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REVIEW ARTICLE

Emerging trends in hypertension epidemiology in India

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Abstract

Hypertension is the most important risk factor for chronic disease burden in India. Studies from various parts of India have reported high prevalence of hypertension. These studies have also reported that hypertension is increasing and there is low awareness and control. Two recent studies have been conducted with uniform tools and nationwide sampling to determine the true prevalence of hypertension in the country. Fourth National Family Health Survey evaluated hypertension in a large population based sample ($n = 799{,}228$) and reported hypertension in 13.8% men vs. 8.8% women (overall 11.3%) aged 15–49 and 15–54 respectively. More representative data (age > 18 years, $n = 1{,}320{,}555$) in Fourth District Level Household Survey reported hypertension in 25.3% with greater prevalence in men (27.4%) than women (20.0%). This translates into 207 million persons (men 112 million, women 95 million) with hypertension in India. Prevalence would be much higher using 2017 American guidelines. Global Burden of Diseases study reported that hypertension led to 1.63 million deaths in India in 2016 as compared to 0.78 million in 1990 (+108%). The disease burden (DALYs) attributable to hypertension increased from 21 million in 1990 to 39 million in 2016 (+89%). Social determinants of hypertension are important and Indian states with greater urbanization, human development and social development have more hypertension. There is poor association of hypertension prevalence with healthcare availability although there is positive association with healthcare access and quality. The health system in India should focus on better hypertension screening and control to reduce cardiovascular morbidity and mortality.

Introduction

Raised blood pressure (BP) has emerged as the most important risk factor for global morbidity and mortality. The latest iteration of Global Burden of Diseases (GBD) study has reported that high systolic BP, poor dietary intake and tobacco use are most important risk factors for mortality as well as morbidity [1]. GBD has reported that in 2017, high systolic BP was the leading risk factor globally, accounting for 10.2 million [95% uncertainty intervals (UI) 9.16–11.3 million] deaths and 208 million (UI 188–227 million) disability adjusted life years (DALYs). Overall, 8.61% (UI 7.66–9.56) of total DALYs were attributable to high SBP. Most of the burden attributable to high SBP was due to ischemic heart disease and stroke, and high SBP accounted for 55.5% (UI 48.0–62.7) and 56.5% (UI 49.0–63.2) of DALYs due to ischemic heart disease and stroke, respectively [1]. In India also, it has emerged as the most important risk factor for deaths and disability [2]. According to reports from World Health Organization (WHO) [3], GBD study [4], and Non-Communicable Disease Risk Factor Collaboration (NCDRiSC) [5] prevalence of hypertension is increasing globally and currently more than 1 billion people have hypertension (defined with standard criteria as systolic BP ≥ 140 and/or diastolic BP ≥ 90 mm Hg). NCDRiSC study reported that number of adults with high BP increased from 594 million in 1975 to 1.13 billion in 2015 and the increase was mostly in low-income and middle-income countries [5]. In this article we review emerging data on hypertension prevalence in India using systematic reviews of previous epidemiological studies, two recent large nationwide surveys and GBD study estimates for determining the burden of hypertension in India. We

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Table 1 Hypertension prevalence in studies among urban populations

First author	Year reported	Place	Age group	Sample size	Prevalence (%)
Gupta	1995	Jaipur	≥20	2212	30.9
Anand	2000	Mumbai	30–60	1662	34.0
Gupta	2002	Jaipur	≥20	1123	33.4
Shanthirani	2003	Chennai	≥20	1262	21.1
Gupta	2004	Mumbai	≥35	88653	47.9
Prabhakaran	2005	Delhi	20–59	2935	30.0
Reddy	2006	Multisite	20–69	19973	27.2
Mohan	2007	Chennai	≥20	2350	20.0
Kaur	2007	Chennai	18–69	2262	27.2
Yadav	2008	Lucknow	≥30	1746	32.2
Gupta	2012	National	≥35	2616	48.2
Prince	2012	Chennai	≥60	1000	60.0
Gupta	2012	Jaipur	≥20	739	32.1
Joshi	2012	Multisite	49(mean)	15662	46.0
Gupta	2013	Multisite	≥20	6106	31.5
Bhagyalaxmi	2013	Gujarat	15–64	1805	29.0
Bhansali	2014	Multisite	>20	14059	26.3
Sharma	2015	Ahmedabad	≥20	2483	57.3
Krishnan	2016	Kerala	≥18	5167	28.0
Thakur	2016	Punjab	18–69	5127	40.1
Gupta	2017	Multisite	35–70	15846	38.6
Tripathy	2017	Punjab	18–69	1991	40.4

have also summarized association of hypertension prevalence in various Indian states with macrolevel social determinants and healthcare availability, access and quality.

Systematic reviews of epidemiological studies

In India, multiple reviews of previous studies of hypertension epidemiological studies have been conducted. All have reported a significant and increasing burden of hypertension [6–9]. This increase has been reported from urban as well as rural areas of India. In mid-1950s, epidemiological studies from urban populations in India used older World Health Organization criteria for diagnosis of hypertension (known hypertension or BP ≥ 160 mm Hg systolic and/or 95 mm Hg diastolic) reported it in 1.2–4.0% adults [6]. Subsequent studies have and reported that prevalence of hypertension in urban locations increased from 3.0 to 4.5% in 1960's to 11.0–15.5% in mid 1990's [6]. Although prevalence of hypertension was lower in rural populations in mid-20th century, there has been a significant increase in hypertension in these populations from >1% in 1960's to 5–7% in 1990's [6, 7].

Systolic BP of ≥140 and/or diastolic BP of ≥90 mmHg is the currently accepted standard threshold for diagnosis of hypertension worldwide, although the 2017 American College of Cardiology/American Heart Association (ACC/AHA) hypertension guidelines have proposed a lower threshold of ≥130 and/or ≥80 mmHg [10]. Many epidemiological studies of hypertension prevalence that have defined it by the standard criteria have been performed in India. These studies in urban and rural populations are shown in Tables 1 and 2, respectively [9]. Most of these studies are regional. In combination, these studies show increasing trend in hypertension prevalence from mid 1990's to the present in urban as well as rural populations with greater increase in urban populations (R^2 urban 0.10068, rural 0.04605) (Fig. 1).

