114.46 (74.79,156.87)	192.00 (159.01,227.94)
Khorasan, Razavi	17.07 (11.46,23.23)	36.50 (21.67,54.47)	161.08 (129.07,195.12)	148.80 (119.29,178.83)	141.32 (111.46,173.50)	141.47 (110.01,174.04)	188.91 (165.01,213.96)
Isfahan	18.37 (11.34,26.17)	34.41 (19.50,50.65)	145.43 (115.04,176.42)	146.05 (116.92,175.38)	120.91 (93.87,149.49)	171.05 (129.92,215.96)	206.08 (179.47,233.63)
Sistan -Baluch-istan	19.90 (12.32,28.37)	33.84 (19.43,51.29)	143.58 (113.16,174.82)	151.32 (121.85,185.06)	175.12 (135.18,222.58)	89.67 (55.26,128.34)	157.48 (123.54,194.93)
Kordestan	13.47 (7.70,20.70)	30.69 (16.93,47.70)	144.64 (114.50,177.21)	143.77 (113.65,175.41)	109.17 (84.89,134.97)	164.79 (105.04,231.89)	213.96 (169.45,262.45)
Hamadan	18.62 (12.54,25.14)	47.32 (30.84,67.13)	148.67 (118.85,180.33)	105.23 (78.19,134.36)	145.03 (115.63,176.19)	140.73 (85.47,204.40)	179.32 (140.31,221.27)
Chahar Mahal and Bakhtiari	21.21 (13.84,29.83)	35.42 (20.51,53.31)	137.31 (108.05,168.30)	132.05 (102.10,161.93)	126.51 (98.00,158.01)	104.92 (58.33,154.17)	204.04 (165.27,248.80)
Lorestan	12.69 (7.23,19.60)	30.15 (16.65,46.81)	157.04 (123.61,194.12)	131.17 (101.76,160.27)	156.28 (125.64,189.99)	190.21 (126.22,261.22)	206.68 (165.40,251.75)
Ilam	19.16 (12.32,27.37)	69.66 (48.01,93.97)	130.04 (100.85,161.00)	158.56 (128.21,190.77)	141.15 (112.23,172.90)	129.14 (77.33,193.97)	188.61 (141.23,239.18)

	Hypertension Incidence rate (95% CrI)						
	2004	2006	2007	2008	2009	2011	2016
Kohgiluyeh and Boyer-Ahmad	22.16 (14.31,31.76)	35.63 (20.75,51.95)	157.91 (127.51,189.87)	149.38 (119.81,180.81)	131.02 (102.90,164.42)	139.75 (83.93,198.20)	168.63 (126.53,212.24)
Bushehr	30.70 (21.33,40.94)	41.79 (25.59,59.49)	162.45 (130.61,196.73)	140.92 (113.37,171.43)	153.46 (122.05,187.40)	130.04 (79.92,189.67)	160.02 (114.63,209.44)
Zanjan	24.27 (16.30,33.38)	35.62 (21.45,53.01)	166.87 (134.15,202.54)	138.92 (109.15,169.31)	122.70 (96.10,152.35)	144.30 (91.60,210.97)	162.64 (128.07,200.26)
Semnan	18.55 (11.34,26.22)	37.57 (23.49,56.10)	147.37 (115.55,178.68)	152.32 (117.04,186.19)	124.69 (97.23,155.25)	131.05 (76.03,189.32)	236.67 (186.47,294.59)
Yazd	18.57 (11.46,26.83)	33.32 (19.22,49.60)	191.15 (155.35,230.66)	154.72 (125.91,186.53)	148.37 (118.37,180.92)	158.75 (99.96,225.00)	215.54 (172.57,260.81)
Hormozgan	21.89 (13.89,30.66)	36.25 (21.30,52.78)	152.87 (122.18,185.01)	151.44 (120.72,182.47)	130.86 (102.86,160.49)	118.91 (71.43,176.47)	157.82 (119.30,200.00)
Tehran	9.67 (5.47,14.37)	56.91 (37.76,79.14)	175.64 (142.81,209.28)	165.40 (132.96,199.69)	133.57 (104.48,163.78)	132.54 (110.23,156.07)	178.34 (162.01,195.16)
Ardabil	20.16 (12.64,28.72)	48.04 (30.49,68.08)	133.63 (105.42,164.66)	149.95 (120.12,180.99)	120.39 (92.69,149.95)	186.59 (115.43,267.69)	236.88 (185.40,293.75)
Qom	9.69 (4.67,15.90)	31.86 (17.36,48.52)	159.24 (126.63,194.84)	163.05 (133.64,197.63)	132.25 (103.12,162.82)	160.56 (98.71,227.68)	-
Qazvin	15.98 (9.56,23.46)	30.39 (17.19,46.51)	160.08 (129.33,193.99)	156.02 (127.55,187.86)	141.98 (113.17,173.87)	125.57 (72.38,180.38)	171.81 (127.66,219.15)
Golestan	13.97 (8.20,21.25)	11.88 (4.09,21.64)	138.77 (108.92,170.26)	146.52 (117.69,176.89)	152.81 (121.55,184.47)	183.04 (135.18,237.63)	196.56 (156.95,240.66)
Khorasan, North	-	45.39 (27.78,64.70)	153.77 (124.61,189.04)	159.02 (127.70,190.56)	137.75 (108.58,169.70)	132.06 (68.35,196.13)	226.41 (181.25,278.28)
Khorasan, South	-	44.30 (27.78,65.93)	184.00 (148.83,221.20)	157.05 (126.56,189.63)	173.30 (139.90,209.48)	65.83 (82.95,207.24)	182.18 (140.02,227.27)
Alborz	-	-	-	-	-	122.96 (70.83,179.21)	214.98 (178.31,252.43)

