Original Article

Geospatial epidemiology of hypertension and its risk factors in India: Findings from National Family Health Survey (2015–2016)

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Abstract

Background: The fourth round of National Family Health Survey (2015–2016) measured blood pressure for the first time and provided a unique opportunity of exploring trends in hypertension prevalence across states and districts for the first time. **Aim:** This study will be the first in India to estimate the geospatial variation of hypertension among those in the 15–49 years age group in India. **Materials and Methods:** Out of a total of 616,346 selected occupied households, 601,509 were successfully interviewed, giving a response rate of 98%. We adjusted the proportion of hypertension obtained by using national sample weights. We built a multivariable logistic regression model to assess the determinants of hypertension. **Results:** The overall weighted prevalence of hypertension was 11.7%, and the prevalence was 11.1% in females and 11.0% in males. Urban areas had a higher prevalence (13.0%) compared to rural areas (11.0%). Those with no education (14.4%) and those who reported smoking (16.5%) had hypertension. Consumption of alcohol, fruits, and eggs was also found to be significantly related to hypertension. **Conclusion:** Hypertension epidemic is spreading alarmingly in India across rural and urban populations. Disturbingly, the hypertension prevalence is now becoming more concentrated among the poor. This phenomenon has serious implications for the country's social and economic well-being. Urgent preventive measures need to be taken at a multidisciplinary level.

Keywords: Hypertension, NCDs, NFHS-4, prevalence, risk factors

Introduction

The World Health Organization estimates that 15 million people in the age group of 30–69 years will die prematurely every year due to noncommunicable diseases (NCDs).[1] Among them, cardiovascular diseases (CVDs) account for most fatalities, or death of 17.9 million people annually, followed by cancers, respiratory disease, and diabetes, respectively.[2] Hypertension, one of the most important risk factors for CVDs, and diabetes have affected almost 1.13 billion people worldwide. Most of the hypertension cases are in low- and middle-income countries.[3] Global Burden of Hypertension study has reported that of the global burden of 212 million disability-adjusted life years (DALYs) related to hypertension, 18% occurred in India in the year 2015.[4]

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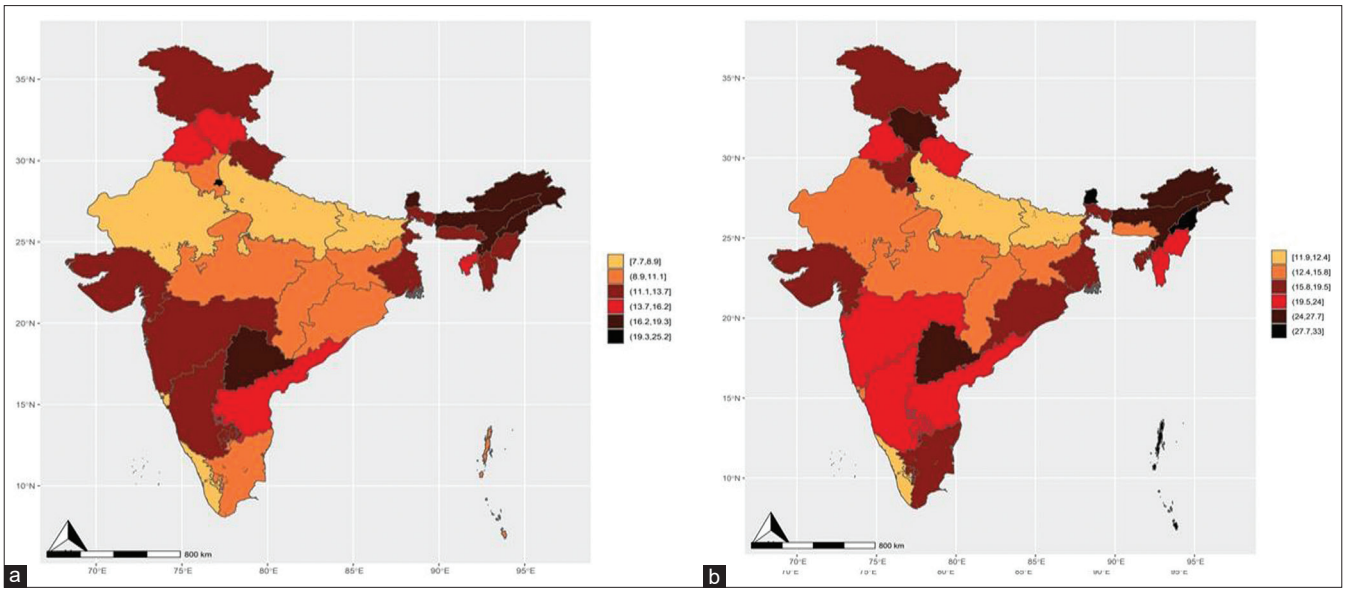