There are only a few multicentric studies in India that have determined prevalence of hypertension using similar tools. All these studies reveal that hypertension is more in urban populations as compared to the rural (Fig. 2) [8]. A recent review which included many of these studies reported that hypertension has increased more rapidly in rural populations as compared to the urban and there is an urban-rural convergence in its prevalence [9]. These studies also show that one in four adults in India have hypertension. This is similar to other countries in the developing world and only slightly lower than prevalence in the developed countries [3]. There are, however, multiple limitations of these studies. The studies are mostly confined to a small geographical region, and have a wide variability in methodology. Other limitations include variability in age-groups

Table 2 Hypertension prevalence in studies among rural populations

First author	Year reported	Place	Age group	Sample size	Prevalence (%)
Gupta	1994	Rajasthan	≥20	3148	16.9
Kusuma	2004	Andhra	≥20	1316	21.0
Hazarika	2004	Assam	≥30	3180	33.3
Krishnan	2008	Haryana	15–64	2828	9.3
Todkar	2009	Maharashtra	≥20	1297	7.2
Bhardwaj	2010	Himachal	≥18	1092	35.9
By	2010	Karnataka	≥18	1900	18.3
Kinra	2010	Multisite	20–69	1983	20.0
Gupta	2012	Multisite	>35	4624	31.5
Prince	2012	Tamilnadu	>65	1000	29.0
Kaur	2012	Tamilnadu	25–64	10463	21.4
Kokiwar	2012	Tamilnadu	>30	924	19.0
Dutta	2012	West Bengal	>18	1186	24.7
Borah	2012	Assam	>30	916	55.6
Haddad	2012	Kerala	18–96	1660	23.5
Bansal	2012	Uttarakhand	>18	968	28.9
Meshram	2012	Kerala	>20	4193	40.0
Bhagyalaxmi	2013	Gujarat	15–64	1684	15.4
Menon	2014	Kerala	≥18	84456	11.8
Laxmaiah	2015	Multisite Tribal	≥20	47401	26.7
Negi	2016	Himachal	20–70	3582	19.7
Gupta	2017	Multisite	35–70	17577	26.3
Tripathy	2017	Punjab	18–69	3064	40.0

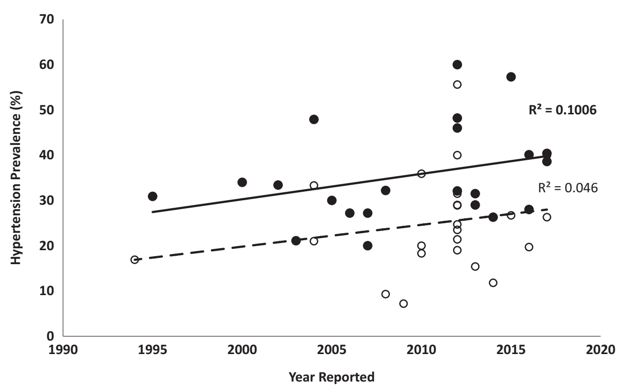

Fig. 1 Increasing trend in hypertension prevalence in India in urban (top panel) and rural (bottom panel) populations according to cross-sectional regional studies from 1990's to date. The increase is greater in urban ($R^2 = 0.101$) compared to rural ($R^2 = 0.046$) studies. Data are from Tables 1 and 2. Size of bubbles corresponds to number of participants in each study

studied (>20 years, 20–75 years, 35–64 years, 35–70 years, etc), different types of BP instruments (mercury, aneroid, or electronic), number of readings (1 vs. 3), days of measurement (usually single but more than a day in some), method of averaging (all three, last two readings, or the lowest reading) and others [7–9].

Systematic reviews of various local and regional hypertension epidemiological studies in India have reported that hypertension is present in 25–30% urban and 10–20% rural adults [7–9]. These reviews have also reported that there are regional variations in its prevalence. These rates may, therefore, not be truly representative. Multisite studies that determined prevalence of hypertension using similar tools in multiple regions of the country are few. These studies are limited to either industrial workers [11], women of lower socioeconomic status [12], men and women from middle class locations [13], urban and rural men and women at select locations [14–17], or rural men and women [18]. Hypertension prevalence in these studies varies from 15 to 20% in rural and 20–35% in adult participants (Fig. 2). All these studies lack national representativeness.

Anchala et al. [8] performed a meta-analysis of all major hypertension prevalence studies in India. They obtained studies from leading medical databases—*Medline, Web of Science, Scopus*, etc.—from years 1950 to 2013. These studies were assessed for prevalence, awareness and control of hypertension. From a total of 3047 studies identified, 142 were included. This review reported that the overall estimated prevalence for hypertension in India was 29.8% [95% confidence interval (CI) 26.7–33.0]. Significant

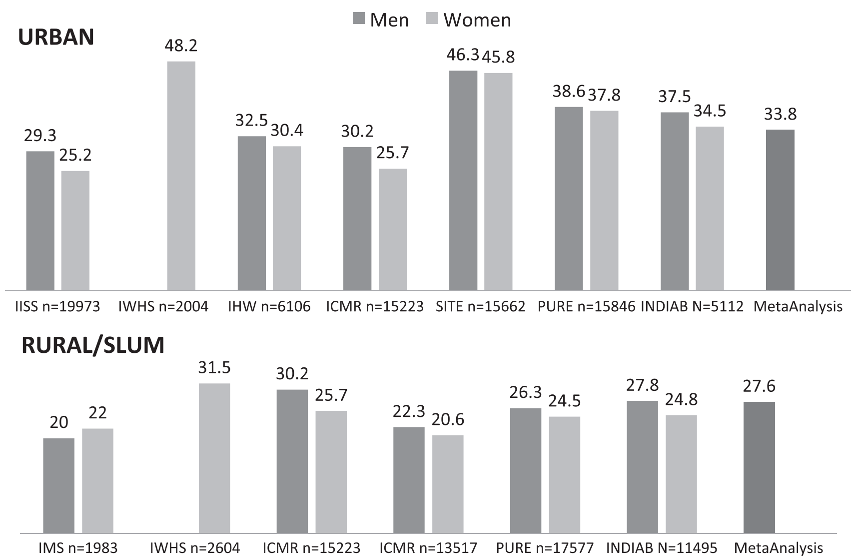

Fig. 2 Recent multisite studies of hypertension prevalence in Indian urban and rural populations. Study acronyms: IISS Indian Industrial Surveillance Study [11]; IWHS India Women Health Study [12]; IHW India Heart Watch [13]; ICMR Indian Council of Medical Research Study [14]; SITE Study for Investigation of Twin Epidemic [15]; INDIAB Indian Diabetes Study [16]; PURE Prospective Urban Rural Epidemiology Study [17]; IMS India Migration Study [18]; and meta-analysis by Anchala et al. [8]

