

## ARTICLE



# Prevalence and associated factors of undiagnosed hypertension among women aged 15–49 years in India: an analysis of National Family Health Survey-4 data

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Hypertension is a major risk factor for cardiovascular diseases globally. Fortunately, there is a vast armamentarium of effective therapeutic options at our disposal so undiagnosed hypertension represents a missed opportunity. In a previous analysis [1] of the NFHS-4 dataset for the prevalence and risk factors for undiagnosed hypertension and its associated risk factors among Indian women aged 15–49 years, we had overestimated prevalence by inclusion of self-reported cases. We have since retracted when this anomaly was highlighted [2]. We have now re-analyzed the same database and here present these data. The current analysis shows that the overall prevalence of undiagnosed hypertension was 8.05% among women aged 15–49 years in India. In rural areas, it was 7.89% compared with 8.38% for urban areas. Factors associated with undiagnosed hypertension in rural and urban areas were age, BMI, wealth quintiles, educational level, religion, caste and geographical zones. Nearly half the women aged 15–49 years in India with hypertension are unaware and this has implications for personal and reproductive health.

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## INTRODUCTION

Hypertension is a major risk factor for cardiovascular diseases (CVD) globally [3]. It is well-established that treatment of elevated blood pressure (BP) results in huge gains in reducing cardiovascular disease, prolonging length and quality of life. According to World Health Organisation (WHO) estimates, raised BP causes 7.5 million deaths annually and accounts for 57 million disabilities adjusted life years (DALYs) [4]. The estimated proportion of DALYs attributed to hypertension in India rose from 21 million in 1990 to 39 million in 2016 [5]. The concept of cascade of care, that is, the proportion with a relevant condition who have been screened, are aware of their diagnosis, are on medication, and have achieved control, is an important aspect of assessing the performance of a health system. Wilber and Barrow first applied the “rule of halves” to the cascade of care on an American population in 1972 [6]. The rule of halves states that half of hypertensives do not know, half of those who know are under treatment and half of those under treatment have their BP under control. Prenissl et al. built the cascade of care in India measuring the loss of individuals at each stage of the process on National Family Health Survey (NFHS-4) data [7]. They found that among those with hypertension, 76.1% had been screened, 44.7% were aware of their diagnoses, 13.3% were treated, and 7.9% had achieved control. This rule seems to work well if we focus on those screened since nearly half of those screened were aware of having elevated blood pressure but the fractions being treated were less than expected. According to a systematic review conducted by Anchala et al., [8] among Indians

suffering from hypertension, only one-fourth in rural areas and one-third in urban areas, are being treated while only one-tenth in rural and one-fifth in urban areas, have blood pressure under control. In a previous analysis [1] of the NFHS-4 dataset for the prevalence and risk factors for undiagnosed hypertension and its associated risk factors among Indian women aged 15–49 years, we had overestimated prevalence by inclusion of self-reported cases. We have since retracted when this anomaly was highlighted [2] and here present the re-analyses of the same database for undiagnosed hypertension among women aged 15–49 years in India.

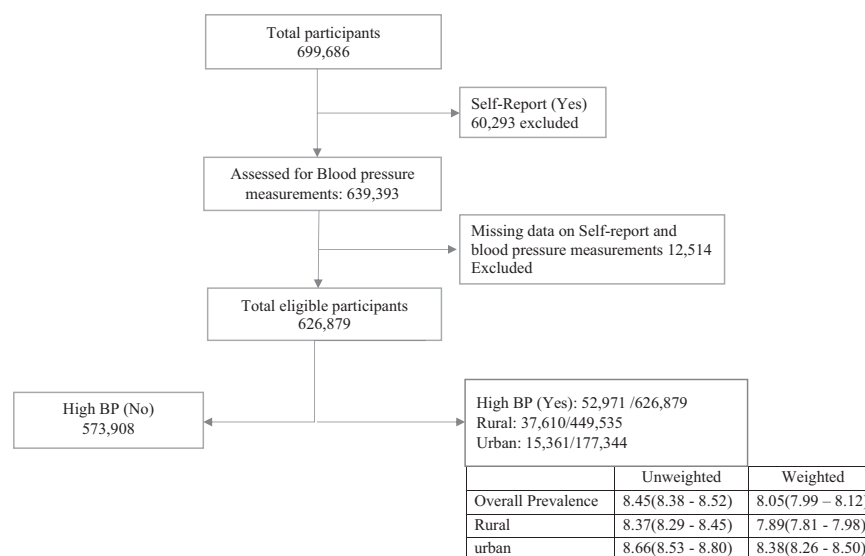
In women, treating or eliminating hypertension has the greatest impact of all modifiable cardiovascular risk factors [9]. Though hypertension is traditionally not seen as a woman’s disease [10, 11], Tyagi, Dhall and Kapoor found a relationship between hypertension and postmenopausal status among women [12]. The current analysis focuses on a much younger population of women who are susceptible to hypertension induced by oral contraceptive pills and pregnancy [13]. Interestingly, many studies have found equitable rates of prevalence between men and women in urban settings but have found prevalence of hypertension to be greater among men than women in rural India [14]. The urban-rural divide is based upon many socio-demographic and dietary differences such as the rural households’ lack of regular cash income, stress on agriculture, high cost of healthcare, poverty, malnutrition, dietary habits and irregular health check-ups while the urban households suffer from poor diets, stress, irregular lifestyles and increased salt intake [10]. The implication is that rural

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**Fig. 1** Flowchart visualising NFHS-4 data: Undiagnosed hypertension among women aged 15–49 years.

households are poorer, uneducated and have diminished access to health care systems. The current study focuses upon women aged 15–49 years in India who were screened for and diagnosed with hypertension but were unaware of its existence. The NFHS-4 dataset allows us an opportunity to define the scale of this unseen epidemic in urban and rural areas of India [15].

## METHODS

### Data

The National Family Health Survey (NFHS-4) is a state representative survey conducted by the Ministry of Health and Family (MoHFW), Government of India and technically managed by the International Institute for Population Sciences (IIPS), Mumbai, covering 29 states and 7 union territories of India [15]. As per the survey conducted and findings of NFHS-4, the cross-sectional survey was self-weighting at the level of the district. It involved 2-stage cluster random sampling approach using population proportionate to size sampling methodology. Data collection for the survey began on 20th January 2015 and ended on 4th December 2016 [15].

BP was measured using standard Omron HEM 8712 monitors [16] with small, medium and large upper arm circumference cuff size [17]. Consenting participants were encouraged not to consume any caffeinated beverages and restrict alcohol and smoking at least 30 minutes prior to measurement of BP. They were asked to relax for at least 5 minutes and to place their left arm on the table at the same level of the heart in a resting position. It involved taking note of first, second and third systolic and diastolic readings respectively at equated time intervals. The mean of all 3 readings were taken as the final reading for our study.