Figure 1: (a) Prevalence of hypertension among females in different states of India. (b) Prevalence of hypertension among males in different states of India

In its commitment to sustainable development goals (SDGs), India has set a target to reduce death due to premature mortality from NCDs by one third by 2030.[5] However, much of the success in meeting this target will depend on the ability to check the rise of hypertension. In order to meet the SDG targets of 2030 of reducing NCD-related mortality, it becomes imperative that population data related to blood pressure and its associated risk factors are monitored to inform policymakers and think tanks of the country for designing appropriate interventions. Due to the paucity of reliable information on the status of hypertension, policymakers had to rely on many communities and field-based surveys done on the prevalence of hypertension and associated risk factors in India.[6-8] The fourth round of the National Family Health Survey (NFHS-4, 2015–2016) measured blood pressure for the first time and provided a unique opportunity of exploring trends in hypertension across states and districts. India, being a large land with diverse geographic and cultural divide, we expect a considerable interstate heterogenicity in prevalence of hypertension. This study will be the first in India to estimate the geospatial variation of hypertension and its associated risk factors among those in 15–49 years age group in India.

Materials and Methods

We used the secondary data obtained in the NFHS-4 collected in the year 2015–2016. NFHS-4 conducted nationwide survey on a representative sample of the population of India, under the stewardship of the Ministry of Health and Family Welfare, Government of India. The International Institute for Population Sciences (IIPS), Mumbai is the nodal agency for all of the surveys. The fieldwork for NFHS-4 was conducted by 14 field agencies.

The representative sample for the NFHS-4 was selected using a stratified two-stage cluster sampling technique. The 2011 census served as the sampling frame for the selection of NFHS-4 sampling units. Within a stratum, primary sampling units (PSUs) were selected with a probability proportional to size (PPS). In the second stage, households were randomly selected with systematic sampling. Out of a total of 616,346 selected occupied households, 601,509 were successfully interviewed, giving a response rate of 98%. The response rate for eligible women was 97% (699,686/723,875) and for eligible men, it was 92% (112,122/122,051). The response rate was higher in rural clusters (97% for women and 93% for men) compared to urban clusters (96% for women and 90% for men). A detailed methodology for participant selection has been published (reference: International Institute for Population Sciences [IIPS] and ICF. 2017. National Family Health Survey (NFHS-4), 2015-16: India. Mumbai: IIPS.)

The NFHS-4 administered four survey questionnaires (Household Questionnaire, Woman's Questionnaire, Man's Questionnaire, and Biomarker Questionnaire) using computer-assisted personal interviewing. The Household Questionnaire collected information about household characteristics. The Woman's Questionnaire collected information from all eligible women aged 15–49, whereas the Man's Questionnaire (15–54 years) was administered in a 15% subsample of selected households. The subsample was obtained by selecting every alternate selected household in 30% of the selected PSUs. The Biomarker Questionnaire included measurements of height, weight, and blood pressure.

Blood pressure was measured using an Omron Blood Pressure Monitor. Three blood pressure measurements, at least 5 min apart, were taken from each respondent. A maximum of three

readings for systolic and diastolic were taken and an average of the last two readings was used for analysis. In case only one reading was available, the same was used for analysis. Hypertension was defined as a systolic blood pressure ≥140 or a diastolic blood pressure ≥90 or being on treatment for hypertension or having been informed by a doctor at least on two occasions that the person had hypertension. The weight of the respondent was measured using the Seca 874 digital scale. The Seca 213 stadiometer was used to measure height. In addition, information was obtained from respondents about the consumption of tobacco and alcohol.