- no data for these provinces these years

and Lorestan (30.15, [16.65-46.81]), provinces have the lowest.

Finally, according to the fact in 2004, there is no information about Alborz, North Khorasan, and South Khorasan provinces, so it can be said that Tehran (9.67, [5.47-14.37]), Qom (9.69, [4.67-15.90]), and Kermanshah (11.24, [6.07-17.36]) provinces have the lowest incidence rate and Bushehr (30.70, [21.33-40.94]), Markazi (27.30, [20.02-35.68]), and Fars (26.82, [17.87-36.54]) provinces have the highest hypertension incidence rate. According to Figure 1, you can see the difference in hypertension incidence rate by province level separately for each year.

One way to gain a more general understanding of the results is to compare the incidence rate

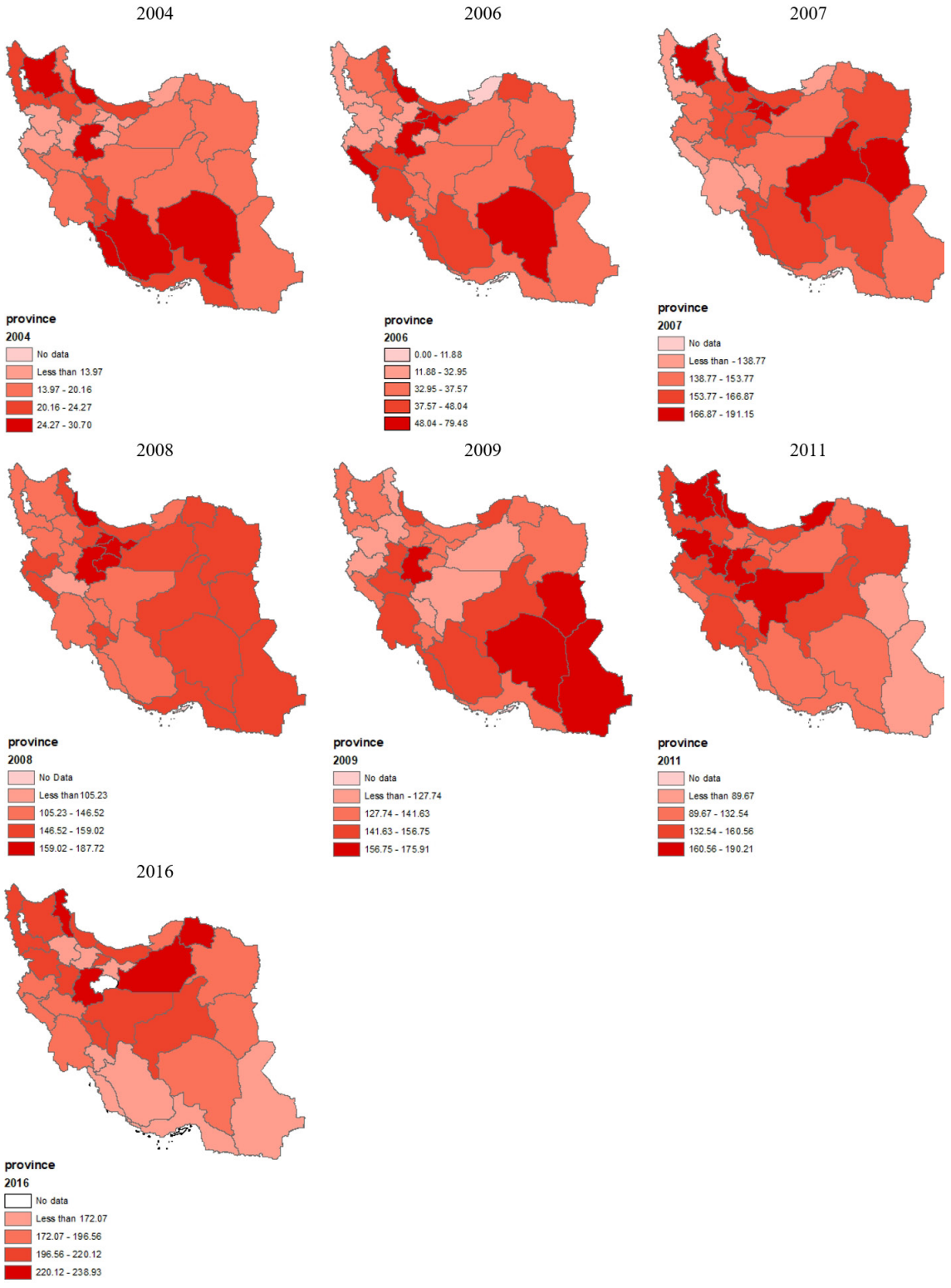

Figure 1. a. Map of hypertension incidence rate by province level for each year

of hypertension in the first and last year of the study. For instance, in 2016, the provinces of Markazi, Ardabil, and Semnan exhibited the highest incidence rates of hypertension, while Sistan-Baluchistan, Hormozgan, and Bushehr provinces displayed the lowest rates. However, in 2004, the scenario was different, with Bushehr, Markazi, and Gilan provinces experiencing the highest incidence rates of hypertension, while Tehran, Qom, and Kermanshah provinces recorded the lowest rates. This demonstrates a significant shift in the regional prevalence of hypertension over the years.

By presenting the data in this way, it becomes easier to identify trends and patterns in the incidence rate of hypertension across different regions and over time. It also highlights the need for targeted interventions to address the varying prevalence of hypertension in different regions of the country (Fig 1).

Figure 2 shows the general trend of observed and estimated hypertension at the national level between 2004 and 2016. The increase in the incidence rate of hypertension in recent years is visible.

Discussion

One of the most widespread preventable causes of death is hypertension, which is a significant public health issue on a global scale. The current study reports the incidence rate of hypertension in 31 provinces of Iran between 2004, 2006, 2007, 2008, 2009, 2011, and 2016. At the national level, a significant increase in the incidence rate has been observed (from 19.87 in 2004 to 193.02 in 2016 per 1000 person-years). According to the same study on Chinese adults, the incidence of hypertension (per 100 person-years) significantly increased from 2.9 in 1991–1997 to 5.3 in 2004–2009.[17] Also, in a cohort study in the UK from 1995-2015[18] hypertension increased from 0.93 cases