differences in hypertension prevalence were noted between rural (27.6%, CI 23.2–32.0) and urban (33.8%, CI 29.7–37.8) studies ($p = 0.05$]. There were differences in regional estimates of hypertension prevalence and these were, in rural populations: north 14.5% (13.3–15.7), east 31.7% (30.2–33.3), west 18.1% (16.9–19.2), and south 21.1% (20.1–22.0); and in urban populations: north 28.8% (26.9–30.8), east 34.5% (32.6–36.5), west 35.8% (35.2–36.5), and south 31.8% (30.4–33.1), respectively. In this review, hypertension was more in eastern regions of the country as compared to others. It was suggested that more studies to detect true prevalence of hypertension in the country were required. The study also reported low awareness, treatment and control of hypertension in both urban and rural studies [8]. In urban vs. rural participants with hypertension it was reported that awareness was in 42% vs. 25%, treatment in 38% vs. 24% and control in 20% vs. 11% with large regional variations.

Some years ago, we recommended that periodic surveys conducted by the government of India, e.g., National Family Health Surveys (NFHS), National Statistical Survey Organization (NSSO) surveys and District Level Household Surveys (DLHS) should focus on hypertension screening using standardized tools and uniform methodology [9]. Government of India, under the National Program for Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke, has initiated a large project of opportunistic screening in India [19]. In the first phase of this program more than 5.5 million adults were screened and it was reported that 6.15% participants were suffering from diabetes while hypertension was in 5.12% [19]. These numbers are clearly an underestimate and much lower that the government sponsored studies by Indian Council of Medical Research as well as recent national studies [14, 20, 21].

National Family Health Survey-4

The Fourth National Family Health Survey (NFHS-4) has focused on obtaining multiple adult socioeconomic, demographic and lifestyle factors using a nationally representative sample [20]. For the first time, this survey also determined prevalence of hypertension among young and middle-aged men and women in India using a representative sampling across the country [2]. The survey was performed in urban and rural areas of the country [22]. A uniform sampling method was adopted in all districts of the country. A whole village was the primary sampling units for rural areas while for urban it were census enumeration blocks. Field research agencies from across the country were recruited and provided lists of sampling units for each selected state or union territories. NFHS-4 was designed to provide information on various demographic parameters, family welfare and health indicators at the state level and, for the first time, at a district level. Because of this requirement, NFHS-4 sample size was increased to 571,660 households, as compared with 109,041 households in NFHS-3 [20]. In this survey, 601,509 households which included 699,686 women and 103,525 men from 28,583 primary sampling units in 640 districts of the country were evaluated. In NFHS-4, clinical, anthropometric and biochemical evaluation included measurement of random blood glucose and standardized BP measurements. Data were reported at the district level for women aged 15–49 and men aged 15–54 using proportionate sampling. All physiological measurements were performed using portable equipment. An automatic battery operated BP instrument was used. Only medical or paramedical personnel with specific training in study methodology were involved in the survey. Detailed methodology of BP measurement are available at NFHS-4 website [20] and have been reported

Table 3 Hypertension Prevalence (%) in Young Men (15–54 years) and Women (15–49 years) in National Family Health Survey (NFHS-4)

State (alphabetic)	Sample size	Hypertension (known or BP ≥ 140/90 mmHg)		
		Men	Women	Total
Andaman and Nicobar	3219	27.9	9.0	18.5
Andhra Pradesh	11,826	16.2	10.0	13.1
Arunachal Pradesh	16,224	21.6	15.0	18.3
Assam	32,307	19.6	16.0	17.8
Bihar	51,243	9.4	5.9	7.7
Chandigarh	866	13.5	9.3	11.4
Chhattisgarh	28,701	12.7	8.8	10.8
Delhi	6586	4.2	7.6	5.9
Goa	2457	13.2	8.5	10.9
Gujarat	28,506	13.0	9.7	11.4
Haryana	25,032	16.8	9.2	13.0
Himachal Pradesh	12,114	21.9	12.1	17.5
Jammu and Kashmir	29,384	13.7	11.6	12.7
Jharkhand	32,866	12.2	7.8	10.0
Karnataka	30,034	15.4	9.7	12.6
Kerala	12,897	9.5	6.8	8.2
Madhya Pradesh	72,313	10.9	7.9	9.4
Maharashtra	33,957	15.9	9.1	12.5
Manipur	15,342	20.4	11.4	15.9
Meghalaya	10,347	10.4	9.9	10.2
Mizoram	13,896	17.9	9.8	13.9
Nagaland	12,230	23.1	16.0	19.6
Odisha	37,930	12.5	9.0	10.8
Punjab	22,511	21.8	13.2	17.5
Pondicherry	4618	15.1	9.1	12.1
Rajasthan	47,857	12.4	6.9	9.7
Sikkim	6096	27.3	16.5	21.9
Tamilnadu	33,614	15.5	8.3	11.9
Telangana	8625	18.2	10.1	14.2
Tripura	5623	13.6	12.6	13.1
Uttarakhand	19,290	17.2	9.6	13.4
Uttar Pradesh	110,600	10.1	7.6	8.9
West Bengal	20,057	12.4	10.3	11.4
Total	799,228	13.6	8.8	11.3

earlier [23]. Standard international guidelines have been used for BP measurement [10]. Sitting BP was measured while the participant was sitting in a chair quietly for 5 min, three readings at 5-minute interval were obtained and the last two averaged for the final BP calculation.