Statistical Analysis

To obtain the prevalence of hypertension at the national level, we adjusted the proportion obtained by using national sample weights. We reported the prevalence as a percentage and calculated 95% Agresti–Coull confidence intervals. We obtained separate estimates of hypertension prevalence for males and females. We also report the mean systolic and diastolic blood pressure (in mmHg) and their 95% confidence intervals. We built a multivariable logistic regression model to assess the determinants of hypertension. We identified a set of predefined variables for univariable analysis. We used variables significant at $P < 0.02$ level in the univariable model for inclusion in the multivariable models.

Ethical Approval

The study was ethically approved by the institute's ethics committee, Postgraduate Institute of Medical Education and Research (PGIMER), Chandigarh (PGI/IEC/2021/001139).

Results

The NFHS-4 data contains observations on 699,686 females and 112,122 males. We dropped those observations from the final analysis wherein either systolic or diastolic blood pressure readings were missing, or the blood pressure measurements were outside the 20–300 mmHg range. There were 15,771 observations with missing blood pressure readings and 2689 observations with blood pressure measurements outside the 20–300 range. The final analysis was thus done on 793,348 observations, 108,791 males, and 684,557 females.

The overall weighted prevalence of hypertension was 11.7%. The weighted prevalence of hypertension was 16.1% in males and 11.0% in females [Figure 1]. The distribution of both systolic and diastolic blood pressure was slightly shifted toward the right for males compared to females [Table 1 and Figure 2].

The prevalence of hypertension increased with age from 2.9% in 15–19 year olds to 26.5% in 45–49 year olds. Urban areas had a higher prevalence (13.0%) compared to rural areas (11.0%). Overall, the prevalence of hypertension seemed to decrease with education. Those with no education had the highest prevalence (14.4%). However, a similar trend was not observed among males. In males, the prevalence of hypertension was high at both ends of the education spectrum: 17.2%, 18.4%, 14.9%, and 17.5% in males with no education, primary education, secondary education, and higher education, respectively. Those who reported smoking seemed to have a higher prevalence of hypertension (16.5%) compared to those who did not report smoking (11.0%). Alcoholics had a higher prevalence of hypertension (20.1%) compared to nonalcoholics (11.2%) [Table 2]. We calculated the prevalence of hypertension, smoking, alcohol use, and consumption of specific foods for each district. We constructed a multiple linear regression model using this data, with hypertension prevalence as the dependent variable. We dropped consumption of chicken and fish from the analysis because of multicollinearity (variance inflation factor (VIF) was 73.7 and 21.9 for chicken and fish, respectively). The results of this analysis are presented in [Table 3]. Consumption of alcohol, fruits, and eggs was found to be significantly related to hypertension prevalence. A correlation matrix of the district-level analysis has been depicted in [Figure 3].

Table 1: Weighted prevalence of hypertension among males and females in India

Variables	Hypertensives	Non-hypertensives
Males		
n	18,174	90,617
%	16.7	83.3
Weighted %	16.1	83.9
Females		
n	77,703	606,854
%	11.4	88.6
Weighted %	11.0	89.0
Overall		
n	95,877	697,471
%	12.1	87.9
Weighted %	11.7	88.3

Discussion

The present study estimates the prevalence of hypertension across different geographic areas in India and examines risk factors associated with this condition, from the findings of NFHS-4. A few previous pieces of research have been attempted to understand the prevalence of hypertension in India.[9-12] To the best of our knowledge, this study is the first in India to estimate the geospatial variation of hypertension and its associated risk factors among those in the 15–49 years age group in India.