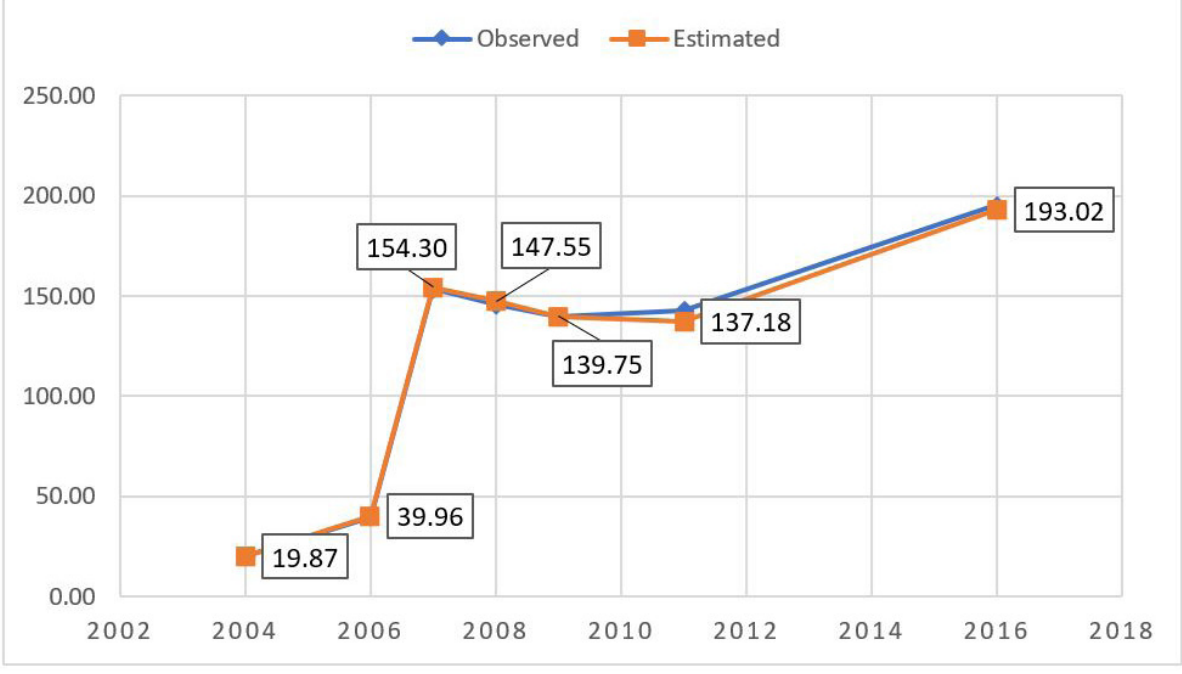

Figure 2. The trend of the observed and estimated incidence rate of hypertention between 2004-2016

per 100 person-years in 1996 to a peak level of 2.07 cases per 100 person-years (2.03 to 2.12) in 2004. Meanwhile, the Incidence rate then decreased to 0.42 cases per 100 person-years in 2015. In contrast, according to a study in the United States, the age-standardized prevalence of hypertension decreased from 48.4% in 1999-2000 to 45.4% in 2015-2016.[19]

According to the estimates of 2016, we found that the provinces of Markazi, Ardabil, and Semnan had the highest rate of hypertension, and the provinces of Sistan and Baluchistan, and Hormozgan had the lowest rate.

In 2016, compared to 2004, Kurdistan, Semnan, Lorestan, Yazd, and Ardabil provinces increased by more than 10 ranks in terms of blood pressure incidence compared to other provinces (Fig 3). This means that they performed