### Ascertaining hypertension

The sample data were weighted by state, and urban/rural places of residence, and within major cities for population differences. A total of 699,686 females within the age group 15–49 years were interviewed. From the database, we discarded data for women who reported that they had been told that they had high blood pressure (i.e. pre-existing/self-reported hypertension) on two or more occasions by a doctor or health care professional. These constituted 60,293 out of the total female population and are presented as women with self-reported hypertension in Fig. 1. Three systolic readings and three diastolic readings were recorded by OMRON BP monitor by trained surveyors. We then applied our definition for hypertension on the rest of the observations in the following manner:

We applied the threshold values of 70–270 mmHg for systolic readings and 40–140 mmHg for diastolic readings and then calculated the mean of the three readings. Those excluded from the study were women whose response to the question whether they had been told that they had high blood pressure (i.e. pre-existing/self-reported hypertension) on two or more occasions by a doctor or health care professional was not available and if all three systolic or diastolic readings were missing. Women were then classified

as normotensive or hypertensive according to JNC 7 guidelines in which systolic readings above 140 or diastolic readings above 90 or both were considered high BP [18]. The JNC 7 guidelines were chosen over the AHA/ACC 2017 criteria for the following reasons: it has not been proven that the more stringent criteria viz., 130/80 by AHA/ACC compared with 140/90 set by the JNC 7 are beneficial criteria for treatment [19, 20] or optimal in Asian populations [21, 22]. The SPRINT trial conducted on a US population showed that interventions aiming achievement of systolic blood pressure with a target of less than 120 mm Hg produced vastly more significant reduction of all major cardiovascular end points compared with a target of less than 140 mmHg, albeit, with higher adverse event rates for hypotension, syncope, bradycardia, electrolyte abnormality and acute kidney injury or acute renal failure in the intensive-treatment group [23]. Since our analyses were based on a cross-sectional survey, we have maintained the JNC 7 guidelines. Furthermore, NFHS-4 had used the JNC 7 guidelines because the JNC 8 guidelines were released later in 2014, after the groundwork for the survey had been completed and manuals prepared. We arrived at a final sample of 52,971 women respondents with 37,610 women living in rural areas and 15,361 women living in urban areas. These women were those who did not self-report having hypertension but whose mean BP readings taken during the survey indicated that they were hypertensive by JNC 7 criteria.

### Explanatory variables

The characteristics used for analysis of the weighted prevalence were as follows: age, smoking history, alcohol consumption, tobacco consumption, wealth index, education, social caste, religion, BMI, geographical zones and diet. The wealth index is a composite measure developed by the DHS based upon household's ownership of selected assets, such as television and bicycles; materials used for housing construction; and types of water access and sanitation facilities. All 29 states and 7 union territories were divided into 6 zones - (I) northern zone comprising Delhi, Chandigarh, Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab and Rajasthan, (II) central zone comprising Chhattisgarh, Madhya Pradesh, Uttar Pradesh, Uttarakhand, (III) eastern zone comprising Bihar, Jharkhand, Odisha and West Bengal, (IV) western zone comprising Dadra & Nagar Haveli, Daman and Diu, Goa, Gujarat and Maharashtra, (V) southern zone comprising Andaman and Nicobar, Andhra Pradesh, Karnataka, Kerala, Lakshadweep, Puducherry, Tamil Nadu and Telangana and (VI) north-eastern zone comprising Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. Diet had 7 independent variables such as milk or curd, pulse or beans, vegetables, fruits, eggs, fish and chicken or meat. Each of these variables were subdivided into 2 categories namely never or occasional and daily or weekly. See Table 1 for categorisations used for the variables.

### Statistical analyses

Analysis involved weighted data and we calculated overall prevalence of undiagnosed hypertension and its prevalence in rural and urban areas.

**Table 1.** List of variables for the study of undiagnosed hypertension among women aged 15–49 years (NFHS-4 2015–2016).

Study Variables	Description and Categories
Outcome Variable	Undiagnosed hypertension (0 = No; 1 = Yes)
Explanatory Variables	
Age	Age of participants in years (0 = 15–19 ; 1 = 20–24 ; 2 = 25–29 ; 3 = 30–34; 4 = 35–39; 5 = 40–44; 6 = 45–49)
Current Smoker	Smoking habit (0 = Nonsmoker; 1 = smoker)
Current Alcohol Use	Alcohol usage (0 = Nonalcoholic; 1 = alcoholic)
Current Tobacco Use	Tobacco usage (0 = Nontobacco User; 1 = tobacco User)
Wealth	Wealth index (0 = Poorest; 1 = Poorer; 2 = Middle, 3 = Richer; 4 = Richest)
Education	Education level (0 = no Education; 1 = primary; 2 = secondary; 3 = higher)
Social Caste	Social caste (0 = caste; 1 = scheduled tribe; 2 = no caste/tribe; 3 = don't know)
Religion	Religion (0 = Hindu; 1 = Muslim; 2 = Christian; 3 = others/not stated)
Body mass Index (BMI)	Body mass index (BMI) of women participants (0 = normal; 1 = underweight; 2 = pre-obesity; 3 = obesity class I; 4 = obesity class II; 5 = obesity class III)
Zones	Zones (0 = Northern; 1 = Central; 2 = Eastern; 3 = Western; 4 = Southern; 5 = North-Eastern)
Diet	Diet (0 = never/occasional (N/O); 1 = daily/weekly (D/W) milk/curd (0 = N/O; 1 = D/W); pulse/beans ((0 = N/O; 1 = D/W); vegetables (0 = N/O; 1 = D/W); fruits (0 = N/O; 1 = D/W); eggs (0 = N/O; 1 = D/W); fish (0 = N/O; 1 = D/W); chicken/meat (0 = N/O; 1 = D/W).

Baseline characteristics and prevalence with 95% confidence intervals (CI) are provided since CIs provide a range in which a true value of a parameter is expected to lie. Logistic regression was chosen as the appropriate statistical tool for analysis. To study the data, we examined both unadjusted and adjusted logistic regression analyses and results are presented for overall weighted odds ratio for women aged 15–49 years suffering from undiagnosed hypertension [24]. The prevalence of undiagnosed hypertension among various geographical regions was mapped using open GeoDa software for spatial data analysis. Local Indicators of Spatial Association (LISA) is part of GeoDa statistical test which supplement visualization by creating hot & cold spots on the map [25]. All analysis related to prevalence estimation of undiagnosed hypertension, body mass index (BMI), other biomarkers and socio-demographic profiles were conducted using Stata statistical software 14.2 (StataCorp LLC) [26].

## RESULTS

The overall weighted prevalence of undiagnosed hypertension among women aged 15–49 years in India was 8.05% (95%CI 7.99–8.12) with prevalence at 8.38% (95%CI 8.26–8.50) in urban areas and at 7.89% (95%CI 7.81–7.98) in rural areas. There were a total of 12,514 missing observations that were excluded from the study. The baseline characteristics are presented in Table 2. We provide prevalence with 95% confidence intervals.

### Age

Age showed a linear relationship with undiagnosed hypertension among women in rural and urban areas. The age group 45–49 years showed the highest prevalence of undiagnosed hypertension of 20.33%, with 19.25% in rural areas and 20.89% in urban areas, respectively.

### Smoking status, alcohol and tobacco consumption

Weighted prevalence of undiagnosed hypertension was 12.23% among smokers, 16.22% among alcoholics, and 12.02% among tobacco users. It was higher among smokers and alcoholics in rural areas and higher among tobacco users in urban areas.

### Wealth index

In terms of wealth index, overall weighted prevalence increased from poorest to richest wealth index. It ranges between 7.58% to 8.69% in rural areas and between 7.70% and 8.87% in urban areas. It was highest in the “richer” wealth quintile in both rural and urban areas.

### Educational attainment

Prevalence of undiagnosed hypertension ranged between 5.23% to 11.30% in all classifications of the variable education. It was consistently higher in urban areas compared to rural areas.

### Caste and religion

Prevalence of undiagnosed hypertension ranged from 9.69% among members of no caste/ tribe to 7.88% among those who knew their caste. In terms of religion, 9.30% followers of the Christian faith were found suffering from undiagnosed hypertension. The corresponding figures for followers of the Hindu (7.86%) and Muslim faiths (8.55%) were lower. Except for the followers of the Hindu faith, prevalence was higher for the followers of the Muslim, Christian and Other religions in rural areas.

### BMI

According to BMI classifications, prevalence was lowest among those who were underweight (BMI < 18.5 Kg/m<sup>2</sup>). It was consistently lower in urban areas as compared to rural areas in all categories except for Obesity Class III (BMI >= 40 Kg/m<sup>2</sup>).

