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REVIEW

Prevalence, risk factors and awareness of hypertension in India: a systematic review

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Indians have high rates of cardiovascular disease. Hypertension (HTN) is an important modifiable risk factor. There are no comprehensive reviews or a nationally representative study of the burden, treatments and outcomes of HTN in India. A systematic review was conducted to study the trends in prevalence, risk factors and awareness of HTN in India. We searched MEDLINE from January 1969 to July 2011 using prespecified medical subject heading (MeSH) terms. Of 3372 studies, 206 were included for data extraction and 174 were observational studies. Prevalence was reported in 48 studies with sample size varying from 206 to 167 331. A significant positive trend ($P<0.0001$) was observed over time in prevalence of HTN by region and gender. Awareness and control of HTN (11 studies) ranged from 20 to 54% and 7.5 to 25%, respectively. Increasing age, body mass index, smoking, diabetes and extra salt intake were common risk factors. In conclusion, from this systematic review, we record an increasing trend in prevalence of HTN in India by region and gender. The awareness of HTN in India is low with suboptimal control rates. There are few long-term studies to assess outcomes. Good quality long-term studies will help to understand HTN better and implement effective prevention and management programs.

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Keywords: blood pressure; prevalence; India

INTRODUCTION

Hypertension (HTN) is a modifiable and major risk factor for coronary artery disease, heart failure, cerebrovascular disease and chronic renal failure.[1–3] HTN affects about 1 billion people worldwide[4] and it is estimated that by 2025, up to 1.58 billion adults worldwide will suffer from complications of HTN.[5] The high prevalence of HTN makes it a significant factor for mortality and morbidity.[6] Adequate management of HTN can effectively reduce the risks of stroke, myocardial infarction,[6] chronic kidney disease[7] and heart failure.[8,9]

HTN is a major public health problem in India. HTN accounts for 57% of all stroke deaths and 24% of all coronary heart disease deaths in India.[10] It is estimated that a 2-mmHg decrease in blood pressure (BP) population wide can prevent 151 000 strokes and 153 000 coronary heart disease deaths in India.[10]

The prevalence of HTN varies widely across the countries. A recent systematic review estimated that the overall worldwide prevalence of HTN is approximately 26% in the adult population.[11] Awareness varies from 25 to 75% and treatment from 11 to 66%.[11] The control of HTN widely ranges from a low of 5 up to 58%.[10] Some studies have also reported a higher prevalence of HTN among Asian Indian population apart from higher incidence of diabetes and coronary heart disease.[12–16]

Asian Indians comprise over 17% of the world's population. Yet, we do not have a nationally representative study of the burden, treatments and outcomes of HTN in India. Small studies have been conducted in different pockets of India and have reported the prevalence, management and outcomes of HTN. We urgently need nationwide programs to effectively control HTN to reduce the burden of its well-known and potentially fatal complications. Therefore, it is important to systematically quantify the available data from various studies (cohort, case–control and cross-sectional studies) conducted in India.

We conducted a systematic review of observational studies published between January 1969 to July 2011 from India. The objectives of this systematic review were to evaluate the changing trends in prevalence by region and gender and to study the risk factors, awareness and control of HTN in India.

METHODS

We prepared a study protocol and predefined the data sources, search strategy, study eligibility criteria, data extraction and criteria for quality assessment of the studies. We defined HTN as systolic BP of at least 140 mmHg and or diastolic BP of at least 90 mmHg. Awareness of HTN was defined as self-reported prior diagnosis of HTN. Treatment of HTN was

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defined as self-reported current use of antihypertensive medication. Control of HTN was defined as BP less than 140/90 mmHg.

Data sources

We performed a systematic review from MEDLINE using the following MeSH terms: (a) search 1: BP or high-BP; (b) search 2: India (or Indian) or South Asia; and (c) search 3: search 1 and search 2.

We included studies conducted among adult Indians with HTN and published in the English language between January 1969 to July 2011. We did not include studies on Indians with HTN staying outside India because the exposure to the environmental and risk factors will be different in this set of population compared with those Indians living in India. We also carried out extensive hand searches and contacted authors for further information.

Study selection

Two independent reviewers systematically searched the literature using the prespecified strategy. We eliminated duplicates using the Reference Manager Software version 12 (Thomson Reuters, New York).

The type of studies in our review include cohort studies, case–control studies and cross-sectional studies. We excluded randomized controlled trials due to small follow-up periods and nonavailability of safety or outcome data to provide meaningful conclusions. We also excluded case series, individual case reports, editorials and commentaries because they did not have original data. We excluded the genetic studies as these were stand-alone studies with small sample size to generalize the findings to the Indian population.

Data extraction

Two reviewers independently screened each study identified by the search, and any discrepancy between the reviewers was resolved by a third reviewer.

We extracted data from full-length articles wherever available. We included abstracts only when they had sufficient data. Using a structured format, we extracted data on year, study design, sample size, patient characteristics, prevalence, risk factors, treatments and outcomes. These data were extracted by two independent reviewers on the structured data abstraction form. Two different investigators (MR and PD) verified the data independently for accuracy after extraction. Discrepancy was resolved by discussion with a third investigator (DX).

Study quality

We assessed the quality of observational studies using STROBE (strengthening the reporting of observational studies in epidemiology) statement. For cohort studies, the parameters were (a) eligibility criteria (defined or not),(b) source of cohort (specified or not), (c) methods of selection and (d) methods of follow up. The maximum score possible was 4 and the minimum was 0.