We obtained the hypertension prevalence data from the NFHS website [20]. Hypertension prevalence in various states of India among men and women is reported in Table 3. The sample sizes were population proportionate

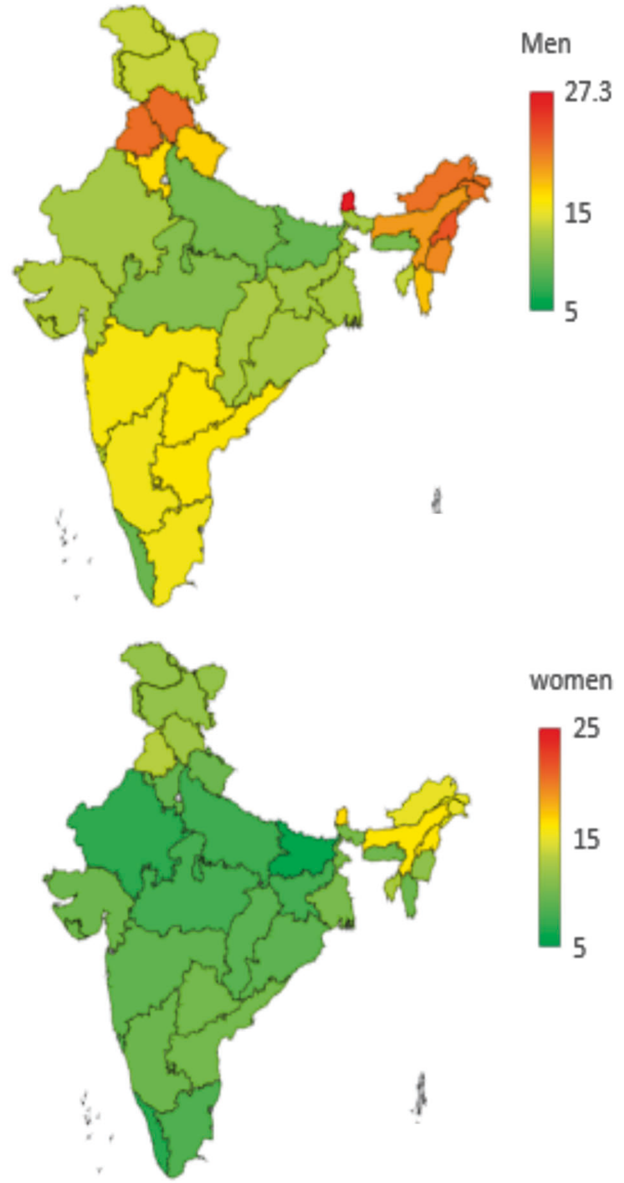

Fig. 3 Heat map showing hypertension prevalence in various states of India in National Family Health Survey-4

and data shows that there are significant differences in prevalence of hypertension in different states of the country. Hypertension prevalence is much greater in southern, north-eastern and north-western states of the country and is significantly greater in men as compared to women (Table 3). Of the 33 states that are represented in Table 3, hypertension prevalence of >15% has been observed in 8 (24.2%) and low prevalence (<5%) in 6 (18.2%) states. NFHS-4 has reported that the overall country-level prevalence of hypertension among the younger age individuals (men 15–49 years, women 15–54 years) in India is 13.6% in men, 8.8% in women and 11.3% overall [20]. It also shows that the prevalence is significantly greater in urban as compared to rural locations: men 15.1% vs. 12.6%, women 9.6% vs.

8.5% ($p < 0.01$). A surprising finding is that the urban-rural difference is not as large as reported in earlier regional studies (Fig. 2). Figure 3 is heat-map showing prevalence of hypertension among men and women in various states of India. Prevalence of hypertension is the highest in northern and north-eastern states that include Punjab, Himachal Pradesh, Assam and North-eastern states while the lowest prevalence is observed in central Indian states extending from Rajasthan in the west to Bihar in the east.

Limitations of the NFHS-4 have been discussed earlier [23]. A major shortcoming of the overall NFHS program (NFHS-1 to NFHS-4 studies) has been exclusion of older age adults. It is well known that hypertension prevalence increases with age [24], and if this high risk group is excluded, the prevalence of hypertension would be lower as compared to previous regional studies. On the other hand, the Prospective Studies Collaboration (Oxford) has reported that intervention and control of hypertension at a younger age is associated with greater benefit in terms of vascular protection and reduction of cardiovascular mortality and morbidity [24]. Therefore these data are important and convey an important message to healthcare providers and policy-makers.

District level household survey-4

Government of India along with the Registrar General of India have developed a more robust method to estimate a few cardiovascular risk factors (overweight, obesity, hypertension, and diabetes) in all states of the country [25]. In this program a standardized measurement of BP and data on hypertension prevalence are being obtained since the year 2012. Geldsetzer et al pooled data from District Level Household Survey-4 (DLHS-4) and Annual Health Survey (AHS). These large surveys were undertaken between the years 2012–2014 [21]. The methodology of measurement of BP was similar to the NFHS-4 [20]. The data obtained are representative at the district level of India and jointly cover 29 states. Data from 2 states- Gujarat and Jammu & Kashmir- were not available to the investigators. Results of this study have been published [21]. In this study, out of 1,320,555 adults, there were 46.9% men and 53.1% women. The unadjusted prevalence of hypertension reported in the study was 25.3% (95% CI 25.0–25.6%) with greater prevalence in men (27.4%, CI 27.0–27.7%) compared to women (23.6%, CI 23.3–23.8%). Age-standardized prevalence was significantly greater in men (24.5%, CI 24.2–24.9%) as compared to women (20.0%, CI 19.7–20.3%). The prevalence was greater in urban than rural participants. The age-standardized prevalence in different states ranged from a low of 13.5% (CI 12.2–14.9%) among women in Chhattisgarh to a high of 43.5% (CI 38.3–48.9%) among men in Daman and Diu.