### Geographical zones

13.84% of women with undiagnosed hypertension lived in the North-Eastern zone of India. Undiagnosed hypertension was highest in the North-Eastern states of Assam, Arunachal Pradesh and Nagaland, irrespective of the area of residence. In the rural areas, Lakshadweep had the highest prevalence of over 20 percent. Prevalence was greater in the rural areas than urban areas in the states of Punjab, Himachal Pradesh, Chhattisgarh, Jharkhand, Meghalaya, Kerala and Bihar, and union territories of Lakshadweep, Andaman and Nicobar, Daman and Diu (Fig. 2 (Rural Areas) and Fig. 3 (Urban Areas)). Prevalence was nearly similar in the urban and rural areas of Madhya Pradesh and Telangana.

### Dietary habits

In terms of diet, prevalence was higher among those who did not consume milk/curd never or occasionally rather than daily or weekly.

### Multiple logistic regression analyses

Table 3 reports the unadjusted and adjusted odds ratio along with 95% confidence interval for undiagnosed hypertension in women aged 15–49 years in India.

**Table 2.** Socio-demographic characteristics of women aged 15–49 years with undiagnosed hypertension (NFHS-4 2015–2016).

Characteristics	Undiagnosed hypertension	Weighted prevalence of undiagnosed hypertension		
	Total (%)	Overall (95% CI)	Rural (95% CI)	Urban (95% CI)
<b>Age (years)</b>				
15–19	2456 (4.64)	1.75 (1.68, 1.83)	1.85 (1.76, 1.95)	1.51 (1.39, 1.65)
20–24	3893 (7.35)	3.00 (2.9, 3.09)	3.17 (3.05, 3.30)	2.62 (2.46, 2.79)
25–29	5777 (10.91)	5.11 (4.98, 5.25)	5.16 (5.00, 5.33)	5.01 (4.78, 5.24)
30–34	7619 (14.38)	8.26 (8.08, 8.45)	8.21 (7.99, 8.44)	8.35 (8.04, 8.67)
35–39	10,129 (19.12)	12.27 (12.05, 12.50)	12.05 (11.77, 12.33)	12.69 (13.31, 13.09)
40–44	10,910 (20.60)	16.12 (15.84, 16.40)	15.62 (15.28, 15.97)	17.05 (16.57, 17.55)
45–49	12,187 (23.01)	20.33 (20.01, 20.66)	19.25 (18.87, 19.63)	20.89 (20.33, 21.47)
<b>Current Smoker</b>				
Non-Smoker	51,615 (97.44)	8.00 (7.93, 8.07)	7.82 (7.74, 7.90)	8.35 (8.24, 8.48)
Smoker	1356 (2.56)	12.23 (11.52, 12.97)	12.34 (11.57, 13.17)	11.65 (10.04, 13.47)
<b>Current Alcohol Use</b>				
Non-Alcoholic	50,321 (95.00)	7.95 (7.88, 8.02)	7.76 (7.67, 7.84)	8.34 (8.22, 8.46)
Alcoholic	2650 (5.00)	16.22 (15.41, 17.05)	16.81 (15.91, 17.76)	13.64 (11.96, 15.50)
<b>Current Tobacco Use</b>				
Non-Tobacco	47,524 (89.72)	7.87 (7.80, 7.94)	7.68 (7.59, 7.76)	8.24 (8.12, 8.36)
Tobacco User	5447 (10.28)	12.02 (11.35, 12.41)	11.87 (11.45, 12.32)	12.51 (11.73, 13.33)
<b>Wealth</b>				
Poorest	10,171 (19.20)	7.76 (7.60, 7.91)	7.74 (7.59, 7.90)	8.00 (7.34, 8.73)
Poorer	11,333 (21.39)	7.59 (7.44, 7.74)	7.58 (7.43, 7.74)	7.70 (7.27, 8.15)
Middle	10,870 (20.52)	7.68 (7.53, 7.83)	7.66 (7.50, 7.83)	7.73 (7.44, 8.02)
Richer	10,835 (20.45)	8.78 (8.63, 8.94)	8.69 (8.45, 8.91)	8.87 (8.65, 9.10)
Richest	9762 (18.43)	8.43 (8.27, 8.58)	8.53 (8.23, 8.84)	8.39 (8.21, 8.57)
<b>Education</b>				
No Education	20,712 (39.10)	11.30 (11.15, 11.45)	10.96 (10.80, 11.13)	12.81 (12.45, 13.18)
Primary	7974 (15.05)	9.95 (9.74, 10.16)	9.40 (9.16, 9.64)	11.43 (11.00, 11.87)
Secondary	20,216 (38.16)	6.40 (6.31, 6.49)	5.73 (5.62, 5.84)	7.57 (7.41, 7.73)
Higher	4069 (7.68)	5.23 (5.08, 5.39)	4.28 (4.07, 4.52)	5.86 (5.65, 6.07)
<b>Social Caste</b>				
Caste	40,261 (76.23)	7.88 (7.81, 7.95)	7.65 (7.56, 7.74)	8.31 (8.18, 8.43)
Tribe	9724 (18.41)	9.45 (9.18, 9.74)	9.42 (9.12, 9.73)	9.64 (8.93, 10.40)
No Caste/Tribe	2619 (4.96)	9.69 (9.32, 10.07)	9.88 (9.40, 10.37)	9.38 (8.80, 10.00)
Don't know	212 (0.40)	8.25 (7.46, 9.11)	9.65 (8.53, 10.88)	6.34 (5.30, 7.57)
<b>Religion</b>				
Hindu	37,629 (71.03)	7.86 (7.79, 7.94)	7.66 (7.57, 7.75)	8.31 (8.18, 8.46)
Muslim	7251 (13.69)	8.55 (8.36, 8.74)	8.71 (7.46, 9.00)	8.36 (8.09, 8.64)
Christian	4703 (8.88)	9.30 (8.84, 9.79)	9.44 (8.84, 10.01)	9.08 (8.35, 9.87)
Others/Not Stated	3388 (6.40)	9.80 (9.40, 10.22)	10.16 (9.65, 10.70)	9.17 (8.53, 9.85)
<b>BMI (kg/m<sup>2</sup>)</b>				
Normal (18.5–24.9)	28,134 (53.23)	6.89 (6.81, 6.97)	7.21 (7.11, 7.31)	6.19 (6.06, 6.34)
Underweight (< 18.5)	6329 (11.97)	4.05 (3.95, 4.16)	4.47 (4.35, 4.60)	2.65 (2.48, 2.82)
Pre-obesity (25–29.9)	13,434 (25.42)	15.32 (15.09, 15.56)	16.53 (16.20, 16.88)	14.04 (13.71, 14.37)
Obesity Class I (30–34.9)	3938 (7.45)	20.59 (20.05, 21.14)	22.20 (21.33, 23.09)	19.48 (18.80, 20.19)
Obesity Class II (35–39.9)	795 (1.50)	22.01 (20.81, 23.26)	23.71 (21.61, 25.94)	21.15 (19.71, 22.67)
Obesity Class III (>= 40)	224 (0.42)	25.62 (23.25, 28.15)	23.09 (19.46, 27.17)	27.16 (24.10, 30.44)
<b>Zones</b>				
Northern	8549 (16.14)	7.72 (7.54, 7.91)	7.63 (7.40, 7.88)	7.87 (7.57, 8.19)
Central	14,236 (26.88)	7.45 (7.32, 7.58)	7.45 (7.30, 7.60)	7.44 (7.20, 7.70)
Eastern	8252 (15.58)	7.43 (7.29, 7.56)	7.27 (7.11, 7.42)	8.00 (7.70, 8.32)
Western	4510 (8.51)	8.85 (8.67, 9.04)	8.44 (8.20, 8.70)	9.31 (9.04, 9.59)
Southern	6493 (12.26)	8.13 (7.98, 82.76)	7.89 (7.70, 8.09)	8.42 (8.21, 8.66)
North-Eastern	10,931 (20.64)	13.84 (13.39, 14.31)	13.90 (13.40, 14.42)	13.60 (12.60, 14.66)
<b>Diet:</b>				
Milk/Curd (N/O)	20,447 (38.60)	8.31 (8.20, 8.44)	8.22 (8.08, 8.36)	8.86 (8.38, 8.87)
Milk/Curd (D/W)	32,524 (61.40)	7.92 (7.84, 8.01)	7.70 (7.60, 7.80)	8.30 (8.16, 8.43)