The parameters for quality criteria for case–control studies were (a) eligibility criteria (defined or not), (b) sources (methods of case ascertainment and control selection) and (c) rationale for the choice of cases and controls. The quality criteria for cross-sectional studies were (a) eligibility criteria, (b) sources and (c) methods of selection. The maximum score for case–control and cross-sectional studies was 3 and the minimum was 0.

Data synthesis

Estimates of prevalence, incidence, awareness, treatment and control of BP are indicated as proportions. Estimates of risk factors are summarized as median and range. Trends for prevalence of HTN by region and gender was analyzed using the Mantel Haenzel Chi square test (SAS version 9.2, Cary, NC, USA).

RESULTS

Search results

Of 3372 articles, after removing duplicates (2612), 760 articles were considered for review. Among these studies, 206 articles were considered for data extraction (Figure 1).

Type of studies

Among 174 observational studies, there were 4 cohort studies, 11 case–controlled studies and 134 cross-sectional studies (Figure 2).

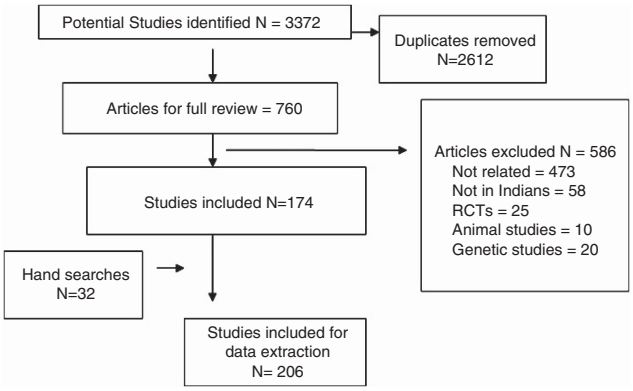

Figure 1. Flow chart providing the number of studies identified, excluded for various reasons and included in systematic review.

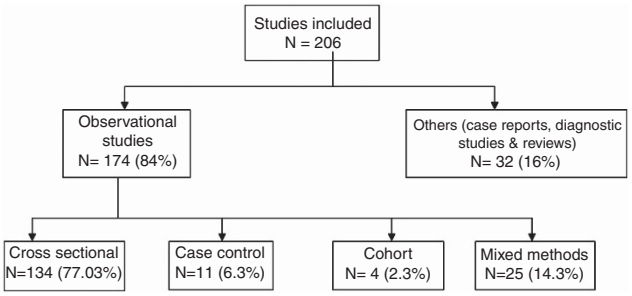

Figure 2. Flow chart providing the type of studies in the systematic review.

Study quality

Out of the 206 included, 174 observational studies were assessed for quality score. One study obtained a maximum quality score of 4 (1%), 42 studies (24%) obtained a score of 3, 55 studies (31.6) obtained a score of 2, 29 studies (16.4%) obtained score of 1 and 47 studies did not obtain any score. A tally based on different parameters of quality criteria is presented in Table 1.

Prevalence and incidence of HTN in India

Prevalence studies ($n = 48$) published between 1971 and July 2011 showed a sample size from 206 to 167 331. Indian urban and rural population studies from 1970s to mid 1990s used the standardized WHO (World Health Organization) guidelines for the diagnosis of HTN (known HTN or BP $\geqslant$160/95 mmHg). The prevalence of HTN in these studies varied from 6.4 to 15.5% in urban and 2.6 to 12.5% in rural populations. A significant positive trend in prevalence of HTN was noticed during this period (Mantel-Haenzel Chi square = 1472.18, $P < 0.0001$; Table 2). Similarly, a significant positive trend in prevalence of HTN was observed in females (Mantel-Haenzel Chi square = 1999.86, $P < 0.0001$) and in males (Mantel-Haenzel Chi square = 812.56, $P < 0.0001$; Table 2).

The prevalence of HTN in studies using BP criteria $\geqslant$140/90 mmHg among urban and rural population ranged from 13.9 to 46.3% and 4.5 to 58.8%, respectively. There was a significant positive trend in prevalence of HTN (Mantel-Haenzel Chi square = 4723.56, $P < 0.0001$) Table 3. A similar trend was observed in males (Mantel-Haenzel Chi square = 1393.13, $P < 0.0001$) and females (Mantel-Haenzel Chi square = 1356.51, $P < 0.0001$) Table 3.

The prevalence of HTN in studies with BP criteria $\geqslant$160/95 from the Northern region varied from 3.5 to 6.4% and in Western region varied from 2.6 to 15.5%. Prevalence in both these regions showed

Table 1. Tally of quality score of studies included in the systematic review[a]

Quality criteria of the study	*Cross sectional (n = 134)*	*Case control (n = 11)*	*Cohort(n = 4)*	*Mixed methods (n = 32)*
Presence of eligibility criteria	60	8	4	Not mentioned
Sources mentioned	53	6	3	Not mentioned
Methods of selection mentioned	36	3	2	Not mentioned
Methods of follow up mentioned	Not applicable	Not applicable	1	Not applicable
Quality criteria (not mentioned)	38	3	0	32

[a]Out of 206 included studies, 174 observational studies were included for quality score estimation.