The overall weighted prevalence of hypertension was 11.7%. The weighted prevalence of hypertension was 16.1% in males and 11.0% in females. The findings of the present study highlighted that prevalence of hypertension is much higher in men compared to women in India. The distribution of both systolic and diastolic blood pressure was slightly shifted toward the right for males compared to females. Besides the high prevalence of hypertension in males, it was also found that the risk of hypertension in males and females differed by age,

Table 2: Characteristics of sample population by gender, National Family Health Survey, India, 2015-2016

Variables	Males (*n*=108,791)				Females (*n*=684,557)				Overall (*n*=793,348)			
	Total	Hypertensives			Total	Hypertensives			Total	Hypertensives		
		n	%	Weighted %		*n*	%	Weighted %		*n*	%	Weighted %
Age, years												
15-19	18,474	748	4.0	3.5	121,550	3781	3.1	2.8	140,024	4529	3.2	2.9
20-24	16,092	1338	8.3	7.2	120,207	5824	4.8	4.4	136,299	7162	5.3	4.8
25-29	15,616	1943	12.4	11.5	112,697	8282	7.3	6.9	128,313	10,225	8.0	7.4
30-34	14,223	2415	17.0	16.0	95,100	10,758	11.3	10.7	109,323	13,173	12.0	11.3
35-39	13,516	2854	21.1	20.7	88,672	14,193	16.0	15.3	102,188	17,047	16.7	16.0
40-44	11,625	2972	25.6	25.8	75,122	15,928	21.2	20.9	86,747	18,900	21.8	21.5
45-49	10,874	3190	29.3	28.4	71,209	18,937	26.6	26.2	82,083	22,127	27.0	26.5
50-54	8371	2714	32.4	31.3	-	-	-	-	8371	2714	32.4	31.3
Residence												
Urban	34,010	6485	19.1	18.1	198,251	24,535	12.4	12.1	232,261	31,020	13.4	13.0
Rural	74,781	11,689	15.6	14.9	486,306	53,168	10.9	10.4	561,087	64,857	11.6	11.0
Education												
No education	14,611	2624	18.0	17.2	192,956	27,832	14.4	14.2	207,567	30,456	14.7	14.4
Primary	13,984	2512	18.0	18.4	86,781	11,693	13.5	13.2	100,765	14,205	14.1	13.9
Secondary	63,339	9796	15.5	14.9	327,624	31,612	9.6	9.4	390,963	41,408	10.6	10.3
Higher	16,857	3242	19.2	17.5	77,196	6566	8.5	7.9	94,053	9808	10.4	9.6
Smoking												
Nonsmoker	54,976	8385	15.3	14.7	612,607	66,815	10.9	10.7	667,583	75,200	11.3	11.0
Smoker	53,815	9789	18.2	17.7	71,950	10,888	15.1	15.2	125,765	20,677	16.4	16.5
Alcohol												
No	74,450	10,865	14.6	14.2	667,570	74,428	11.1	10.9	742,020	85,293	11.5	11.2
Yes	34,341	7309	21.3	20.6	16,987	3275	19.3	18.1	51,328	10,584	20.6	20.1
Dark green leafy vegetables												
Never	445	65	14.6	12.8	2235	227	10.2	9.5	2680	292	10.9	10.0
Occasionally	12,857	1790	13.9	14.1	98,478	9384	9.5	9.5	111,335	11,174	10.0	10.0
Weekly	44,128	6930	15.7	15.6	248,217	27,185	11.0	10.8	292,345	34,115	11.7	11.5
Daily	51,361	9389	18.3	17.0	335,627	40,907	12.2	11.6	386,988	50,296	13.0	12.3
Fruits												
Never	2231	352	15.8	15.3	16,415	2006	12.2	12.0	18,646	2358	12.6	12.3
Occasionally	53,736	8197	15.3	14.7	376,890	40,916	10.9	10.6	430,626	49,113	11.4	11.1
Weekly	41,604	7368	17.7	17.1	217,938	25,862	11.9	11.3	259,542	33,230	12.8	12.2
Daily	11,220	2257	20.1	18.6	73,314	8919	12.2	11.5	84,534	11,176	13.2	12.4
Eggs												
Never	22,390	3559	15.9	15.2	207,092	22,336	10.8	10.8	229,482	25,895	11.3	11.2
Occasionally	37,174	5924	15.9	15.5	227,144	24,904	11.0	10.4	264,318	30,828	11.7	11.1
Weekly	44,580	7824	17.6	16.8	228,464	27,680	12.1	11.5	273,044	35,504	13.0	12.4
Daily	4647	867	18.7	16.7	21,857	2783	12.7	11.9	26,504	3650	13.8	12.6
Fish												
Never	30,861	4855	15.7	14.9	247,305	25,777	10.4	10.4	278,166	30,632	11.0	10.9
Occasionally	39,528	6303	15.9	15.8	231,645	25,713	11.1	10.7	271,173	32,016	11.8	11.5
Weekly	33,880	6139	18.1	17.3	177,038	22,471	12.7	11.8	210,918	28,610	13.6	12.7
Daily	4522	877	19.4	16.0	28,569	3742	13.1	11.8	33,091	4619	14.0	12.3
Chicken/meat												
Never	25,637	3973	15.5	14.9	223,701	23,403	10.5	10.5	249,338	27,376	11.0	10.9
Occasionally	41,598	6697	16.1	15.5	257,191	28,630	11.1	10.8	298,789	35,327	11.8	11.4
Weekly	39,704	7141	18.0	17.3	195,421	24,517	12.5	11.8	235,125	31,658	13.5	12.7
Daily	1852	363	19.6	15.6	8244	1153	14.0	11.2	10,096	1516	15.0	12.1
Fried food												
Never	8517	1602	18.8	18.6	30,817	4255	13.8	12.8	39,334	5857	14.9	14.0
Occasionally	50,409	8133	16.1	15.6	342,814	37,540	11.0	10.7	393,223	45,673	11.6	11.3
Weekly	37,370	6256	16.7	16.0	230,998	25,497	11.0	10.7	268,368	31,753	11.8	11.5
Daily	12,495	2183	17.5	16.4	79,928	10,411	13.0	12.6	92,423	12,594	13.6	13.1
Aerated drinks												