Table 2. continued

Characteristics	Undiagnosed hypertension	Weighted prevalence of undiagnosed hypertension		
	Total (%)	Overall (95% CI)	Rural (95% CI)	Urban (95% CI)
Pulse/Beans (N/O)	6736 (12.72)	7.71 (7.50, 7.92)	7.49 (7.25, 7.73)	8.31 (7.90, 8.73)
Pulse/Beans (D/W)	46,235 (87.28)	8.09 (8.02, 8.16)	7.94 (7.86, 8.03)	8.38 (8.26, 8.51)
Vegetables (N/O)	6681 (12.61)	7.01 (6.85, 7.18)	7.01 (6.81, 7.21)	7.03 (6.73, 7.34)
Vegetables (D/W)	46,290 (87.39)	8.23 (8.16, 8.31)	8.06 (8.00, 8.15)	8.58 (8.45, 8.71)
Fruits (N/O)	30,671 (57.90)	8.08 (7.99, 8.17)	7.90 (7.80, 8.01)	8.68 (8.45, 8.88)
Fruits (D/W)	22,300 (42.10)	8.23 (7.92, 8.12)	7.88 (7.74, 8.01)	8.19 (8.04, 8.34)
Eggs (N/O)	32,525 (61.40)	7.82 (7.73, 7.91)	7.69 (7.59, 7.79)	8.15 (7.99, 8.31)
Eggs (D/W)	20,446 (38.60)	8.39 (8.28, 8.50)	8.24 (8.10, 8.38)	8.64 (8.45, 8.81)
Fish (N/O)	35,322 (66.68)	7.79 (7.71, 7.88)	7.60 (7.51, 7.70)	8.21 (8.06, 8.36)
Fish (D/W)	17,649 (33.32)	8.57 (8.45, 8.69)	8.51 (8.37, 8.67)	8.66 (8.46, 8.86)
Chicken/Meat (N/O)	35,968 (67.90)	7.83 (7.75, 7.91)	7.72 (7.63, 7.82)	9.32 (9.10, 9.55)
Chicken/Meat (D/W)	17,003 (32.10)	8.53 (8.41, 8.66)	8.33 (8.17, 8.49)	8.09 (7.94, 8.24)

N/O Never/Occasional, D/W Daily/Weekly.

### Age

Age is a risk factor in women aged 40–44 years old, adjusted OR 7.57 (95% CI, 7.19–7.97) and 45–49 years old, adjusted OR 9.66 (95% CI, 9.18–10.18). As age increases the odds of having undiagnosed hypertension increase.

### Smoking status, alcohol and tobacco use

The odds of women having undiagnosed hypertension were OR 0.98 (95% CI, 0.82–1.17) for smokers and OR 0.94 (95% CI, 0.87–1.02) for tobacco users in urban areas. Alcohol consumption increased the risk, overall adjusted OR 1.52 (95% CI, 1.42–1.63), rural adjusted OR 1.54 (95% CI, 1.43–1.66) and urban adjusted OR 1.48 (95% CI, 1.25–1.74).

### Wealth index

Compared to those in the poorest wealth bracket, all other quintiles had a lesser risk. Those in the richer wealth quintile had an overall adjusted OR 0.94 (95% CI, 0.91–0.97) but it was not significant in rural areas.

### Educational attainment

Educational status impacted risk of undiagnosed hypertension as increasing educational attainment was negatively associated with undiagnosed hypertension. Multiple logistic regression model showed that up to secondary education had an OR 0.89 (95% CI, 0.87–0.92) and higher education had an OR 0.73 (95% CI, 0.70–0.77).

### Caste and religion

Women who belonged to tribes were more susceptible to undiagnosed hypertension, adjusted OR 1.20 (95% CI 1.15–1.24). Muslims were more likely to have undiagnosed hypertension, adjusted OR 1.10 (95% CI, 1.07–1.13) than Hindus, especially in the rural areas, adjusted OR 1.14 (95% CI, 1.09–1.19).

### BMI

Compared to normal BMI, all other categories besides underweight were risk factors for undiagnosed hypertension. Among those who were underweight (BMI < 18.5 kg/m<sup>2</sup>), the adjusted OR was 0.69 (95% CI, 0.66–0.71), with those in urban areas, adjusted OR 0.59 (95% CI, 0.55–0.64) and rural areas, adjusted OR 0.71 (95% CI, 0.69–0.73).

### Geographical zones

Compared to those living in the Northern zone, those in Eastern, adjusted OR 0.91 (95% CI, 0.88–0.95) and Southern, adjusted OR

0.87 (95% CI, 0.84–0.91) zones were protected. On the other hand, those living in the Western, adjusted OR 1.07 (95% CI, 1.03–1.11) and North-Eastern, adjusted OR 1.85 (95% CI, 1.74–1.95) zones were at greater risk.

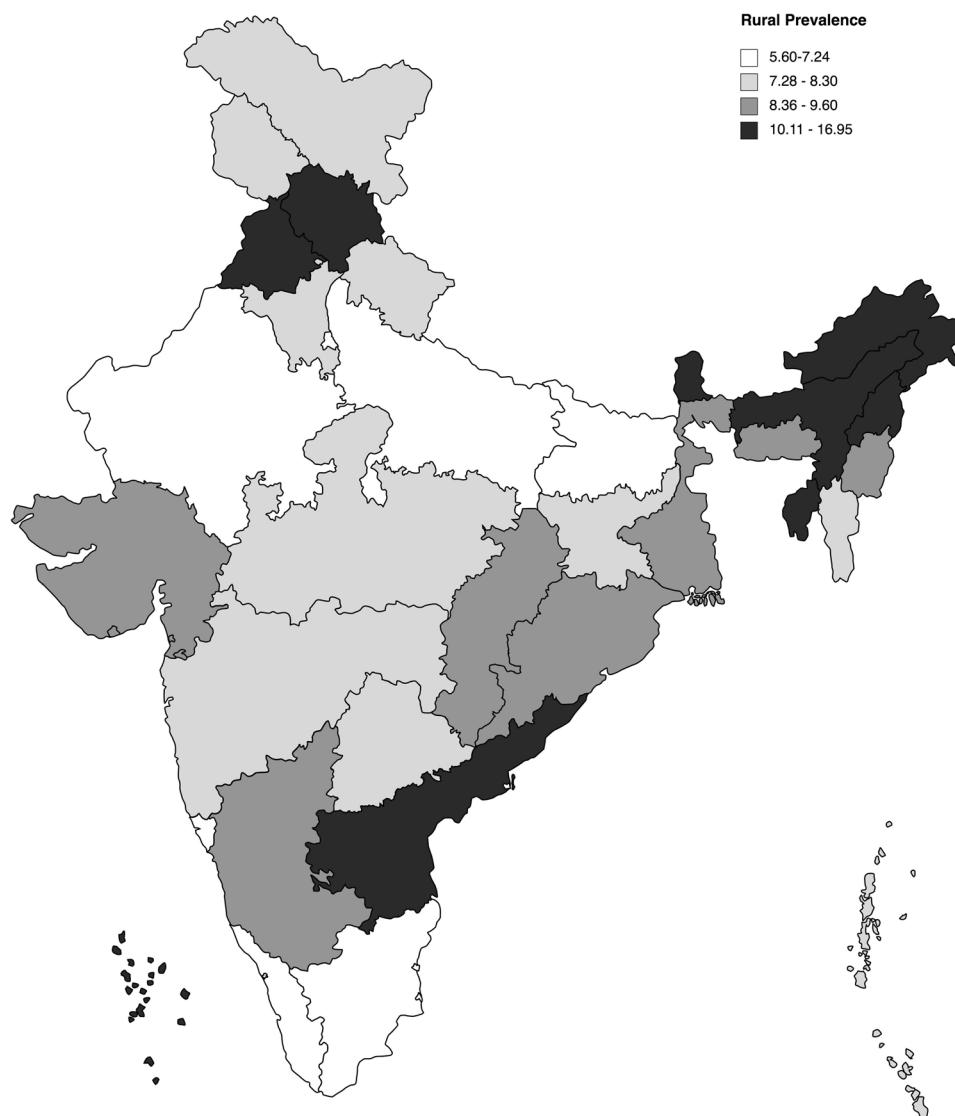
### Dietary habits

Among dietary eating patterns, there was no consistent pattern visible except for those consuming milk/curd on a daily/weekly basis were less likely, adjusted OR 0.94 (95% CI, 0.92–0.96) to have undiagnosed hypertension than those who never/ occasionally consumed them.