Table 2. Indian hypertension prevalence studies (blood pressure ⩾160/95)

First author	*Year*	*Age group*	*Sample size*	*Place*	*Region*	*Overall %*	*Male %*	*Female %*
Urban								
Studies done before 1980								
Malholtra[44a]	1971	20–58	4232	Railways	—	9.2	9.2	—
Gupta[45a]	1978	20–69	2023	Haryana	North India	6.4	5.9	6.9
Dalal[29]	1980	20–80	5723	Bombay	West India	15.5	15.6	15.3
Studies done from 1981 to 1990								
Sharma[30]	1985	20–75	1008	Ludhiana	West India	14.0	15.4	8.7
Studies done from 1991 to 2000								
Thakur[46a]	1999	30–80	1686	Chandigarh	North India	NM	NM	13.1
Rural								
Studies done before 1980								
Gupta[31]	1977	20–69	2045	Haryana	North India	3.5	3.5	3.5
Studies done from 1981 to 1990								
Wasir[47a]	1983	20–69	905	Delhi	North India	5.4	3.2	7.5
Baldwa[48a]	1984	21–60	912	Rajasthan	West India	7.8	6.9	8.8
Sharma[30]	1985	20–75	3340	Ludhiana	West India	2.6	2.6	—
Studies done from 1991 to 2000								
Kumar[49a]	1991	21–70	6840	Rajasthan	West India	3.8	4.0	3.6
Joshi[50a]	1993	16–60	448	Maharastra	West India	4.0	4.8	8.1
Jajoo[51a]	1993	20–69	4045	Maharastra	West India	3.4	2.8	4.0
Gupta[34]	1994	20–80	3148	Rajasthan	West India	7.1	7.6	6.2
Gilberts[32]	1994	20–70	1027	Rural South India	South India	12.5	NM	NM

Abbreviation: NM, not mentioned. Mantel-Haenzel Chi square test for trend = 1472.18, $P<0.0001$. Mantel-Haenzel Chi square test for trend (males) = 812.56, $P\leqslant0.0001$. Mantel-Haenzel Chi square test for trend (females) = 1999.86, $P<0.0001$. [a]Reference numbers 44–51 are provided in the Supplementary Information.

a significant positive trend (Mantel-Haenzel Chi square, Northern India = 41.92, $P<0.0001$; Western India = 447.29, $P<0.0001$). We were not able to assess the trend in other regions as there was only one study from Southern region and no studies from other regions during this period. Studies with BP criteria with ⩾140/90 mmHg in Northern India, Southern India and Western India also showed a significant trend in prevalence of HTN over time (Mantel-Haenzel Chi square, Northern India = 1420.87, $P<0.0001$; Western India = 299.47, $P<0.0001$; Southern India = 894.56, $P<0.0001$).

The study conducted by Gopinath *et al.*[17] (1988–1990) reported an annual incidence of HTN in Delhi at 12.2 per 1000 in both men and women. A 5-year follow-up cohort study conducted by Gopinath *et al.*[18] reported an annual incidence of HTN of 2.8 per 1000 population (male 3.8/1000 and female 2.4/1000) in a rural community of Haryana.

Risk factors associated with HTN

Six studies, published between 1993 and 2008, reported on risk factors associated with HTN with a sample size range of 975 and 4955. The determinants of HTN reported in these studies included age, increased body mass index, abdominal obesity, glucose intolerance, smoking, extra salt intake, excessive alcohol consumption and hypercholesterolemia (Table 4).

Hazarika *et al.*[19] reported that the prevalence of HTN among the elderly (⩾60 years) in Assam is 8.8 times higher compared with those of 30–39.9 years. Deepa *et al.*[20] reported that the prevalence in the age group of 20–40 years was 8.1% in Chennai urban community, whereas that in the elderly community in the same area was 53.4%.

Treatment, awareness and control of HTN

Awareness from 11 rural and urban studies varied from 12 to 54% and 8 to 47% of hypertensive patients who were on treatment. BP control was recorded in 7.5–25% of patients (Table 5).

Clinical outcomes in HTN

Gopinath *et al.*[17] conducted a 3-year follow up, community-based cohort study among adults in Delhi. Clinical outcomes included myocardial infarction in 2.7%, ST-T changes in ECG in 15.3%, left ventricular hypertrophy in 2% and conduction effects in 11% of patients. There were only two long-term studies (cohort)

Table 3. Indian hypertension prevalence studies (blood pressure ⩾140/90)