Rank increased	No change	Rank decreased	Non-information

Rank in 2004	Rank in 2016	prov	DIF
24	8	Kordestan	16
17	3	Semnan	14
25	11	Lorestan	14
18	6	Yazd	12
13	2	Ardabil	11
26	16	Kermanshah	10
20	12	Isfahan	8
23	15	Golestan	8
28	23	Tehran	5
21	18	Khorasan, Razavi	3
2	1	Markazi	1
9	9	Azarbaijan, West	0
3	5	Gilan	-2
8	10	Mazandaran	-2
12	14	Chahar Mahal and Bakhtiari	-2
19	22	Hamadan	-3
22	25	Qazvin	-3
15	19	Ilam	-4
16	20	Khuzestan	-4
6	13	Azerbaijan, East	-7
4	17	Kerman	-13
10	26	Kohgiluyeh and Boyer-Ahmad	-16
14	30	Sistan and Baluchistan	-16
11	29	Hormozgan	-18
5	24	Fars	-19
7	27	Zanjan	-20
1	28	Bushehr	-27
¬	4	Khorasan, North	
¬	7	Alborz	
¬	21	Khorasan, South	
27	¬	Qom	

¬ no data for these provinces these years

Figure 3. provinces are ranked based on incidence rates and changes in ranks for the years 2004 and 2016.

poorly in hypertension control and treatment. While the provinces of Bushehr, Zanjan, Fars, Hormozgan and Sistan, and Baluchistan have been relatively successful in controlling and treating hypertension and had a decrease of more than 10 ranks. Based on available studies,[20] findings showed that the highest and the lowest prevalence of hypertension were in East Azarbaijan, West Azarbaijan, Ardebil, Zanjan, Gilan, and Kordestan provinces and Isfahan, Fars, Bushehr, Chaharmahal and Bakhtiari, Hormozgan and Kohgiloyeh and Boyer Ahmad provinces (33% versus 22%), respectively.

As is well known, a geographic trend has been seen across most of the study's years. According to this pattern, the country's northern and western provinces are more prevalent than its southern and eastern provinces. The physical proximity and way of life of the residents of these provinces may be the cause of this pattern's occurrence. We require more thorough research on the risk factors associated with considering the location's geography to comprehend the root causes of this pattern more precisely.

Our analysis has some advantages and limitations so that the lack of information about Qom province in 2016 and North and South Khorasan provinces in 2004. Also, there were data related to Alborz province only for the years 2011 and 2016. Another limitation is that not all people were present at three times of blood pressure measurement and for some people blood pressure values were used twice or once.

The findings of this study offer new knowledge that can be applied to the management, control, and provision of crucial diagnostic and curative treatments for patients residing in high-risk locations for hypertension. In addition, identifying the high-risk areas of hypertension can help organize and allocate professional teams and care facilities' resources effectively.

Conclusion

In conclusion, our findings showed that hypertension incidence has increased over time in Iran, and the reasons for not reducing the hypertension incidence should be investigated, and strategies for controlling and reducing it should be planned. Markazi and Ardabil have a high incidence of hypertension, which serves as a caution to local politicians to consider the important risk factors and implement prevention programs to lower the incidence of hypertension in this area. To reduce the prevalence of hypertension in Iranian regions, it is crucial to develop regular hypertension screening programs, especially among the elderly. People should also be made more aware of hypertension, the importance of lifestyle modifications, healthy eating, and physical activity.

Acknowledgments

Not applicable

Ethics approval

The National Institute for Medical Research Development Ethics Committee in Iran (IR.TUMS.SPH.REC.1400.144) approved the study protocol.

Availability of data

The data that support the findings of this study are available from [Non-Communicable

Diseases Research Center in Iran] but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of [Non-Communicable Diseases Research Center in Iran].

Competing interests

The authors declare that they have no competing interests.

Funding

No funding Was received for the study

References

1. Katibeh M, Moghaddam A, Yaseri M, Neupane D, Kallestrup P, Ahmadieh H. Hypertension and associated factors in the Islamic Republic of Iran: a population-based study. EMHJ. 2020;26(3-2020).

2. Mills KT, Stefanescu A, He J. The global epidemiology of hypertension. Nature Reviews Nephrology. 2020;16(4):223-37.

3. Mirzaei M, Mirzaei M, Gholami S, Abolhosseini H. Prevalence of hypertension and related risk factors in central Iran: Results from Yazd Health Study. ARYA atherosclerosis. 2021;17(1):1.