### DISCUSSION

According to recent global figures, prevalence of hypertension among adults aged 30–79 years doubled from 331 million women and 317 million men in 1990 to 626 million women and 652 million men in 2019 [27]. While hypertension rates have stabilized or decreased slightly in high-income countries, hypertension has increased in some low and middle-income countries [28, 29]. It is estimated that over 1 billion people live with hypertension in low- and middle-income countries [27]. Hypertension caused 1.6 million deaths and 33.9 million disability-adjusted life years in India in 2015 [30]. The rationale behind the present study was to focus on the prevalence and associated factors of undiagnosed hypertension among women of reproductive age. Hypertension in this age group has implications not only for personal but also reproductive health and inter-generational propagation of cardiovascular risk. While most studies have identified factors associated with hypertension, our study identifies an overall weighted prevalence of “undiagnosed hypertension” of 8.05% among women who were unaware of this diagnosis but who fulfilled JNC 7 criteria for the diagnosis. A methodological difference from other studies is that we applied thresholds of 70–270 mmHg for systolic readings and 40–140 mmHg for diastolic readings in defining hypertension, eliminating as far as possible improbable values obtained during the survey.

In post-menopausal women, hypertension rates are comparable with those among men. It has been theorised that while the risk factors are the same in men and women, their relative weighting varies with age, hypertension, total cholesterol and low-density lipoprotein (LDL)-cholesterol having a greater influence in men while smoking, diabetes, triglyceride and high-density lipoprotein (HDL)-cholesterol levels have greater effect on women in relation to CVDs [31]. Women-specific factors also include polycystic ovary syndrome, menopause, pregnancy-induced hypertension,



**Fig. 2** Map of Rural India: Prevalence of Undiagnosed Hypertension in Women (Aged 15-49 years).

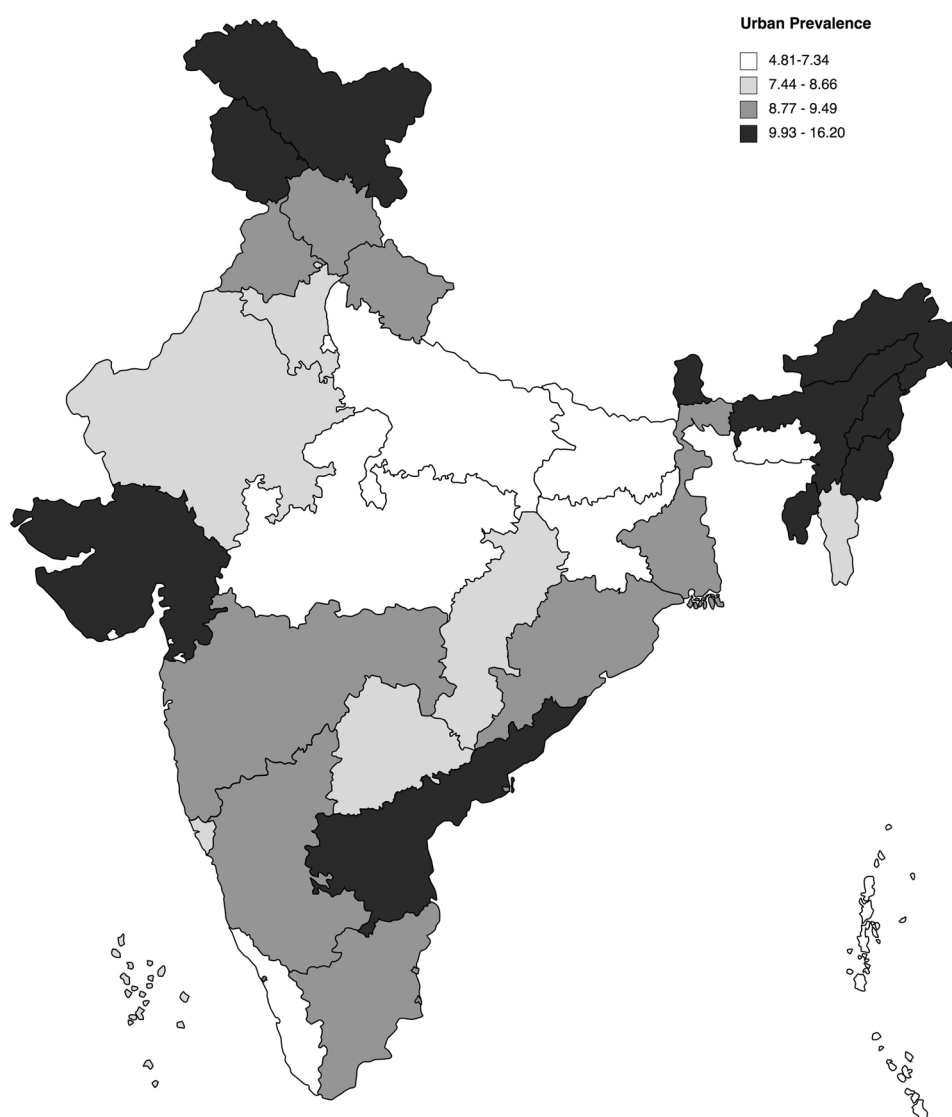
preeclampsia and gestational diabetes. Many of these women-specific conditions occur during their reproductive years and have long ranging effects.

From our study, it was found that the prevalence of undiagnosed hypertension was higher among women in urban India than in rural India. This could be related to higher awareness and better access to health care in urban areas than rural areas, or it could be attributable to diet and stress-related issues as suggested by Swain et al. [10]. Our study found that wealth index, caste, religion and BMI had more pronounced effects in rural areas while age had a more pronounced effect in urban areas. Some regional epidemiological studies have found an urban-rural convergence in hypertension prevalence [32, 33]. Gupta [32] suggests that this urban-rural convergence of hypertension in India is due to rapid urbanization of rural populations with consequent changes in lifestyles (sedentariness, high dietary salt, sugar and fat intake) and increase in overweight and obesity.

As age increases, prevalence of undiagnosed hypertension increases. The prevalence was twelve percent among women in the age group 35–39 years, sixteen percent among women in the age group 40–44 years, and twenty percent among women in the age group 45–49 years. One interesting note is that prevalence was narrowly higher in rural areas in the age groups less than 30

years and the opposite being true in age groups more than 30 years. It is to be noted that undiagnosed hypertension is a point of concern even among younger age groups, those under 30 years of age, which is consistent with other studies [34, 35]. These cases could also be related to oral contraceptive pills induced hypertension since it is suggested that BP rises after menopause in most women due to withdrawal of endogenous estrogen, a potent vasodilator [12, 13, 36]. In all age groups, the odds were either similar or marginally higher in urban than in rural areas.