First author	*Year*	*Age group*	*Sample size*	*Place*	*Region*	*Overall %*	*Male %*	*Female %*
Urban								
Studies done from 1991 to 2000								
Gupta[52a]	1995	20–75	2212	Jaipur	West India	31.0	30.0	33.0
Gupta[26]	1999	18–60	99 589	Mumbai	West India	NM	43.8	44.5
Joseph[53a]	2000	20–89	206	Trivandrum	South India	NM	31.0	41.2
Anand[54a]	2000	30–60	1653	Mumbai	West India	26.8	NM	NM
Studies done from 2001 to 2011								
Gurav[55a]	2001	⩾35 years	1432	Mumbai	West India	13.9	9.5	18.9
Gupta[14]	2002	20–75	1123	Jaipur	West India	36.9	36.4	37.5
Reddy[56a]	2002	NM	3307	Andhra Pradesh	South India	27.3	28.0	19.0
Bharucha[15]	2003	⩾20 years	2415	Mumbai	West India	36.4	32.8	39.4
Shanthirani[57a]	2003	⩾20 years	1262	Chennai	South India	21.1	NM	NM
Deepa[20]	2003	⩾20 years	1262	Chennai	South India	22.1	NM	NM
Gupta[58a]	2004	⩾20 years	458	Punjab	West India	NM	51.3	51.0
Das[59a]	2005	⩾18 years	1662	Malda	East India	24.9	NM	NM
Mahil Maran[37a]	2005	Above 20 years	2318	Chennai	South India	44.0	NM	NM
Prabhakaran[13]	2005	20–59	2122	Delhi	North India	30.0	NM	NM
Chathurvedi[60a]	2007	20–59	1213	Delhi	North India	27.5	NM	NM
Mohan[61a]	2007	⩾20 years	2350	Chennai	South India	20.0	23.2	17.1
Gupta[27]	2007	⩾20 years	1127	Jaipur	West India	NM	57.9	48.9
Midha[62a]	2009	⩾20 years	800	Lucknow	North India	32.8	NM	NM
Pednekar[21]	2009	⩾35 years	148 178	Mumbai	West India	NM	47.3	45.7
Kasliwal[36a]	2010	NM	1927	North India	North India	46.3	NM	NM
Kar[63a]	2010	⩾30 years	400	Chandigarh and Haryana	North India	Urban = 39.0 Slum = 35.0 Rural = 33.0	37.0	34.0
Thankappan[64a]	2010	15–64	7449	Kerala	South India	Total = 32.7 Urban = 34.9 Rural = 32.5 Slum = 30.6	33.9	31.6
Gupta[28a]	2011	35–70 years	4608; Urban = 2004 Rural = 2604	Different regions in India	—	Total = 39.2 Urban = 48.2 Rural = 31.5	—	39.2
Rural								
Studies done from 1991 to 2000								
Gupta[34]	1994	20–75	3148	Rajasthan	West India	21.0	24.0	17.0
Goel[65a]	1996	Above 35 years	1572	Varanasi	North India	7.2	5.6	8.8
Malhotra[33]	1999	16–70	2559	Haryana	North India	4.5	3.0	5.8
Studies done from 2001 to 2011								
Hazarika[16]	2004	⩾30 years	3180	Five districts in Assam	East India	33.3	33.2	33.4
Thankappan[12]	2006	Above 30 years	4955	Kumarakom	South India	36.7	36.1	37.1
Gupta[66a]	2010	25–60 years	577	Delhi	North India	NM	21.8	7.4
Bhardwaj[67a]	2010	⩾18 years	1092	Himachal Pradesh	North India	35.9	39.8	33.2
Jonas[35]	2010	Above 30 years	4711	NM	Central India	22.1	NM	NM
Borah[25]	2010	⩾30 years	12 252	Mizoram *n* = 8058 Indigenous Assamese *n* = 3180 Tea garden workers *n* = 1014	North India	20.0 32.5 58.8	NM	NM
Sauvaget[22]	2010	35–90 years	16 7331	Trivandrum	South India	45.0	NM	NM
Manimunda[24]	2011	Above 18 years	975	Nicobar island	India	50.5	50.7	50.3
Thrift[68a]	2011	NM	1479	Andhra Pradesh	South India	11.4	NM	NM

[a]Reference numbers 52–68 are provided in the Supplementary Information.

that assessed all cause mortality and circulatory system-related mortality in HTN. Results of Mumbai cohort study showed that all cause mortality (hazard ratio, 95% confidence interval) was significantly greater in stage 2 HTN (men 1.41, 1.31–1.52; women 1.46, 1.30–1.64) compared to those with normal BP. This study has demonstrated that circulatory system deaths were significantly more in stage 2 (men 2.05, 1.77–2.39; women 2.06, 1.62–2.61), as well as in stage 1 (men 1.31, 1.14–1.52; women 1.39, 1.10–1.77).[21] Results of Trivandrum cohort study showed systolic BP from 180 mmHg was associated with increased risk of death due to ischemic heart disease (relative risk, 95% confidence interval; 3.06 (2.55–3.67)) and stroke (5.10 (3.96–6.58)) compared with risk associated with diastolic BP more than 110 mmHg. Systolic BP was a stronger predictor of cardiovascular disease than diastolic BP.[22]

DISCUSSION

To our knowledge, this is the largest systematic review on the prevalence, risk factors, treatment, awareness and control of HTN from India. Due to the extensive heterogeneity among studies,

Table 4. Risk factors for hypertension (community-based studies)

Risk factor	*Odds ratio (range)*	*Reference*
Age		
40–49	1.75–4.39	Manimunda *et al.*,[24] Hazarika *et al.*[19]
50–59	2.62–8.17	Hazarika *et al.*,[16] Thankappan *et al.*[12]
⩾60	4.07–13.45	Mohan *et al.*[61a]
Body mass index	1.12–4.10	Shanthirani *et al.*,[57a] Manimunda *et al.*[24]
Waist circumference	1.84	Thankappan *et al.*[12]
Waist–hip ratio	1.54–2.83	Hazarika *et al.*,[16] Hazarika *et al.*[19]
Extra salt intake	1.45–1.76	Hazarika *et al.*,[16] Hazarika *et al.*[19]
Alcohol	1.01–2.33	Shanthirani *et al.*,[57a] Hazarika *et al.*[19]
Smoking	0.72–1.66	Thankappan *et al.*,[12] Shanthirani *et al.*[57a]
Glucose intolerance	4.26	Shanthirani *et al.*[57a]
Diabetes mellitus	2.12	Thankappan *et al.*[12]
Hypercholesteremia	2.08	Mohan *et al.*[61a]

[a]Reference numbers 61, 57 are provided in the Supplementary Information.

