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). 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. 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. 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.

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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. 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. 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–Coulé 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].

**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. 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,
| Variables                        | Males (n=108,791) | Females (n=684,557) | Overall (n=793,348) |
|---------------------------------|-------------------|---------------------|---------------------|
|                                 | Total             | Hypertensives       | Total              | Hypertensives       | Total              | Hypertensives       |
|                                 | n                 | %                   | n                  | %                   | n                  | %                   |
|                                 |                   |                     |                    |                     |                    |                     |
| **Total**                       | 1790              | 12.4                | 85,293             | 12.4                | 19,474             | 16.0                |
| **Residence**                   |                   |                     |                    |                     |                    |                     |
| Urban                           | 34,010            | 64.85               | 198,251            | 24,535              | 12,420             | 217,938             |
| Rural                           | 74,781            | 11.689              | 486,306            | 53,168              | 51,087             | 64,857              |
| Education                       |                   |                     |                    |                     |                    |                     |
| No education                    | 14,611            | 26.24               | 192,956            | 27,832              | 207,567            | 30,456              |
| Primary                         | 13,984            | 25.12               | 86,781             | 11,693              | 100,765            | 14,205              |
| Secondary                       | 63,339            | 97.96               | 327,624            | 31,612              | 390,963            | 41,408              |
| Higher                          | 16,857            | 32.42               | 77,196             | 6566                | 94,053             | 9880                |
| Smoking                         |                   |                     |                    |                     |                    |                     |
| Nonsmoker                       | 54,976            | 83.85               | 612,607            | 66,815              | 675,833            | 75,200              |
| Smoker                          | 53,815            | 97.89               | 71,950             | 10,888              | 125,765            | 20,677              |
| Alcohol                         |                   |                     |                    |                     |                    |                     |
| No                              | 74,450            | 10.865              | 667,570            | 74,428              | 742,020            | 85,293              |
| Yes                             | 34,341            | 70.91               | 16,987             | 327.35              | 51,328             | 10.584              |
| Dark green leafy vegetables     |                   |                     |                    |                     |                    |                     |
| Never                           | 445               | 65.14               | 2235               | 227.10              | 2680               | 292                 |
| Occasionally                    | 12,857            | 17.90               | 98,478             | 9384.5              | 111,335            | 11.14               |
| Weekly                          | 44,128            | 69.30               | 248,217            | 27,185              | 292,345            | 31.14               |
| Daily                           | 51,361            | 93.89               | 335,027            | 40,907              | 386,988            | 50.296              |
| Fruits                          |                   |                     |                    |                     |                    |                     |
| Never                           | 2231              | 35.15               | 16,415             | 2006.12             | 18,646             | 2358                |
| Occasionally                    | 53,736            | 81.97               | 376,890            | 40,916              | 430,626            | 49.113              |
| Weekly                          | 41,604            | 73.68               | 217,938            | 25,862              | 259,542            | 33.230              |
| Daily                           | 11,220            | 225.01              | 73,314             | 8912.11             | 84,534             | 11.176              |
| Eggs                            |                   |                     |                    |                     |                    |                     |
| Never                           | 22,390            | 35.59               | 207,092            | 22,336              | 229,482            | 25,895              |
| Occasionally                    | 37,174            | 59.24               | 227,144            | 24,904              | 264,318            | 30,828              |
| Weekly                          | 44,580            | 78.24               | 228,464            | 27,680              | 273,044            | 35,504              |
| Daily                           | 4647              | 86.17               | 21,857             | 2783.12             | 26,504             | 35,608              |
| Fish                            |                   |                     |                    |                     |                    |                     |
| Never                           | 30,861            | 48.55               | 247,305            | 25,777              | 278,166            | 30,632              |
| Occasionally                    | 39,528            | 63.03               | 231,645            | 25,713              | 271,173            | 32,016              |
| Weekly                          | 33,800            | 51.39               | 177,038            | 22,471              | 210,918            | 28,610              |
| Daily                           | 4522              | 78.77               | 28,569             | 3742.13             | 33,091             | 46,194              |
| Chicken/meat                    |                   |                     |                    |                     |                    |                     |
| Never                           | 25,637            | 39.73               | 223,701            | 23,403              | 249,338            | 27,376              |
| Occasionally                    | 41,598            | 66.97               | 257,191            | 28,630              | 298,789            | 35,327              |
| Weekly                          | 39,704            | 71.41               | 195,421            | 24,517              | 235,125            | 31,658              |
| Daily                           | 1852              | 36.19               | 8244               | 1153.14             | 10,096             | 1516.50             |
| Fried food                      |                   |                     |                    |                     |                    |                     |
| Never                           | 8517              | 1602.18             | 30,817             | 4255.13             | 39,334             | 5857.14             |
| Occasionally                    | 50,409            | 8133.16             | 342,914            | 37,540              | 393,223            | 45,673              |
| Weekly                          | 37,370            | 6256.16             | 230,998            | 25,497              | 268,368            | 31,753              |
| Daily                           | 12,495            | 2183.17             | 79,928             | 10,411              | 92,423             | 12,594              |
| Aerated drinks                  |                   |                     |                    |                     |                    |                     |

*Contd...*
The prevalence of hypertension has been reported to be more in north and north-eastern states. 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. 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.

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. 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.

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. However, few studies 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. 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.

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. Similar findings were observed in previous studies, where the prevalence of hypertension was higher among literate people compared with illiterates. 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.

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. 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 of hypertension.
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.\textsuperscript{[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.\textsuperscript{[34,38]} 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 [HPFSS]) totaling 188,518 participants with 2,936,359 person-years of follow-up, Borgi et al\textsuperscript{[39]} 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\textsuperscript{[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.

\textbf{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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\textbf{Conflicts of interest}

There are no conflicts of interest.

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