Around eight percent of non-smokers, non-alcoholic, and non-tobacco consumers have undiagnosed hypertension while around twelve to sixteen percent of smokers, alcoholic and tobacco consumers have undiagnosed hypertension. Smoking and tobacco consumption lost their significance when adjusted in presence of other factors, meaning that smoking and tobacco consumption were not directly linked to undiagnosed hypertension. Smoking and tobacco consumption may be linked to other healthier factors such as dietary controls and physical exercise. It is also more likely that smokers and tobacco users visit the doctor more frequently due to other morbidities and hence, the factors are not significant among those with undiagnosed hypertension. It has been found that smoking has a more harmful effect among women at younger ages (<50 years) than among men leading to a greater risk of chronic



**Fig. 3** Map of Urban India: Prevalence of Undiagnosed Hypertension in Women (Aged 15-49 years).

heart disease and acute myocardial infarction [31]. Alcohol consumption increased undiagnosed hypertension compared to those who did not consume alcohol in both rural and urban areas. It is also known that light to moderate drinkers are at a lower risk of hypertension than non-drinkers while heavy drinkers are at a higher risk than light to moderate and non-drinkers [28]. The same review also pointed out that there is no direct causality between cigarette smoking and hypertension because stopping to smoke does not lower the blood pressure. Our study did not look at factors such as the number of cigarettes smoked per day or number of alcoholic drinks per day/week/monthly in greater detail. The consumption patterns are also prone to self-reported biases. Mere presence of smoking and tobacco consumption do not show an increased risk for hypertension when adjustments are made for other factors [37].

Similarly, wealth index showed little effect on prevalence rates. This may be because a woman's position in a household is often not governed by the household's wealth index. Prevalence was highest in the "richer" wealth quintile in both rural and urban areas. It is noteworthy that the "richer" middle-class shows the highest prevalence. In the multivariate logistic regression analyses, wealth index had a protective effect on the prevalence of undiagnosed hypertension, meaning an increase in wealth did not show an increase in undiagnosed hypertension. Education,

too, had a protective effect since the prevalence rates decreased as level of educational attainment increased. As education levels increased above primary level, prevalence of undiagnosed hypertension decreased. This is in line with many other studies as reported by Zhou et al. [29]. Wealth and education may be directly related to access to healthcare facilities as well as access to information that allows for healthier eating and lifestyle choices. On the flip side, an increase in wealth status may also lead to an unhealthier sedentary lifestyle. Thus, the underlying social structures that push women up in the wealth scale and acquire education may also be responsible for their healthier status.

Women belonging to tribes had higher prevalence rates than those belonging to castes. The highest rates were seen in those who did not identify their caste and/or tribe. Tribes living in the Amazon with less socialization and almost no salt in their diets do not show elevated levels of blood pressure with age. This is not true for India because those who belong to "scheduled tribes" are people who may in fact be living not in their communities but among the general population due to rapid urbanization and their integration into urban lifestyles. They still describe themselves as "scheduled tribes" to benefit from governmental social schemes. This was more evident in the rural areas than in urban areas. Also, those women who did not identify their caste/tribe were more

**Table 3.** Univariate and multivariate analysis with weighted odds ratio and 95% confidence interval from logistic regression analysis for undiagnosed hypertension in women (15–49 yrs), NFHS-4 2015–2016.

Variables	Unadjusted Odds Ratio (95% CI)			Adjusted Odds Ratio (95% CI)		
	Overall	Rural	Urban	Overall	Rural	Urban
<b>Age (years)</b>						
15–19	1	1	1	1	1	1
20–24	1.73 (1.63, 1.83)***	1.73 (1.62, 1.85)***	1.74 (1.57, 1.95)***	1.59 (1.50, 1.68)***	1.59 (1.48, 1.69)***	1.59 (1.42, 1.77)***
25–29	3.02 (2.86, 3.18)***	2.88 (2.71, 3.06)***	3.43 (3.11, 3.79)***	2.46 (2.33, 2.59)***	2.37 (2.22, 2.52)***	2.67 (2.41, 2.95)***
30–34	5.04 (4.80, 5.30)***	4.73 (4.46, 5.02)***	5.92 (5.38, 6.52)***	3.77 (3.58, 3.97)***	3.63 (3.41, 3.86)***	4.13 (3.74, 4.56)***
35–39	7.84 (7.46, 8.23)***	7.24 (6.84, 7.68)***	9.45 (8.61, 10.38)***	5.63 (5.35, 5.92)***	5.37 (5.05, 5.71)***	6.25 (5.67, 6.89)***
40–44	10.77 (10.26, 11.30)***	9.80 (9.25, 10.37)***	13.37 (12.18, 14.67)***	7.57 (7.19, 7.97)***	7.20 (6.77, 7.65)***	8.46 (7.67, 9.32)***
45–49	13.82 (13.17, 14.51)***	12.61 (11.92, 13.35)***	17.17 (15.65, 18.85)***	9.66 (9.18, 10.18)***	9.17 (8.62, 9.76)***	10.82 (9.81, 11.94)***
<b>Current Smoker</b>						
Non-Smoker	1	1	1	1	1	1
Smoker	1.60 (1.50, 1.72)***	1.66 (1.54, 1.79)***	1.45 (1.22, 1.71)***	1.01 (0.93, 1.07)	1.01 (0.93, 1.09)	0.98 (0.82, 1.17)
<b>Current Alcohol Use</b>						
Non-Alcoholic	1	1	1	1	1	1
Alcoholic	2.24 (2.11, 2.38)***	2.40 (2.25, 2.57)***	1.74 (1.49, 2.02)***	1.52 (1.42, 1.63)***	1.54 (1.43, 1.66)***	1.48 (1.25, 1.74)***
<b>Current Tobacco Use</b>						
Non-Tobacco	1	1	1	1	1	1
Tobacco User	1.60 (1.54, 1.66)***	1.62 (1.55, 1.69)***	1.59 (1.48, 1.72)***	0.95 (0.92, 0.99)***	0.96 (0.92, 1.01)	0.94 (0.87, 1.02)
<b>Wealth</b>						
Poorest	1	1	1	1	1	1
Poorer	0.98 (0.95, 1.01)	0.98 (0.95, 1.01)	0.96 (0.86, 1.07)	0.91 (0.89, 0.95)***	0.92 (0.89, 0.95)***	0.88 (0.78, 0.98)*
Middle	0.99 (0.96, 1.02)	0.99 (0.96, 1.02)	0.96 (0.87, 1.07)	0.89 (0.86, 0.92)***	0.91 (0.87, 0.94)***	0.81 (0.73, 0.91)***
Richer	1.14 (1.11, 1.18)***	1.13 (1.10, 1.17)***	1.12 (1.01, 1.23)*	0.94 (0.91, 0.97)***	0.97 (0.92, 1.01)	0.88 (0.73, 0.90)*
Richest	1.09 (1.06, 1.13)***	1.11 (1.06, 1.16)***	1.05 (0.96, 1.16)	0.82 (0.79, 0.86)***	0.88 (0.83, 0.94)***	0.78 (0.70, 0.87)***
<b>Education</b>						
No Education	1	1	1	1	1	1
Primary	0.87 (0.84, 0.89)***	0.84 (0.82, 0.87)***	0.88 (0.83, 0.93)**	1.02 (0.99, 1.05)	1.02 (0.99, 1.06)	0.99 (0.94, 1.05)
Secondary	0.54 (0.53, 0.55)***	0.49 (0.48, 0.51)***	0.56 (0.54, 0.58)***	0.89 (0.87, 0.92)**	0.89 (0.86, 0.92)**	0.88 (0.83, 0.92)**
Higher	0.43 (0.42, 0.45)***	0.36 (0.34, 0.39)***	0.42 (0.40, 0.45)***	0.73 (0.70, 0.77)***	0.74 (0.69, 0.78)***	0.73 (0.68, 0.78)***