Table 5. Awareness, treatment and control of blood pressure

Study	*Sample size*	*Awareness (%)*	*Treatment (%)*	*Blood pressure control (%)*
Kalavathi *et al.*[69a]	357	50.0	NM	25.0
Barucha *et al.*[15]	2415	51.5	NM	13.6
Deepa *et al.*[20]	1262	37.3	18.7	7.5
Hazarika *et al.*[16]	3180	21.6	21.4	18.1
Thankappan *et al.*[12]	4955	45.0	NM	10.0
Chaturvedi *et al.*[60a]	1213	54.0	42.0	10.5
Yadav *et al.*[70a]	294	50.0	39.0	14.6
Bhardwaj *et al.*[67a]	1092	21.9	47.0	20.2
Jonas *et al.*[35]	4711	20.0	8.0	NM
Thankappan *et al.*[64a]	7449	36.9	26.9	8.6
Manimunda *et al.*[24b]	975	12.0	0.01	0.01
Gupta *et al.*[28]	4608	42.0	38.6	21.5

Abbreviation: NM, not mentioned. [a]Reference numbers 60, 64, 67, 69, 70 are provided in the Supplementary Information. [b]Study was conducted in Nicobarese tribe living in Car Nicobar Island.

we did not perform a meta-analysis. We have attempted to highlight the changing trends with respect to region and gender in prevalence of HTN in India in this review.

We carefully assessed the methodological quality of observational studies using accepted quality scores. There were very few good quality studies.

We have noticed a predominance of cross-sectional designs (77%). The methodological quality of studies was variable and good quality, cohort (2%) or case–control studies (6%) were limited. In most, the study design was not mentioned and study population was not representative.

The prevalence studies ($n = 48$) from India over last 40 years showed a variable prevalence rates with respect to the time period, BP criteria used for diagnosis of HTN, region and gender differences. The BP measurement was performed at dispensary, home or work site, using a standardized mercury sphygmomanometer, in a sitting position.

Studies published in 1970s, 1980s and mid 1990s had used WHO criteria (BP ⩾160/90 mmHg or known HTN) for diagnosis of HTN. These studies have reported a higher prevalence in urban region (6.4–15.5%) compared to rural (2.6–12.5%) studies. Gupta *et al.*[23] has reported an increase in prevalence of HTN in both rural and urban Indian studies in a metanalysis published in 1996. We have also noticed a similar trend in prevalence of HTN (Mantel-Haenzel Chi square = 1472.18, $P < 0.0001$). We noticed a significant positive trend in the prevalence of HTN in both males (812.56, $P < 0.0001$) and females also (1999.86, $P < 0.0001$; Table 2).

Overall, 15 studies reported the prevalence of HTN in rural areas based on the BP criteria ⩾140/90 mmHg, which varied from 4.5 to 45%. A higher prevalence (13.9–48.2%) was recorded in urban Indian studies with these BP criteria. A significant increasing trend in prevalence of HTN is seen in both urban and rural population, as well as among males and females also in these studies (Table 3).

A high prevalence of HTN (50.5%) was reported among aboriginal Nicobarese tribe living in Car Nicobar Island by Manimunda *et al.*[24] in the year 2009. A similar high prevalence of 58.8% was noted among 1014 tea garden workers aged more than 30 years from rural North India.[25] This high prevalence in these tea garden workers could be explained due to the difference in study time period and difference in life style and dietary pattern between different regions.

We have noticed a significant positive trend in prevalence of HTN among both males and females (males: Mantel-Haenzel Chi square = 1393.13, $P < 0.0001$; females: Mantel-Haenzel Chi square = 1356.51, $P < 0.0001$) in studies using BP criteria ⩾140/90 mmHg (Table 3). The prevalence reported from a large urban study conducted in Mumbai (1999) with a sample size of 99 589 subjects was as high as 43.8% in males and 44% among females.[26] The study conducted by Gupta *et al.*[27] in 1127 subjects from Jaipur reported the highest prevalence among urban males (57.9%).[27] The study conducted among 4608 females in four urban and five rural locations by Gupta *et al.*[28] also reported a high prevalence of 48.2% in urban and 31.5% in rural population.

There were eight studies from West India, four studies from North India and one study from South India that reported HTN prevalence using BP criteria ⩾160/95 mmHg. Highest prevalence of 15.5% was reported by Dalal *et al.*[29] in urban population in Bombay among these studies. Sharma *et al.*[30] reported a prevalence of 2.6% from rural population in Ludhiana and Gupta *et al.*[31] reported a prevalence of 3.5% among rural North Indian population. Gilberts *et al.*[32] have shown a high prevalence of 12.5% in rural South Indian population. The prevalence of HTN reported in these studies from different regions of India were not similar (Table 2). A significant positive trend (Mantel-Haenzel Chi square, Northern India = 41.92, $P < 0.0001$; Western India = 447.29, $P < 0.0001$) was noticed in studies from Northern and Western regions.