Table 4 Hypertension prevalence in adult men and women in district level household survey (DLHS-4)

	Men (%)	Women (%)	Total (%, weighted average)
Andaman and Nicobar Island	37.2	26.3	32.1
Andhra Pradesh	28.3	20.7	24.5
Arunachal Pradesh	27.7	21.4	24.7
Assam	21.3	16.8	19.1
Bihar	20.2	20.8	20.5
Chandigarh	41.8	31.3	37.0
Chhattisgarh	17.1	13.5	15.3
Daman and Diu	43.5	36.3	40.8
Goa	32.9	26.4	29.7
Haryana	28.1	20.3	24.5
Himachal Pradesh	38.5	30.8	34.7
Jharkhand	24.7	18.8	21.8
Karnataka	25.5	21.0	23.3
Kerala	41.4	33.0	37.0
Madhya Pradesh	19.9	16.7	18.3
Maharashtra	28.2	21.8	25.1
Manipur	25.7	17.6	21.7
Meghalaya	22.9	18.3	20.6
Mizoram	24.5	14.8	19.7
Nagaland	39.6	31.8	35.8
NCT of Delhi	27.9	22.4	25.4
Odisha	17.2	15.6	16.4
Puducherry	27.3	17.6	22.4
Punjab	41.4	29.4	35.7
Rajasthan	23.7	16.5	20.2
Sikkim	36.2	30.4	33.5
Tamil	27.7	18.8	23.3
Telangana	26.5	19.6	23.1
Tripura	22.4	18.8	20.6
Uttar Pradesh	20.5	18.2	19.4
Uttarakhand	32.2	22.3	27.4
West Bengal	22.6	21.0	21.8

The study also reported that even among the younger age participants (18–25 years) hypertension was common with prevalence of 12.1% (95% CI 11.8–12.5%). There was significant positive association of socioeconomic status with hypertension prevalence although being in the richest vs poorest household was associated with only a small difference (Δrural 4.15%, Δurban 3.47%). This suggests a convergence of urban-rural and a poor-rich difference in hypertension in India. Similar findings have been reported in earlier reviews and studies [9, 26]. DLHS study also reported significant differences in prevalence of hypertension across the Indian states with age-adjusted prevalence varying from 18.0 to 41.6% as shown in Table 4; Fig. 4.

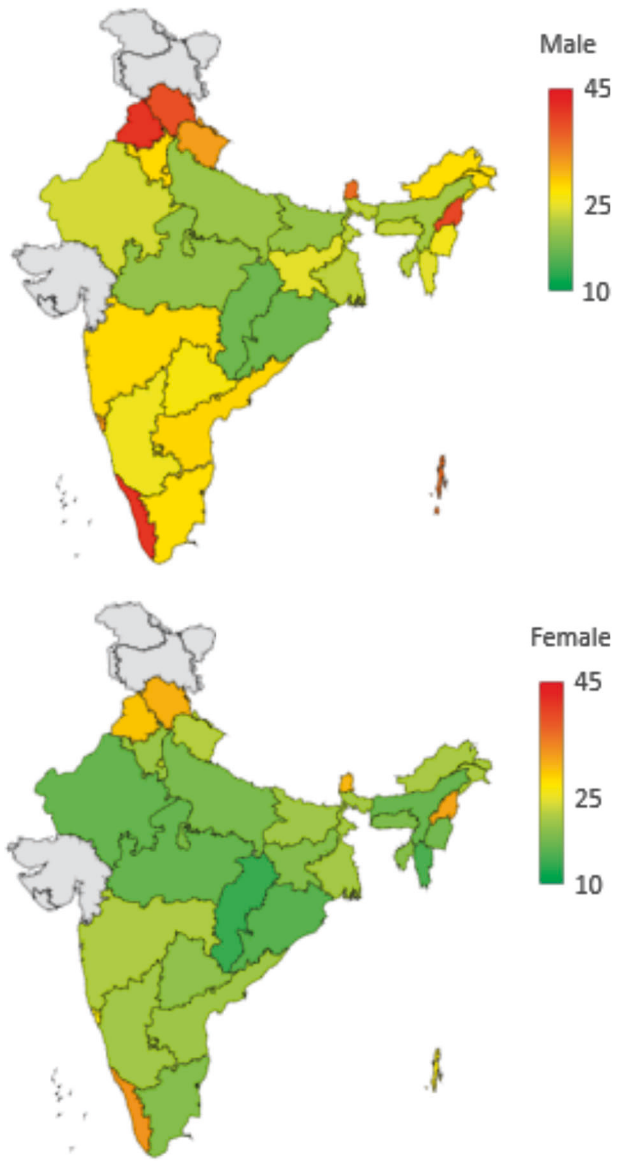

Fig. 4 Hypertension prevalence in various states of India in district level household survey

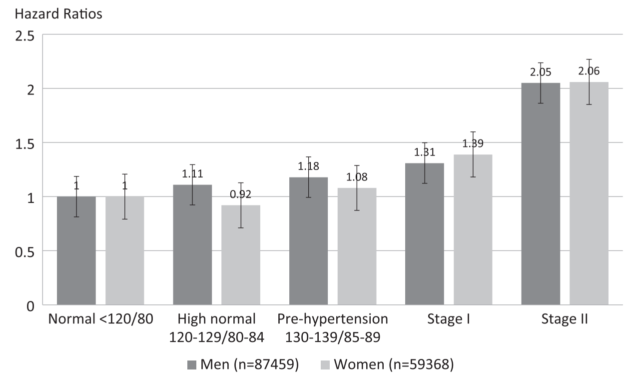

Fig. 5 Increase in cardiovascular mortality with increasing levels of BP in India (Mumbai Cohort Prospective Study, $n = 146,727$; follow-up data 774,139 person years). Hazard ratios of cardiovascular mortality are significantly greater in men with high normal BP (120–129/80–84 mm Hg) and men and women with pre-hypertension (130–139/85–89 mmHg) and stage I and stage II hypertension [27].

This study concluded that there was a high prevalence of hypertension across all socioeconomic groups in India. The prevalence of hypertension was high even among the young age individuals. This is similar to previous regional studies in India [8]. The epidemiological evidence of high hypertension prevalence in India should prompt the Indian governments to increase its efforts on better hypertension screening, detection, treatment and control.

A prospective study in Mumbai, India has reported that even mild to moderate elevation of BP (high-normal and pre-hypertension range 120–139/80–89 mmHg) was associated with significantly greater risk of cardiovascular mortality, especially in men (Fig. 5) [27]. High normal BP is widely prevalent in India, both in urban and rural populations [13, 28]. High normal BP has been recognized as an important risk factor for cardiovascular diseases in 2017 American guidelines [10]. Policy-level efforts to control intake of salt and alcohol and to promote physical activity are essential in this regard, especially to prevent and control the epidemic of high-normal or borderline hypertension.