Table 3. continued

Variables	Unadjusted Odds Ratio (95% CI)			Adjusted Odds Ratio (95% CI)		
	Overall	Rural	Urban	Overall	Rural	Urban
<b>Social Caste</b>						
Caste	1	1	1	1	1	1
Tribe	1.22 (1.18, 1.26)***	1.26 (1.20, 1.30)***	1.18 (1.08, 1.28)***	1.20 (1.15, 1.24)***	1.20 (1.15, 1.26)***	1.16 (1.05, 1.27)**
No Caste/Tribe	1.25 (1.20, 1.31)***	1.32 (1.25, 1.40)***	1.14 (1.06, 1.23)***	1.10 (1.04, 1.15)***	1.10 (1.03, 1.17)**	1.08 (1.00, 1.17)
Don't know	1.05 (0.94, 1.17)	1.29 (1.13, 1.47)***	0.74 (0.62, 0.90)**	1.05 (0.94, 1.18)	1.27 (1.10, 1.46)***	0.78 (0.64, 0.95)*
<b>Religion</b>						
Hindu	1	1	1	1	1	1
Muslim	1.10 (1.07, 1.12)***	1.15 (1.11, 1.19)***	1.01 (0.97, 1.05)***	1.10 (1.07, 1.13)***	1.14 (1.09, 1.19)***	1.05 (1.00, 1.10)*
Christian	1.20 (1.13, 1.27)***	1.26 (1.17, 1.35)***	1.10 (1.00, 1.21)*	0.92 (0.86, 0.98)**	0.90 (0.83, 0.98)*	0.93 (0.84, 1.03)
Others/Not Stated	1.27 (1.21, 1.33)***	1.36 (1.29, 1.45)***	1.11 (1.03, 1.21)**	1.19 (1.13, 1.25)***	1.25 (1.16, 1.33)***	1.08 (0.99, 1.17)
<b>BMI (kg/m<sup>2</sup>)</b>						
Normal (18.5–24.9)	1	1	1	1	1	1
Underweight (< 18.5)	0.57 (0.55, 0.59)***	0.60 (0.59, 0.62)***	0.41 (0.38, 0.44)***	0.69 (0.66, 0.71)***	0.71 (0.69, 0.73)***	0.59 (0.55, 0.64)***
Pre-obesity (25–29.9)	2.44 (2.39, 3.63)***	2.55 (2.48, 2.62)***	2.47 (2.39, 2.57)***	1.98 (1.93, 2.02)***	2.06 (2.00, 2.13)***	1.85 (1.78, 1.93)***
Obesity Class I (30–34.9)	3.50 (3.38, 3.63)***	3.67 (3.48, 3.87)***	3.66 (3.48, 3.85)***	2.76 (2.66, 2.86)***	2.94 (2.77, 3.11)***	2.57 (2.44, 2.71)***
Obesity Class II (35–39.9)	3.81 (3.55, 4.10)***	4.00 (3.55, 4.51)***	4.06 (3.71, 4.45)***	3.00 (2.79, 3.24)***	3.23 (2.85, 3.66)***	2.80 (2.54, 3.08)***
Obesity Class III (> 40)	4.66 (4.09, 5.30)***	3.86 (3.11, 4.79)***	5.65 (4.80, 6.64)***	3.91 (3.42, 4.48)***	3.37 (2.67, 4.24)***	4.18 (3.53, 4.94)***
<b>Zones</b>						
Northern	1	1	1	1	1	1
Central	0.96 (0.93, 0.99)**	0.97 (0.94, 1.01)	0.94 (0.89, 0.99)*	1.01 (0.97, 1.04)	1.04(0.99, 1.06)	0.99 (0.93, 1.05)
Eastern	0.96 (0.93, 0.99)**	0.95 (0.91, 0.99)***	1.02 (0.96, 1.08)	0.91 (0.88, 0.95)***	0.93 (0.88, 0.98)***	0.96 (0.90, 1.03)
Western	1.16 (1.12, 1.20)***	1.12 (1.07, 1.17)***	1.20 (1.14, 1.27)***	1.07 (1.03, 1.11)***	1.09 (1.03, 1.14)***	1.09 (1.03, 1.15)***
Southern	1.06 (1.02, 1.09)***	1.04 (0.99, 1.08)	1.08 (1.02, 1.13)**	0.87 (0.84, 0.91)***	0.86 (0.82, 0.91)***	0.89 (0.83, 0.94)***
North-Eastern	1.91 (1.83, 2.01)***	1.95 (1.85, 2.06)***	1.84 (1.67, 2.03)***	1.85 (1.74, 1.95)***	1.89 (1.77, 2.02)***	1.82 (1.62, 2.04)***
<b>Diet:</b>						
Milk/Curd (N/O)	1	1	1	1	1	1
Milk/Curd (D/W)	0.95 (0.93, 0.97)***	0.93 (0.91, 0.95)***	0.96 (0.92, 0.99)***	0.94 (0.92, 0.96)***	0.93 (0.91, 0.95)***	0.96 (0.92, 1.01)
Pulse/Beans (N/O)	1	1	1	1	1	1
Pulse/Beans (D/W)	1.05 (1.02, 1.09)**	1.07 (1.03, 1.10)*	1.01 (0.95, 1.07)	1.04 (0.99, 1.07)	1.07 (1.02, 1.11)*	0.97 (0.91, 1.02)

Table 3. continued

Variables	Unadjusted Odds Ratio (95% CI)			Adjusted Odds Ratio (95% CI)		
	Overall	Rural	Urban	Overall	Rural	Urban
Vegetables (N/O)	1	1	1	1	1	1
Vegetables (D/W)	1.19 (1.15, 1.22)***	1.16 (1.13, 1.20)***	1.24 (1.18, 1.30)***	1.13 (1.09, 1.17)***	1.11 (1.07, 1.15)***	1.16 (1.10, 1.22)**
Fruits (N/O)	1	1	1	1	1	1
Fruits (D/W)	0.99 (0.97, 1.01)	0.99 (0.97, 1.02)	0.94 (0.91, 0.97)***	0.98 (0.95, 0.99)**	1.00 (0.97, 1.03)	0.94 (0.91, 0.98)***
Eggs (N/O)	1	1	1	1	1	1
Eggs (D/W)	1.07 (1.05, 1.10)**	1.08 (1.05, 1.10)**	1.07 (1.03, 1.10)***	1.06 (1.03, 1.09)***	1.04 (1.01, 1.07)*	1.09 (1.05, 1.14)***
Fish (N/O)	1	1	1	1	1	1
Fish (D/W)	1.11 (1.09, 1.13)***	1.13 (1.10, 1.16)**	1.06 (1.03, 1.09)***	0.98 (0.95, 1.01)	1.01 (0.97, 1.04)	0.91 (0.87, 0.95)***
Chicken/Meat (N/O)	1	1	1	1	1	1
Chicken/Meat (D/W)	0.85 (0.84, 0.86)**	1.09 (1.06, 1.11)***	1.10 (1.06, 1.13)***	1.04 (1.03, 1.07)**	1.02 (0.98, 1.05)	1.09 (1.04, 1.13)***

N/O Never/Occasional, D/W Daily/Weekly

\* $p \leq 0.05$ . \*\* $p \leq 0.01$ . \*\*\* $p \leq 0.001$ 

likely to have undiagnosed hypertension, and this was also more in evidence in rural than urban areas. Muslims, Christians and those who belong to other religions and/or those who did not state their religion had higher prevalence rates than Hindus. Compared to those belonging to Hindu religion, Muslim women living in rural areas were more likely to have undiagnosed hypertension than those living in urban areas. Though any discussion of differences only due to caste and religion is insensitive to their position in local social hierarchies, it could be conjectured that caste and religion do play a role in their choice of diets and lifestyles.