There were 10 studies each from Northern India and Western India, 9 studies from Southern India and 1 study from Eastern India that reported prevalence of HTN using BP criteria ⩾140/90 mmHg. Malhotra *et al.*[33] studied 2559 rural North Indian subjects and observed a very low prevalence rate of 4.5%. Gupta *et al.*[34] and Jonas *et al.*[35] have reported a prevalence of 21% and 22.1% from Western India and Central India, respectively. We noticed a higher prevalence in selected rural population. Studies by Hazarika *et al.*[16] reported a prevalence of 33.3% in Assam (2004), and Thankappan *et al.*[12] enrolled 4955 individuals in rural Kerala reported a prevalence rate of 36.7%. Sauvaget *et al.*[22] also reported a high prevalence of 45% in Trivandrum, South India.

In the Jaipur Heart Watch 2 study, out of 1123 subjects enrolled, HTN prevalence was 36.9%. Study conducted by Kasiwal *et al.*[36] (2010) reported a prevalence of 46.3% in urban North Indian population. A prevalence of 44% was reported from Chennai in 2007[37]among 2318 asymptomatic individuals. Although there is a regional difference in prevalence rates in rural and urban India, a significant positive trend over time was noticed in Northern, Western and Southern regions of India. (Mantel-Haenzel Chi square, Northern India = 1420.87, $P < 0.0001$; Western India = 299.47, $P < 0.0001$; Southern India = 894.56, $P < 0.0001$).

A wide range of prevalences of HTN is reported by these studies from different regions of India. There is an extensive cultural, linguistic, social and biological diversity within the population of India. The diversity and heterogeneity of distribution of the population makes it very challenging to arrive at a precise prevalence among Indian population.

The prevalence of HTN varies around the world. A systematic review by Kearney *et al.*[11] reported that the lowest prevalence of HTN was in rural India (3.4% in men and 6.8% in women) and the highest prevalence in Poland (68.9% in men and 72.5% in women). The prevalence rates in Indian studies were lower than that recorded in Spain by Banegas (68.3%)[38] and in Italy by Prencipie (64.8%) in their study.[39]

A cohort study by Gopinath *et al.*[18] in Haryana State reported an incidence of 2.8 per 1000 in a rural population. A 3-year follow-up study of HTN conducted from 1988 to 1990 in Delhi demonstrated an annual incidence of 12.2 per 1000 in men and women.[17]

Six studies in three states of India reported on risk factors associated with HTN. Age, higher body mass index, abdominal obesity, smoking, extra salt intake, alcohol consumption and hypercholestremia were associated with HTN. Age was an important independent risk factor associated with HTN in all the six studies. Increase in BP with age was reported in studies from other parts of the world.[40] Thankappan *et al.*[12] reported that a body mass index of $\geqslant$25 was associated with a 1.65-fold (95% confidence interval: 1.37–1.98) prevalence of HTN. There could be a linear relationship between obesity and occurrence of HTN in Indians. However, prevalence of HTN in nonobese Indians is an area that needs further exploration. It is also reported that chronic malnutrition in fetus and early childhood can lead to HTN.[41]

Extra salt intake is reported as a risk factor irrespective of age. All five studies we reviewed found that increased salt intake is an important determinant for occurrence of HTN. Smoking and glucose intolerance were found as risk factors in two studies. The study by Hazarika *et al.*[16,19] among tea garden workers of Assam found that salt added in the tea and local alcohol consumption are significant risk factors associated with HTN. Smoking and diabetes mellitus were reported as risk factors by Thankappan *et al.*[12] among 4955 individuals in rural Kerala.

The close association of diabetes with HTN is thought to be due to underlying obesity, insulin resistance and/or hyperinsulinemia. Through increased quantities of advanced glycation end products, reactive oxygen species and sorbitol, hyperglycemia can lead to vasoconstriction (by alterations of endothelin and nitric oxide) and to extracellular matrix deposition leading to vascular remodeling. Also hyperinsulinemia is associated with increased sympathetic activation. Diabetes mellitus as a risk factor associated with HTN is more relevant in current scenario considering the burden of diabetes in the Indian subcontinent.[42]

There were 12 studies that reported awareness of elevated BP in four different regions of India. Awareness varied from 12 to 54%. Of 10 studies, 6 reported awareness below 40%, demonstrating a striking lack of awareness among Indians.

Among the hypertensive's who were aware of their condition, only small proportions were being treated (8–47%) and still smaller proportions (7.5–25%) were controlled (Table 5). The least awareness, control and treatment were among the tribal's of Nicobar Island.[24] A majority of Indian patients with HTN are unaware of their condition and, among those diagnosed, treatment is inadequate. The figures from India are low compared with the figures from Finland (adequately controlled BP in men is 23.5% and 36.7% in females).[43]

The 3-year cohort study by Gopinath *et al.*[17] among 1115 patients reported myocardial infarction in 2.7%, LVH in 6.2% and conduction defects in 11% of patients. The Mumbai cohort study conducted in 148 173 patients and followed up for 6 years revealed that Indian urban subjects with stage II HTN have increased risk of all cause mortality compared to normotensives.[21] The Trivandrum cohort study done in 167 331 adults in rural area showed high systolic and diastolic BP was associated with cardiovascular disease mortality at thresholds lower than current HTN definition (110 mmHg for casual systolic BP and 75–80 mmHg for casual diastolic BP).[22]

There are some limitations and strengths in our systematic review. We did not access unpublished data. The outcomes that are reported in this manuscript mainly relate to cross-sectional studies. The genetic studies were not included in our review as these studies were stand-alone studies and not conclusive to generalize to the data to the Indian population. Also data on Asians living outside India were not considered in this review. The key strength of this systematic review is that it is the first comprehensive systematic review of prevalence, risk factors and awareness of HTN from India. Although the studies were heterogeneous, we summarized estimates from different studies.