There is a significant association of state-level hypertension prevalence among NFHS-4 and DLHS studies in both men ($r = 0.55$, $p = 0.004$) and women ($r = 0.35$, $p = 0.077$). This suggests that high BP in the younger population, as observed in NFHS-4, has tracked into the older age as in DLHS-4. This has important implications for primordial prevention of hypertension [10]. These associations suggest that policies for reducing weight, dietary salt and fat, alcohol and sedentariness and promoting fruit and vegetable intake in India should begin at younger age groups in all regions of the country.

Global burden of disease study

The Global Burden of Diseases (GBD) study has estimated mortality and morbidity from various diseases and burden of multiple health risk factors for the last two decades [1]. Since the year 2010, the investigators have estimated burden of disease from various factors from the year 1990 onwards [29]. High BP has emerged as the most important risk factor for disease burden globally and the estimates from GBD 2016 study suggest that more than 12% of global deaths were attributable to this risk factor [1]. Estimated data on deaths and disability adjusted life years (DALYs) for India are available at GBD website [30].

Table 5 shows secular trends in deaths and DALY's attributed to high systolic BP for India. High systolic BP led to 784,700 deaths in 1990 which more than doubled to

Table 5 Increasing trends in deaths and disability adjusted life years (DALYs) due to high systolic blood pressure in India (Global Burden of Diseases Study 2016)

	1990	1995	2000	2005	2010	2016
Deaths						
Absolute numbers (thousands)	784.7	885.3	1005.0	1153.6	1385.6	1634.7
Death Rate/ 100,000	90.8	92.7	95.9	101.3	113.1	124.2
% of total deaths	8.9	9.9	10.8	12.2	14.4	16.7
DALY's						
Absolute numbers (millions)	20.9	23.4	26.2	29.3	34.4	39.4
DALY Rate/ 100,000	2415	2451	2497	2576	2807	3000
% of total DALYs	3.9	4.4	5.0	5.7	7.0	8.5

1,634,7000 deaths in 2016, an increase of 108.3%. The death rate increased from 90.8/100,000 in 1990 to 124.2/ 100,000 in 2016, an increase by 36.8%. Similarly, absolute number of DALY's lost due to hypertension increased from 20.86 million in 1990 to 39.41 million in 2016 (increase by 88.9%) and DALY's/100,000 increased from 2415 in 1990 to 3000 in 2016, an increase by 24.2%. These increases in deaths and DALY's from hypertension in India are in contrast to high-income countries, where the rates are declining [30]. Absolute number of patients with hypertension is not available for India but increasing trends in DALYs and other parameters confirms that hypertension is increasing in the country and is one of the most important cause of deaths and disability [2].

In 2016, GBD study for the first time estimated subnational (state-level) causes of deaths and risk factors in India [31]. However, details of hypertension and related morbidity and mortality are not yet available. It is expected that future iterations of GBD study shall have these data. However, as GBD study estimates are based on synthesis of real-time data from various national and subnational studies, it is expected that the study shall report similar state-level differences as highlighted in the present review.

Association of hypertension with macrolevel risk factors

There are multiple reasons for increasing hypertension prevalence in India. These include individual-level factors such as unhealthy lifestyles- sedentary habits, unhealthy diet (high calorie, high unrefined carbohydrate, high fat, high salt and high alcohol intake, low fruits, and vegetables intake) and stress, overweight, obesity, abdominal obesity, insulin resistance and various genetic factors. Complex interplay of these factors is involved in the pathogenesis of hypertension [32]. All these factors are widely prevalent in India and are well known and, therefore, have not been highlighted in the current review. Factors specific to South Asian and Indians have been highlighted earlier and include overweight and obesity especially abdominal adiposity, diabetes, smoking and alcohol consumption, nutrition transition, and sedentary lifestyles [33].

Data on association of hypertension with various social, economic, developmental and other social determinants of health are sparse in India. A review highlighted importance of epidemiological transition with increasing prevalence of hypertension in India [34]. There is evidence that urban-rural differences in hypertension are decreasing and there is an urban-rural convergence [9]. Similar data are reported in the DLHS study [21]. To determine association of prevalence of hypertension in different states in India with various social determinants we performed a macro-level analysis.

We used data on hypertension prevalence available from the DLHS (Table 4) and correlated it with various social determinants of health, healthcare availability and other factors. These factors include state-level human development index (HDI) derived from income, education and fertility statistics [35], social development index (SDI) derived from multiple socioeconomic factors [36], urbanization index (UI), a ratio of urban to rural population [37], epidemiological transition index (ETI), a ratio of communicable to non-communicable disease mortality [31], healthcare availability index (HAI, availability of facilities at primary care [38], and healthcare access and quality index (HAQI) [39] from GBD study group. Data for individual states are shown in Table 6.

We calculated Pearson's correlation coefficient (r) for each of these variables using state-level hypertension prevalence data from Table 4 (DLHS-4) and state-level socioeconomic factors (Table 6). Results (Table 7) show that there is a significant positive association of HDI and SDI with hypertension prevalence at a macro level suggesting that these factors are important. The findings are graphically depicted for men and women in Fig. 6. These findings are also similar to results from 11-city India Heart Watch study where it was reported that hypertension prevalence was greater in cities with greater HDI and SDI [40]. There is a weak positive association (insignificant) with urbanization suggesting that urban-rural differences in hypertension prevalence in India are low. Projections show that hypertension would be more common in rural areas of India in near future [9]. This would be, then, similar to high- and middle-income countries where hypertension is more common in rural areas [3, 4]. Significant inverse association of hypertension with ETI (more hypertension in states with lesser communicable, childhood and maternal mortality) and positive association with state-level prevalence of

Table 6 Socioeconomic, healthcare, and health-related variables in different states of India