Contd...

Table 2: Contd...

Variables	Males (*n*=108,791)				Females (*n*=684,557)				Overall (*n*=793,348)			
	Total	Hypertensives			Total	Hypertensives			Total	Hypertensives		
		n	%	Weighted %		*n*	%	Weighted %		*n*	%	Weighted %
Never	14,331	2775	19.4	19.3	113,086	14,670	13.0	12.7	127,417	17,445	13.7	13.4
Occasionally	60,926	9908	16.3	15.7	412,673	45,435	11.0	10.7	473,599	55,343	11.7	11.4
Weekly	26,607	4301	16.2	15.4	126,259	13,609	10.8	10.2	152,866	17,910	11.7	11.1
Daily	6927	1190	17.2	15.5	32,539	3989	12.3	11.9	39,466	5179	13.1	12.5

Table 3: Multiple linear regression analysis for the associated risk factors of hypertension

Variables	Regression coefficient	95% confidence interval		*P>t*
		Lower limit	Upper limit	
Smoking	−0.011	−0.039	0.018	0.460
Alcohol	0.198	0.148	0.248	<0.001
Green leafy vegetables	−0.341	−0.882	0.200	0.216
Fruits	0.196	0.039	0.353	0.014
Eggs	0.020	0.005	0.034	0.007
Aerated drinks	−0.029	−0.062	0.004	0.085

Adjusted R^2=0.1461

socioeconomic, demographic, and lifestyle factors. These results are similar to those of various previous studies.[11,13-16]

The prevalence of hypertension has been reported to be more in north and north-eastern states.[9] Similar findings were observed in the present study, wherein the highest prevalence of hypertension was found in the states of Telangana, Delhi, Sikkim, and Nagaland, followed by Himachal Pradesh, Arunachal Pradesh, and Assam. The states with the lowest prevalence were Uttar Pradesh, Bihar, and Kerala, followed by Rajasthan and Goa. The north-eastern states have low per capita income, but the prevalence was way higher than in states with a much higher level of socioeconomic development, which could be attributed to the ethnicity and diversity in food habits. Geldsetzer *et al.*[10] found the highest prevalence of hypertension in the northern states of Punjab and Himachal Pradesh, the southern state of Kerala, and the north-eastern states of Sikkim and Nagaland, quite similar to the findings of the present study. A few previous studies have shown that high intake of salt and increased consumption of tobacco and alcohol could be a possible cause for the higher prevalence in north and north-eastern states.[13,17]