Although prevalence of HTN in Indians seemed to be similar from developed countries, a low level of awareness, treatment and control among Indian patients has important public health implications. We recommend research to investigate the reasons for these observations. There are very few good quality, long-term studies from India. We also recommend implementation of comprehensive program to improve infrastructure for better patient care and research, as well as education at all levels in HTN.

CONCLUSIONS

This large systematic review revealed the changing trends in HTN prevalence in India. Higher prevalence rates were observed in urban population compared to rural population. An increasing positive trend in prevalence of HTN was observed in urban, and rural population and also in both genders. A significant increase in prevalence of HTN over time was also noticed within different regions in India. There are only a very few good quality studies on risk factors and awareness of HTN. There are no long-term outcome studies on treatment of HTN. There is a lack of awareness, suboptimal level of treatment and control of HTN in Indians. There is a need for good quality studies focusing on HTN and its treatment in Indians to develop optimal strategies for HTN management. Special guidelines for desirable levels of risk factors may be necessary for prevention of HTN. The findings from this review can be useful to implement population-based India-specific cost-effective HTN control programs to reduce the burden and optimize patient care in HTN.

References 36–70 are provided as supplementary information and is available at *Journal of Human Hypertension*'s website http://www.nature.com/jhh.

What is known about this topic

- Indians have high rates of cardiovascular disease and HTN is an important modifiable risk factor.
- Previous studies show that there is a significant increase in the prevalence of HTN and low levels of awareness, treatment and control.

What this study adds

- This largest comprehensive systematic review from India revealed significant positive trends in prevalence of HTN over time by region and gender (1969–2011).
- There are no long-term outcome studies on the treatment of HTN.
- The findings supported the lack of awareness and that treatment and control of HTN in Indians are suboptimal.
- There is an urgent need to implement India-specific programs to reduce the burden and optimize care, and for primary prevention of HTN.

CONFLICT OF INTEREST

Drs Xavier, Pais and Sigamani have received research funds from AstraZeneca, India. Dr Pais has received consultancy fees from AstraZeneca. All the three of them received these funds in to the Institution (St John's) account. Remaining authors declare no conflict of interest.