	Human development index (HDI)	Social development index (SDI)	Urbanization index (UI)	Epidemiological transition index (ETI)	Healthcare availability index (HAI)	Healthcare access & quality index (HAQI)	Overweight/ Obesity (%)		Smoking/ Tobacco use (%)	
Data sources	Government of India	Government of India	Census of India	GBD Study	NITI Aayog	GBD Study	National Family Health Survey-4		National Family Health Survey-4	
							Men	Women	Men	Women
Andaman and Nicobar	–	–	35.67	–	50.00	54.3	–	–	–	–
Andhra Pradesh	0.309	0.652	33.49	0.37	60.16	46.5	33.5	33.2	26.8	2.3
Arunachal Pradesh	0.124	–	22.67	0.55	49.51	44.3	20.6	18.8	60.0	17.7
Assam	0.138	0.632	14.08	0.62	44.13	34.0	12.9	13.2	63.9	19.7
Bihar	0.158	0.226	11.30		38.46	37.0	12.6	11.7	50.1	2.8
Chandigarh	–	–	97.25	–	52.27		–	–	–	–
Chhattisgarh	0.180	0.543	23.24	0.6	52.02	37.4	10.2	11.9	55.2	21.6
Delhi	–	–	97.50	0.38	50.02	56.2	–	–	–	–
Goa	0.803	–	62.17	0.21	53.13	64.8	32.6	33.5	20.8	1.9
Gujarat	0.477	0.670	42.58	0.46	61.99	45.0	19.7	23.7	51.4	7.4
Haryana	0.493	0.635	34.79	0.4	46.97	45.0	20.0	21.0	35.8	1.6
Himachal Pradesh	0.647	–	10.04	0.3	61.20	51.7	22.0	28.6	40.5	0.5
Jammu and Kashmir	0.479	–	27.21	0.34	60.35	46.7	20.5	29.1	38.2	2.8
Jharkhand	0.222	0.499	24.05	0.69	45.33	37.4	11.1	10.3	48.6	5.8
Karnataka	0.42	0.639	38.57	0.34	58.70	46.4	22.1	23.3	34.3	4.2
Kerala	0.911	0.921	47.72	0.16	76.55	63.9	28.5	32.4	25.7	0.8
Madhya Pradesh	0.186	0.468	27.63	0.6	40.09	39.5	10.9	13.6	59.5	10.4
Maharashtra	0.629	0.729	45.23	0.33	61.07	49.8	23.8	23.4	36.5	5.8
Manipur	0.199	–	30.21	0.42	57.78	44.2	19.8	26.0	70.6	48.8
Meghalaya	0.246	–	20.08	0.64	56.83	39.6	10.1	12.2	72.2	32.3
Mizoram	0.408	–	51.51	0.53	73.7	48.9	21.0	21.1	80.4	59.2
Nagaland	0.257	–	28.97	0.47	37.38	46.1	14.0	16.2	69.4	27.5
Odisha	0.261	0.467	16.68	0.58	39.43	36.3	17.2	16.5	55.9	17.3
Puducherry	–	–	37.49	–	47.48	–	–	–	–	–
Punjab	0.538	0.766	68.31	0.29	65.21	49.5	27.8	31.3	19.2	0.1
Rajasthan	0.324	0.508	24.89	0.66	36.79	40.7	13.2	14.1	46.9	6.3
Sikkim	0.324		24.97	0.45	53.2	50.5	34.8	26.7	40.3	7.3
Tamilnadu	0.633	0.732	48.45	0.26	63.38	51.2	28.2	30.9	31.7	2.2
Telangana	–	0.652	48.45	0.38	55.39	48.5	–	–	–	–
Tripura	0.354	–	26.18	0.45	43.51	42.3	15.9	16.0	67.8	42.2
Uttarakhand	0.426	–	22.28	0.46	45.22	43.2	17.7	20.4	43.7	2.9
Uttar Pradesh	0.122	0.339	30.55	0.68	33.69	34.9	12.5	16.5	53.0	7.6
West Bengal	0.483	0.709	31.87	0.33	58.25	47.1	14.2	19.9	58.8	8.7

GBD Global Burden of Disease, *NITI* National Institution for Transforming India obesity (body-mass index ≥ 25 kg/m^2) (Table 6) confirms internal consistency of the data.

We also correlated hypertension prevalence (DLHS-4) with index of healthcare availability as published by the National Institution for Transforming India (NITI Aayog). No significant correlation is observed of hypertension prevalence with availability of primary healthcare in men ($R^2 = 0.06$) or women ($R^2 = 0.01$). This is in contrast to the expectation that states with greater hypertension prevalence would have better primary care. However, available data show that states with high prevalence of hypertension have similar availability of primary healthcare as those with low prevalence. Moreover, this health index has been developed with focus on mother and child health care and a better index needs to be developed that also focuses on healthcare delivery for chronic diseases, important for hypertension control.

Global Burden of Study 2016 has reported a state-level healthcare access and quality index for India [39]. This index is based on mortality and incidence (MIR) rates of cancer in various countries and states and is used as surrogate for healthcare access and availability for non-communicable diseases. There is a significant correlation of hypertension prevalence with healthcare access and quality parameter in both men ($R^2 = 0.548$) and women ($R^2 = 0.450$) showing that populations in states with greater hypertension prevalence have better access and quality of care (Fig. 7). These data augur well for hypertension control in India and suggest that once healthcare availability is established, the health system response for its control would be appropriate. The focus of policy should be to improve healthcare availability in all states of India and to ensure universal access and appropriate quality to achieve better control of hypertension in India [41]. Focus is required on a variety of factors including physical access to health facilities, better health system infrastructure and scaling up of medical technologies, and provision of effective services across continuums of care [42]. These factors could be overcome by better focus on strengthening primary care in the country [2, 41]. Clearly more effort is required in India to upgrade primary care services for better hypertension control [43]. Moreover, the recently released European guidelines, while retaining the older criteria for definition of hypertension, have significantly reduced treatment goal to

Table 7 Correlation of hypertension prevalence in Indian States with various socioeconomic and lifestyle indicators (Pearson's *r*)

	State level hypertension prevalence (DLHS)	
	Men	Women
Socioeconomic factors		
Human development index	0.620 (0.001)	0.558 (0.003)
Social development index	0.739 (0.001)	0.603 (0.010)
Urbanization index	0.432 (0.014)	0.338 (0.058)
Epidemiological transition index	−0.646 (<0.001)	−0.621 (0.001)
Healthcare parameters		
Healthcare availability index	0.262 (0.148)	0.127 (0.488)
Healthcare access and quality index	0.722 (<0.001)	0.688 (<0.001)
Lifestyle factors		
Smoking/Tobacco use	−0.511 (0.008)	−0.399 (0.043)
Alcohol intake	0.061 (0.767)	0.120 (0.559)
Overweight/Obesity (BMI > 25 kg/m^2)	0.629 (<0.001)	0.570 (0.002)