The prevalence rates were lowest in the underweight category (BMI < 18.5 kg/m<sup>2</sup>) and highest in Obesity Class III (BMI ≥ 40 kg/m<sup>2</sup>). It was consistently lower in urban areas as compared to rural areas in all categories except for Obesity Class III (BMI ≥ 40 kg/m<sup>2</sup>). While being underweight was a protective factor, as BMI increased the likelihood of undiagnosed hypertension increased. Underweight women were less likely to have hypertension than normal or overweight women. The effect was more in evidence in rural areas than urban areas for those with BMIs in pre-obesity, obesity class I and obesity class II categories while the prevalence was higher in urban areas than in rural areas for those in obesity class III. Shihab et al., [38] found that the rate of change in BMI over the life course increased the risk of incident hypertension. Lee, Lim and Hong [39] have found a causal association of BMI with hypertension with each 1 kg/m<sup>2</sup> increase in BMI associated with a 19% increase in risk of hypertension. In a longitudinal study by Li et al., [40] it was found that earlier age at onset of overweight, not necessarily obesity, was more strongly associated with subsequent risk of hypertension. Basu and Millett reported that obesity increased the probability of hypertension by 3.7 times [41]. They found greater than 10% prevalence of obesity even among the lowest income quintiles. Obesity is a known risk factor for hypertension [42, 43] though Swain et al., did not find hypertension related to obesity among women [10]. There may be a reverse causality between obesity and hypertension resulting in obesity-induced hypertension. Excess adipocyte tissue stimulates insulin secretion that directly acts on the kidneys and an activated renin-angiotensin-aldosterone system elevates BP [39]. Conversely, obesity and hypertension may have an additive effect on cardiovascular diseases [44]. Thus, the presence of overweight/obesity may provide a useful marker of undiagnosed hypertension.

Those living in the North-Eastern region had the highest prevalence rates while those living in the North region had the least prevalence rates. This may be due to genetic, nutritional or behavioural differences. More focused studies are needed to see if the population in the North-Eastern region are actually more susceptible to hypertension than other populations. Anchala et al., [8] found the pooled prevalence of hypertension for the rural and urban population in North India to be 14.5% and 28.8%. The corresponding figures for East India were 31.7% and 34.5%, for West India 18.1% and 35.8%, and for South India 21.1% and 31.8%. The definition for the four zones was different from the NFHS defined 6 zones in India. Geldsetzer et al., [35] found prevalence of hypertension to be highest in the northern states of Punjab and Himachal Pradesh, the southern state of Kerala, and the north-eastern states of Sikkim and Nagaland. They had no data available for Jammu and Kashmir and Gujarat. A WHO-STEPs cross-sectional survey in Punjab found an overall prevalence of 40.1% with 28.7% of cases being newly diagnosed in rural areas and 27.2% being newly diagnosed in urban areas [42].

Women who ate Milk/Curd on a never/occasional basis had a slightly higher prevalence level of undiagnosed hypertension than those who ate Milk/Curd on a daily/ weekly basis. This shows that consuming dairy may have a protective effect. In multivariate logistic regression analyses, diet showed a limited effect on undiagnosed hypertension which was more visible in the urban areas than rural areas. Having milk, vegetables and fruits on a daily/ weekly basis had a consistently protective effect compared to

having them never/occasionally. The scientific community recognizes food types that are either under consumed (fruits, vegetables, legumes, whole grains, nuts and seeds, milk, fibre, calcium, omega-3 fatty acids from plants/seafood, and polyunsaturated fatty acids) or overconsumed (red meat, processed meat, sugar-sweetened beverages, saturated fats, trans-fatty acids, dietary cholesterol and sodium) [28, 45]. Since prevalence was high in the union territories of Lakshadweep, Andaman and Nicobar and Daman and Diu, it may be proposed that the higher prevalence of undiagnosed hypertension was related to their proximity to the sea and their diets since these are island communities. Kerala is also a coastal state and the same may be true. However, we did not do a state-wise analyses of risk factors and hence are unable to make such deductions. Similarly, a proximation of prevalence in the urban and rural areas shows the rapid urbanization of rural areas and these states should be targeted to promote good cardiovascular health aggressively. Though it is difficult to track the actual consumption of these food items in a large population-based study, there is a need to spread awareness and availability about a healthier diet among the general population.

### CONCLUSION AND PERSPECTIVES

Hypertension is a modifiable risk factor for cardio-vascular diseases (CVDs). Hypertension is reported to be higher in low-SES groups, poorer and more rural areas than in richer urban centres in several high-income countries [29]. India's economic rise and rapid urbanisation have led to a confluence of prevalence of hypertension among the urban and rural populations and is often under-reported. Fuchs and Whelton [46] have postulated:

a biologically normal level of BP in humans is considerably lower than what has been traditionally employed in clinical practice and research, leading to an underrepresentation of the role that BP plays as a risk factor for CVD.... Recognizing the potential for underestimation, other confounding risks increase concomitantly with BP, but in clinical trials the absolute risk reduction from BP-lowering accounts for nearly all of the predicted risk, leaving little residual risk to be explained by the other concomitant risks.

It is important that we recognise the short term (stroke, coronary heart disease, heart failure, cardiovascular death) and long term (hypertensive cardiomyopathy, heart failure with low ejection fraction, atrial fibrillation, valvular heart disease, aortic syndromes, peripheral arterial disease, chronic kidney disease, dementias, diabetes mellitus and erectile dysfunction) detrimental effects of elevated BP [46]. It is also important to note that the burden of CVD has shifted from high-income countries to low-and middle-income countries. There are multiple factors for this shift, chief among which are that population detection rates have stabilized in High-income countries while ageing, greater access, increased buying power, social and cultural changes due to greater physical and internet connectivity are allowing for higher detection rates in low-and middle-income countries. However, these higher rates may not be gender-neutral. Therefore, it is important to recognise that women in poorer and poor wealth quintiles remain vulnerable to undiagnosed hypertension in a low- and middle-income country such as India. High sodium and low potassium intake should be monitored so that effective strategies could be devised for the poorer populations. Dietary controls may be difficult to implement in rural settings where a woman cooks food for the entire family who may not wish to have a saltless or low salt diet. Secondly, obesity or higher BMIs should be looked at in conjunction with waist-to-hip ratio or computed tomographic measures of central fat distribution [28]. Our study did not look at these factors nor did we include factors such as air pollution, psychological stress, sleep disorders and noise exposure, which may contribute to women

having undiagnosed hypertension. Similarly, the concept of physical activities/ exercise does not exist for women in rural settings even though their daily routine is more physically challenging than of women in urban settings. While our study recognises several risk factors such as age, alcohol consumption and higher BMIs for undiagnosed hypertension, pro-active interventions such as greater and more informed awareness, dietary controls and physical exercise can help reduce the burden of this disease among women aged 15–49 years in India and also encourage healthier lifestyles that would delay the onset of hypertension in later life.

### SUMMARY

What is known about topic

- Raised blood pressure causes 7.5 million deaths annually.
- Factors associated with hypertension include age, higher BMI, poor access to health facilities, rural area of residence and irregular lifestyles.

What this study adds

- Our study focuses on undiagnosed hypertension among women in the reproductive age group, 15–49 years.
- Nearly half the women aged 15–49 years in India with hypertension are unaware about it.
- Overall prevalence of undiagnosed hypertension was 7.89% in rural areas compared with 8.38% in urban areas in India.

### DATA AVAILABILITY

The datasets generated during and/or analysed during the current study are available in the DHS repository. The DHS website provides access to data on submission and approval for a proposal of study. DHS website: <http://dhsprogram.com/data/new-user-registration.cfm>.

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#### AUTHOR CONTRIBUTIONS

VT and DT conceived and designed the study, analyzed the data, and prepared the first draft; ST and MT reviewed study results and write up.

#### COMPETING INTERESTS

The authors declare no competing interests.

#### ETHICS APPROVAL

The NFHS-4 (2015–16) survey strictly adhered to internationally recognized ethical guidelines for medical research [15]. This study is based on publicly available DHS data, which contains no identifiable information about survey participants, thereby rendering it exempt from the requirement of ethical review.

#### ADDITIONAL INFORMATION

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