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REFERENCES

1 D'Agostino Sr RB, Vasan RS, Pencina MJ, Wolf PA, Cobain M, Massaro JM *et al.* General cardiovascular risk profile for use in primary care: the Framingham Heart Study. *Circulation* 2008; **117**(6): 743–753.
2 Klag MJ, Whelton PK, Randall BL, Neaton JD, Brancati FL, Ford CE *et al.* Blood pressure and end-stage renal disease in men. *N Engl J Med* 1996; **334**(1): 13–18.
3 Stokes III J, Kannel WB, Wolf PA, D'Agostino RB, Cupples LA. Blood pressure as a risk factor for cardiovascular disease. The Framingham Study—30 years of follow-up. *Hypertension* 1989; **13**(5 Suppl): I13–I18.
4 Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo Jr JL *et al.* The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: the JNC 7 report. *JAMA* 2003; **289**(19): 2560–2572.
5 Kearney PM, Whelton M, Reynolds K, Muntner P, Whelton PK, He J. Global burden of hypertension: analysis of worldwide data. *Lancet* 2005; **365**(9455): 217–223.
6 Ezzati M, Lopez AD, Rodgers A, Vander HS, Murray CJ. Selected major risk factors and global and regional burden of disease. *Lancet* 2002; **360**(9343): 1347–1360.
7 Toto RD. Treatment of hypertension in chronic kidney disease. *Semin Nephrol* 2005; **25**(6): 435–439.
8 Yusuf S, Thom T, Abbott RD. Changes in hypertension treatment and in congestive heart failure mortality in the United States. *Hypertension* 1989; **13**(5 Suppl): I74–I79.
9 Moser M, Hebert PR. Prevention of disease progression, left ventricular hypertrophy and congestive heart failure in hypertension treatment trials. *J Am Coll Cardiol* 1996; **27**(5): 1214–1218.
10 Rodgers A, Lawes C, MacMahon S. Reducing the global burden of blood pressure-related cardiovascular disease. *J Hypertens Suppl* 2000; **18**(1): S3–S6.
11 Kearney PM, Whelton M, Reynolds K, Whelton PK, He J. Worldwide prevalence of hypertension: a systematic review. *J Hypertens* 2004; **22**(1): 11–19.
12 Thankappan KR, Sivasankaran S, Sarma PS, Mini G, Khader SA, Padmanabhan P *et al.* Prevalence-correlates-awareness-treatment and control of hypertension in Kumarakom, Kerala: baseline results of a community-based intervention program. *Indian Heart J* 2006; **58**(1): 28–33.
13 Prabhakaran D, Shah P, Chaturvedi V, Ramakrishnan L, Manhapra A, Reddy KS. Cardiovascular risk factor prevalence among men in a large industry of Northern India. *Natl Med J India* 2005; **18**(2): 59–65.
14 Gupta R, Gupta VP, Sarna M, Bhatnagar S, Thanvi J, Sharma V *et al.* Prevalence of coronary heart disease and risk factors in an urban Indian population: Jaipur Heart Watch-2. *Indian Heart J* 2002; **54**(1): 59–66.
15 Bharucha NE, Kuruvilla T. Hypertension in the Parsi community of Bombay: a study on prevalence, awareness and compliance to treatment. *BMC Public Health* 2003; **3**: 1.
16 Hazarika NC, Narain K, Biswas D, Kalita HC, Mahanta J. Hypertension in the native rural population of Assam. *Natl Med J India* 2004; **17**(6): 300–304.
17 Gopinath N, Chadha SL, Shekhawat S, Tandon R. A 3-year follow-up of hypertension in Delhi. *Bull World Health Organ* 1994; **72**(5): 715–720.
18 Gopinath N, Chadha SL, Shekhawat S, Tandon R. A 5-year follow-up study of hypertension in a rural community. *Indian Heart J* 1995; **47**(2): 129–133.
19 Hazarika NC, Biswas D, Narain K, Kalita HC, Mahanta J. Hypertension and its risk factors in tea garden workers of Assam. *Natl Med J India* 2002; **15**(2): 63–68.
20 Deepa R, Shanthirani CS, Pradeepa R, Mohan V. Is the 'rule of halves' in hypertension still valid?—Evidence from the Chennai Urban Population Study. *J Assoc Physicians India* 2003; **51**: 153–157.
21 Pednekar MS, Gupta R, Gupta PC. Association of blood pressure and cardiovascular mortality in India: Mumbai cohort study. *Am J Hypertens* 2009; **22**(10): 1076–1084.
22 Sauvaget C, Ramadas K, Thomas G, Thara S, Sankaranarayanan R. Prognosis criteria of casual systolic and diastolic blood pressure values in a prospective study in India. *J Epidemiol Community Health* 2010; **64**(4): 366–372.
23 Gupta R, al Odat NA, Gupta VP. Hypertension epidemiology in India: meta-analysis of 50 year prevalence rates and blood pressure trends. *J Hum Hypertens* 1996; **10**(7): 465–472.
24 Manimunda SP, Sugunan AP, Benegal V, Balakrishna N, Rao MV, Pesala KS. Association of hypertension with risk factors & hypertension related behaviour among the aboriginal Nicobarese tribe living in Car Nicobar Island, India. *Indian J Med Res* 2011; **133**(3): 287–293.
25 Borah PK, Hazarika NC, Biswas D, Kalita HC, Mahanta J. Population-specific left ventricular hypertrophy in three groups from the northeastern region of India. *Natl Med J India* 2010; **23**(6): 336–339.
26 Gupta PC, Gupta R. Hypertension prevalence and blood pressure trends among 99,589 subjects in Mumbai, India. Abstract. *Indian Heart J* 1999; **51**: 691.
27 Gupta R, Kaul V, Bhagat N, Agrawal M, Gupta VP, Misra A *et al.* Trends in prevalence of coronary risk factors in an urban Indian population: Jaipur Heart Watch-4. *Indian Heart J* 2007; **59**(4): 346–353.
28 Gupta R, Pandey RM, Misra A, Agrawal A, Misra P, Dey S *et al.* High prevalence and low awareness, treatment and control of hypertension in Asian Indian women. *J Hum Hypertens* 2011; **26**(10): 585–593.
29 Dalal PM. *Hypertension. A Report on Community Survey of Casual Hypertension in Old Bombay*. Sir HN Hospital Research Society: Bombay 1980.
30 Sharma BK, Arora OP, Bansal BL, Sagar S, Khurana SK. Hypertension among the industrial workers and professional classes in Ludhiana, Punjab. *Indian Heart J* 1985; **37**(6): 380–385.
31 Gupta SP, Siwach SB, Moda VK. Epidemiology of hypertension based on total community survey in the rural population of Haryana. *Indian Heart J* 1977; **29**(2): 53–62.
32 Gilberts EC, Arnold MJ, Grobbee DE. Hypertension and determinants of blood pressure with special reference to socioeconomic status in a rural South Indian community. *J Epidemiol Community Health* 1994; **48**(3): 258–261.
33 Malhotra P, Kumari S, Kumar R, Jain S, Sharma BK. Prevalence and determinants of hypertension in an un-industrialised rural population of North India. *J Hum Hypertens* 1999; **13**(7): 467–472.
34 Gupta R, Sharma AK. Prevalence of hypertension and subtypes in an Indian rural population: clinical and electrocardiographic correlates. *J Hum Hypertens* 1994; **8**(11): 823–829.
35 Jonas JB, Nangia V, Matin A, Joshi PP, Ughade SN. Prevalence, awareness, control, and associations of arterial hypertension in a rural central India population: the Central India Eye and Medical Study. *Am J Hypertens* 2010; **23**(4): 347–350.

Supplementary Information accompanies the paper on the Journal of Human Hypertension website (http://www.nature.com/jhh)