4. Tabrizi JS, Sadeghi-Bazargani H, Farahbakhsh M, Nikniaz L, Nikniaz Z. Prevalence and associated factors of prehypertension and hypertension in Iranian population: the lifestyle promotion project (LPP). PloS one. 2016;11(10):e0165264.

5. Malekzadeh MM, Etemadi A, Kamangar F, Khademi H, Golozar A, Islami F, et al. Prevalence, awareness and risk factors of hypertension in a large cohort of Iranian adult population. Journal of hypertension. 2013;31(7):1364.

6. Organization WH. A global brief on hypertension: silent killer, global public health crisis [Internet]. Geneva: WHO; 2013 [cited 2018 Jun 4].

7. Farzadfar F, Delavari A, Malekzadeh R, Mesdaghinia A, Jamshidi HR, Sayyari A, et al. NASBOD 2013: design, definitions, and metrics. Archives of Iranian medicine. 2014;17(1):0-.

8. Asgari F, Haghazali M, Heydarian H. Non-communicable diseases risk factors surveillance in Iran. 2009.

9. Djalalinia S, Modirian M, Sheidaei A, Yoosefi M, Zokaiee H, Damirchilu B, et al. Protocol design for large–scale cross–sectional studies of surveillance of risk factors of non–communicable diseases in Iran: STEPs 2016. Archives of Iranian medicine. 2017;20(9):-.

10. Rahimzadeh S, Burczynska B, Ahmadvand A, Sheidaei A, Khademioureh S, Pazhuheian F, et al. Geographical and socioeconomic inequalities in female breast cancer incidence and mortality in Iran: A Bayesian spatial analysis of registry data. PloS one. 2021;16(3):e0248723.

11. Besag J, York J, Mollié A. Bayesian image restoration, with two applications in spatial statistics. Annals of the institute of statistical mathematics. 1991;43(1):1-20.

12. Ayubi E, Mansournia MA, Motlagh AG, Mosavi-Jarrahi A, Hosseini A, Yazdani K. Exploring neighborhood inequality in female breast cancer incidence in Tehran using Bayesian spatial models and a spatial scan statistic. Epidemiology and health. 2017;39.

13. Djalalinia S, Azadnajafabad S, Ghasemi E, Yoosefi M, Rezaei N, Farzi Y, et al. Protocol Design for Surveillance of Risk Factors of Non--communicable Diseases During the COVID-19 Pandemic: An Experience from Iran STEPS Survey 2021. Archives of Iranian Medicine (AIM). 2022;25(9).

14. Edwards W, Lindman H, Savage LJ. Bayesian statistical inference for psychological research. Psychological review. 1963;70(3):193.

15. Xiong Y, Bingham D, Braun W, Hu X. Moran's I statistic-based nonparametric test with spatio-temporal observations. Journal of Nonparametric Statistics. 2019;31(1):244-67.

16. David JS, Nicola G, Bradley PC, Angelika vdL. Bayesian measures of model complexity and fit. Journal of the Royal Statistical Society: Series B (Statistical Methodology). 2002;64(4):583-639.

17. Liang Y, Liu R, Du S, Qiu C. Trends in incidence of hypertension in Chinese adults, 1991–2009: the China Health and Nutrition Survey. International journal of cardiology. 2014;175(1):96-101.

18. Sinnott S-J, Smeeth L, Williamson E, Douglas IJ. Trends for prevalence and incidence of resistant hypertension: population based cohort study in the UK 1995-2015. Bmj. 2017;358.

19. Dorans KS, Mills KT, Liu Y, He J. Trends in prevalence and control of hypertension according to the 2017 American College of Cardiology/American Heart Association (ACC/AHA) guideline. Journal of the American Heart Association. 2018;7(11):e008888.

20. Oori MJ, Mohammadi F, Norozi K, Fallahi-Khoshknab M, Ebadi A, Gheshlagh RG. Prevalence of HTN in Iran: Meta-analysis of Published Studies in 2004-2018. Current hypertension reviews. 2019;15(2):113-22.