The prevalence of hypertension increased with age from 2.9% in 15–19 year olds to 26.5% in 45–49 year olds, which may be attributed to a high workload and lack of physical activity in older age groups. Also, at older ages, the aorta and arterial walls get stiffened and this contributes to raised blood pressure. The results of current study are similar to various other studies, as mentioned in the previous reports.[18-20] The present study did not have any data for females of the age group 50–54 years, wherein the risk of hypertension is significantly high compared to males in the same age group, as mentioned in earlier studies.[21,22]

Urban areas had a higher prevalence (13.0%) of hypertension compared to rural areas (11.0%). The higher prevalence of hypertension among men and women in urban areas can be attributed to hectic and unhealthy lifestyles, reduced physical and outdoor activities, and increased stressful conditions among people living in urban areas.[9,23] However, few studies[9,11,23] have shown that rural women are at higher risk of developing hypertension than males, which was, however, not observed in the present study. This disparity in the prevalence of hypertension in urban and rural areas may also be due to the different levels of awareness about health care and health-seeking facilities, along with access to good-quality health-care services.[24,25] A few regional epidemiological studies have suggested an urban–rural convergence in hypertension prevalence due to the rapid urbanization of rural populations, with consequent changes in lifestyles, unhealthy eating habits, and an increase in overweight and obesity.[26,27]

The current study also reported that the prevalence of hypertension decreased with the level of education, with the highest prevalence of 14.4% found in uneducated class. However, a similar trend was not observed among males, where hypertension was high at both ends of the education spectrum. The poorly educated class has decreased level of awareness and limited access to the health services, whereas males who are highly educated lack intensive physical activity, lead a sedentary lifestyle, and have unhealthy eating habits.[20] Similar findings were observed in previous studies, where the prevalence of hypertension was higher among literate people compared with illiterates.[17,28] Contrary to this, women with a higher level of education had a better understanding of health-care facilities and were more aware about healthy eating habits, which may be the reason for a lower prevalence of hypertension.[29]

Those who reported smoking had higher prevalence of hypertension (16.5%) compared to those who did not report smoking (11.0%). According to a recent study that examined the life-course impact of smoking on hypertension, no statistically significant relationship was found between smoking and the risk of hypertension in the age group younger than 35, though smoking was found to be significantly associated with hypertension in the later ages.[7] Cigarette smoking is a significant cardiovascular risk factor, and quitting smoking is the single most effective lifestyle intervention for preventing a wide range of cardiovascular illnesses. Endothelial function impairment, arterial stiffness, inflammation, lipid modification, and changes in antithrombotic and prothrombotic variables are all smoking-related significant drivers of the onset and acceleration