Numbers in parentheses are *p* value; *DLHS* District Level Health Survey, *BMI* body mass index

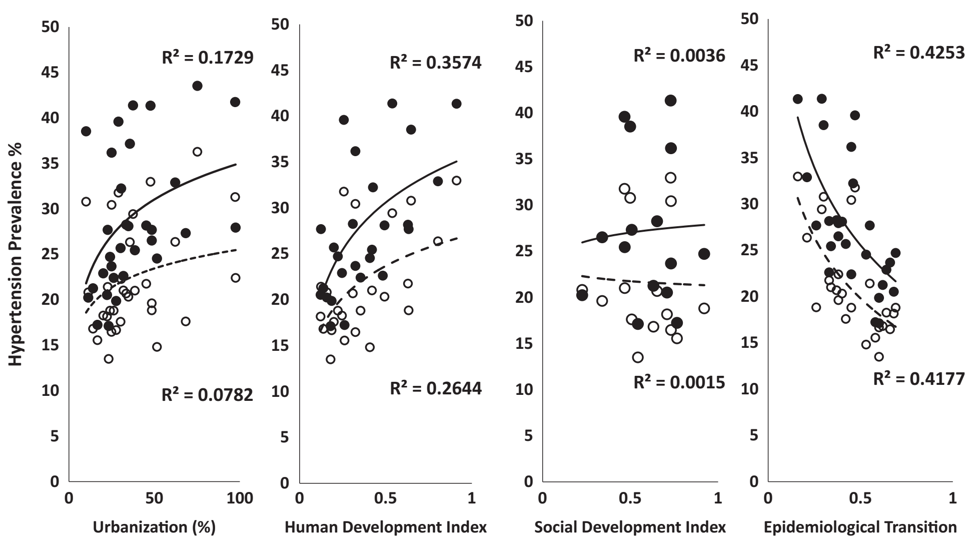

Fig. 6 Correlation of hypertension prevalence in men (black dots, solid line) and women (open dots, dashed line) in various Indian states with social determinants of health: urbanization index, human development index, social development index and epidemiological transition index

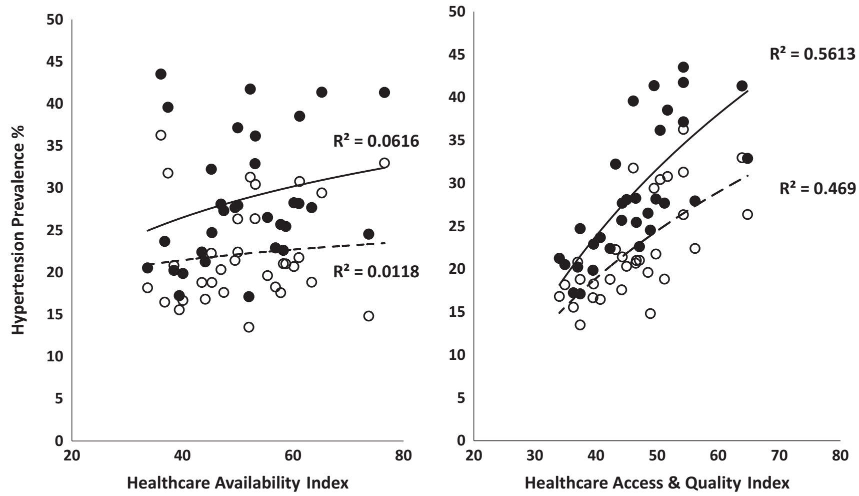

Fig. 7 Correlation of state-level hypertension prevalence in men (black dots, solid line) and women (open dots, dashed line) with healthcare availability (NITI Aayog) [38] and healthcare access and quality (GBD Study) [39]

less than 130/80 mmHg in most patients with hypertension [10, 44]. This lowered goal would need massive efforts to improve education of healthcare providers and gearing-up of healthcare facilities to achieve control of BP in patients with hypertension.

Conclusion

In conclusion, this review highlights that there is a high prevalence of hypertension in both urban and rural locations in India, *circa* 2018. Two recent studies have used proper nationwide sampling and uniform tools to determine the true prevalence of hypertension in India. NFHS-4 evaluated hypertension prevalence in younger men (15–54 years) and women (15–49 years) and reported hypertension in 13.8% men and 8.8% women with an overall prevalence of 11.3%. More age-representative data from DLHS-4 has reported hypertension in 25.3% adults with a greater prevalence in men (27.4%) as compared to women (20.0%) and narrow urban-rural difference. These proportions would translate into massive number of men and women with hypertension in the country. 61% of the total Indian population of 1.342 billion are > 18 years of age ($n = 818.6$ million) [45]. With an age-adjusted prevalence of 25.3% in this age group, this would translate into 207.11 million persons (men 112.15 million, women 94.96 million) with hypertension in the country. Recent US guidelines have lowered the threshold to define hypertension as BP ≥ 130 and/or ≥ 80 mmHg [10, 46]. If this new definition were to be applied to the Indian sub-continent, the prevalence of hypertension will increase steeply given the high prevalence of pre-hypertension in our population [17, 27].

Global Burden of Diseases study reports that hypertension associated mortality and morbidity in India is one of the highest in the world and is increasing [29]. Social determinants of hypertension are important and states with greater human and social development and urbanization have more hypertension. This is in contrast to developed countries, such as USA, where hypertension is more in less developed states [10]. This review also shows poor association of hypertension with healthcare availability. This suggests that primary healthcare system in the country needs to be significantly improved for better hypertension screening and control. Government of India proposals to create 150,000 Health Wellness Centers across the country devoted to preventative care and to strengthen primary care and National Health Protection Scheme for increasing healthcare access and reducing disease-related morbidity and mortality are the right steps in this direction [43]. Non-communicable disease healthcare quality is adequate in states with greater hypertension prevalence (Fig. 7) although status of hypertension control is low [8]. Whether better healthcare availability and uniform access and quality translate into reduction in prevalence of hypertension and decrease hypertension related disease burden awaits future studies. The newly recommended blood pressure treatment goals to < 130/80 mm Hg pose an enormous challenge and a special opportunity for reducing the chronic disease burden in India, triggered mainly by hypertension.

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