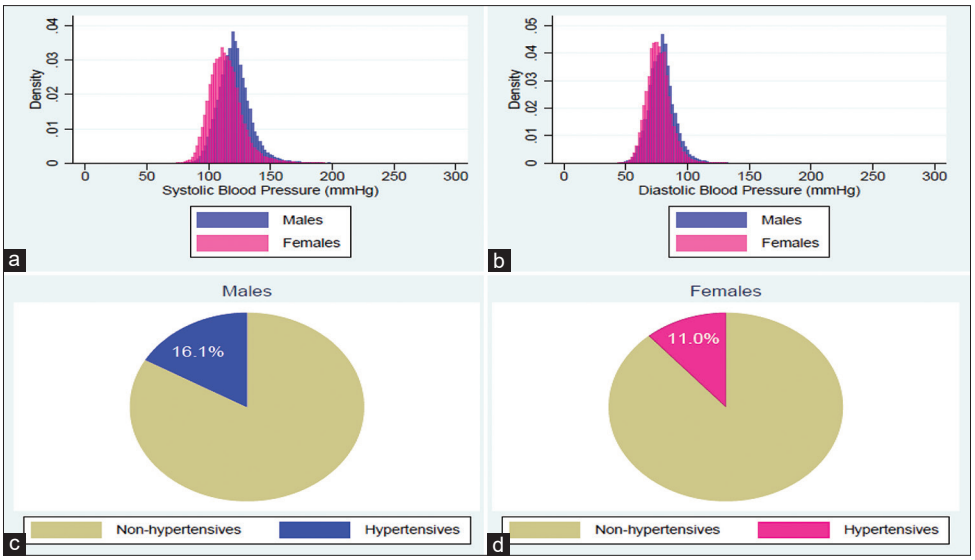

Figure 2: Weighted prevalence of hypertension among males and females in India

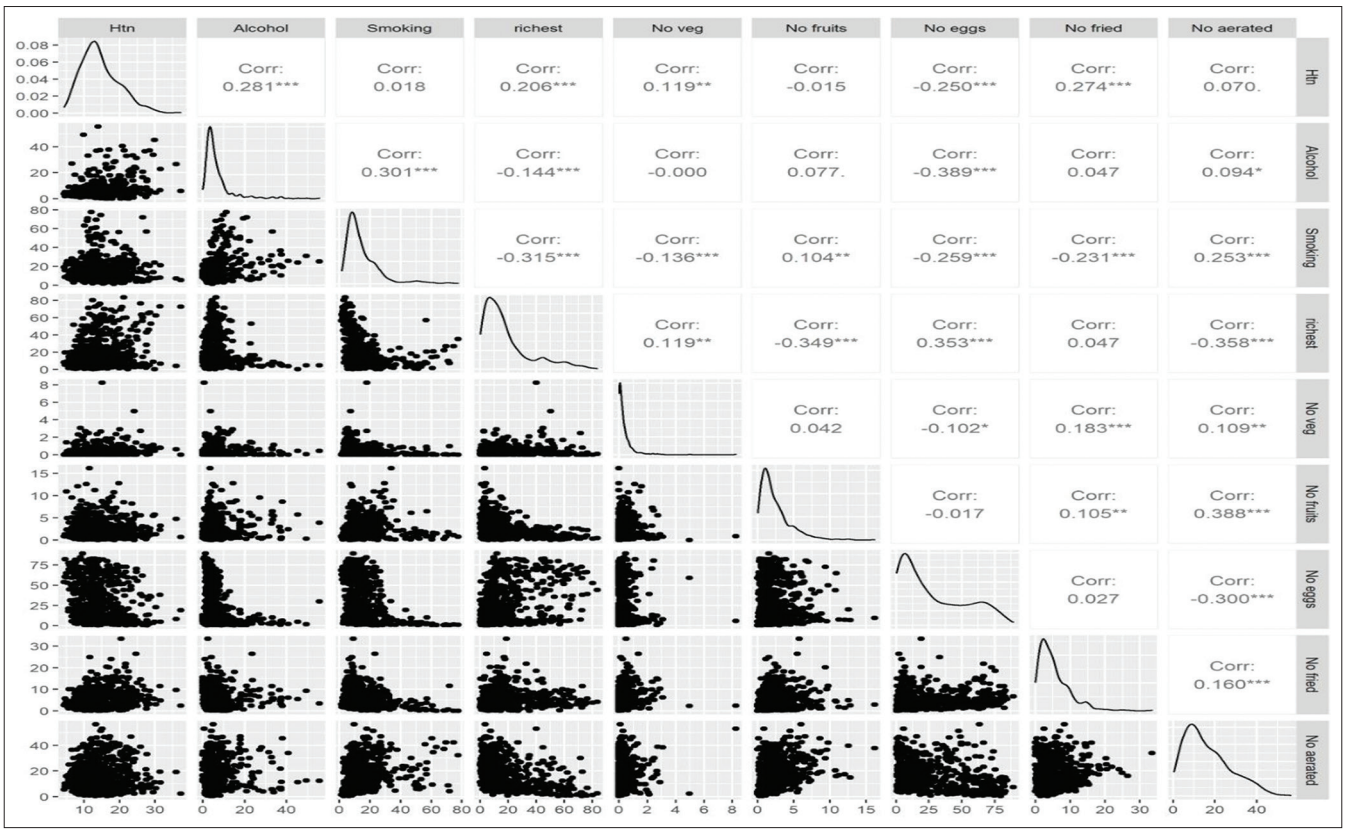

Figure 3: Correlation matrix of the district-level analysis of hypertension and associated risk factors

of the atherothrombotic process, which leads to cardiovascular events.[30,31] Cigarette smoking has also an immediate hypertensive impact, mostly via stimulating the sympathetic nervous system. Further, smoking, which affects arterial stiffness and wave reflection, may be more harmful to central blood pressure, which is more closely associated with target organ damage than brachial blood pressure. Hypertensive smokers are more prone to develop severe types of hypertension, such as malignant and renovascular hypertension, owing to faster atherogenesis.[32] Alcoholics had a higher prevalence of hypertension (20.1%) compared to nonalcoholics (11.2%). The frequency of drinking alcohol, specifically daily consumption of alcohol, was found to be significantly associated with a higher risk of hypertension in both sexes. Various studies have reported similar findings that alcohol consumption is significantly associated with a high prevalence of hypertension.[12,17,29] However, results reveal that

women who drink alcohol are more likely to be hypertensive. It is likely that alcohol consumption elevates blood pressure by lowering vasodilators such as nitric oxide (NO) in the vascular endothelium, either through inhibition of endothelial nitric oxide synthase (eNOS) or endothelial inflammatory/oxidative damage.[33]

The present study calculated the prevalence of hypertension, smoking, alcohol use, and consumption of specific foods in each district. A multiple linear regression model was constructed using this data, with hypertension prevalence as the dependent variable. The consumption of chicken and fish was dropped from the analysis because of multicollinearity (VIF was 73.7 and 21.9 for chicken and fish, respectively). Consumption of alcohol, fruits, and eggs was found to be significantly related to hypertension prevalence. A few previous studies have also shown that nonvegetarian food is significantly associated with hypertension, while another study has shown that a vegetarian diet is protective against hypertension.[34,35] In an analysis of three prospective cohorts (Nurses' Health Study I [NHS I], Nurses' Health Study II [NHS II], and Health Professionals Follow-up Study [HPFS]) totaling 188,518 participants with 2,936,359 person-years of follow-up, Borgi *et al.*[36] discovered a positive association between animal flesh consumption and hypertension risk. The positive link between animal flesh (including red and processed meat, poultry, and seafood) and hypertension was independent of fruit, vegetable, and whole grain diet in this biggest prospective investigation on animal consumption and incident hypertension to date. Another study by Melby *et al.*[37] also reported that blood pressure among vegetarians (n = 135, 114/71) was significantly lower ($P < 0.05$) than the blood pressure among nonvegetarians (n = 53, 122/74).

The present study is based on certain assumptions while using the Geographic Information System (GIS) tool. A GIS is being utilized in the rapid aggregation of multisource big data and rapid visualization of epidemic information. Such analyses can provide region-specific spatial information, which can help in decision-making, policy formulation, and effective assessment of risk factors associated with hypertension prevention and control among adults. However, the study uses secondary data from a cross-sectional NFHS survey to evaluate the relationships, which may not elicit temporal association. There are also recall biases and low truth quotients associated with such surveys. It may also be subjected to misclassification bias since we grouped together missing observations with No self-reported hypertension.

Conclusion

The present study does not only contribute to highlighting remarkable geographic variations in hypertension in India through the GIS tools, but also examines the contextual risk factors affecting its occurrence. Disturbingly, the hypertension prevalence is now becoming more concentrated among the poor in both urban and rural areas. This phenomenon of rising hypertension prevalence among the least resourceful people has serious social and economic implications for the country and warrants immediate policy interventions to prevent the catastrophe.

The study recommends that the public health programs should target the hot spot districts with a high prevalence of hypertension, along with designing specific policies to tackle factors at the national and the subnational level.

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Conflicts of interest

There are no conflicts of interest.

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