BMJ Open

Changes in Hypertension Prevalence, Awareness, Treatment and Control Rates Over Twenty Years in National Capital Region of India

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2016-015639
Article Type:	Research
Date Submitted by the Author:	26-Dec-2016
Complete List of Authors:	Roy, Ambuj; All India Institute of Medical Sciences, Cardiology Praveen , Pradeep A; All India Institute of Medical Sciences, Endocrinology amd Metabolism Amarchand, Ritvik; All India Institute of Medical Sciences, Ramakrishnan, Lakshmy; All India Institute of Medical Sciences, Cardiac Biochemistry Gupta, Ruby; Public Health Foundation of India Kondal, Dimple; Public Health Foundation of India Singh, Kalpana; Public Health Foundation of India Sharma , Meenakshi; Indian Council of Medical Research Shukla, DK; Indian Council Of Medical Research, Non-communicable Diseases Tandon, Nikhil; All India Institute of Medical Sciences, Endocrinology and Metabolism Reddy, KS; Public Health Foundation of India Anand, Krishnan; All India Institute of Medical Sciences, Center for Community Medicine Prabhakaran, Dorairaj; Public Health Foundation of India
Primary Subject Heading:	Cardiovascular medicine
Secondary Subject Heading:	Epidemiology
Keywords:	Hypertension < CARDIOLOGY, Pre Hypertension, Cardiovascular disease risk factors, Secular trends, India

Title: Changes in Hypertension Prevalence, Awareness, Treatment and Control Rates Over Twenty Years in National Capital Region of India

Sub Title: Change in hypertension burden over 20 years-India

List of Authors and Affiliations

Ambuj Roy, MD, DM*
Professor of Cardiology, All India Institute of Medical Sciences, New Delhi, India,
Email:drambujroy@gmail.com

Pradeep A Praveen, MPH
Doctoral Student, Department of Endocrinology and Metabolism,
All India Institute of Medical Sciences, New Delhi, India, Email:praveen.aims@gmail.com

Ritvik Amarchand, MBBS, PhD
Centre for Community Medicine, All India Institute of Medical Sciences, New Delhi, India,
Email: drritvik@gmail.com

Lakshmy Ramakrishnan, PhD
Professor, Department of Cardiac Biochemistry, All India Institute of Medical Sciences, New Delhi, India, Email: lakshmy_ram@yahoo.com

Ruby Gupta, PhD
Scientific Officer (Biochemistry), Public Health Foundation of India, Gurgaon, India,
Email: ruby.gupta@phfi.org

Dimple Kondal, PhD
Statistician, Public Health Foundation of India, Gurgaon, India, Email: dimple@ccdcindia.org

Kalpana Singh, MSc
Statistician, Public Health Foundation of India, Gurgaon, India, Email: kalpana.sing@phfi.org

Meenakshi Sharma, PhD
Scientist E, Indian Council of Medical Research, New Delhi, India, Email:smeenakshi@hotmail.com

Deepak Kumar Shukla, PhD
Scientist G & Head, Division of Non Communicable Diseases, Indian Council of Medical Research, New Delhi, India, Email: shukladk@icmr.org.in

Nikhil Tandon, MD, PhD
Professor & Head, Department of Endocrinology and Metabolism, All India Institute of Medical Sciences, New Delhi, India, Email:nikhil_tandon@hotmail.com

Kolli Srinath Reddy, MD, DM, MSc
President, Public Health Foundation of India, Gurgaon, India, Email: ksrinath.reddy@phfi.org

Anand Krishnan, MD, PhD
Professor, Centre for Community Medicine, All India Institute of Medical Sciences, New Delhi, India,
Email: kanandiyer@yahoo.com

Dorairaj Prabhakaran, MD, DM, MSc
Professor& Vice President, Public Health Foundation of India, Gurgaon, India,
Email: dprabhakaran@ccdcindia.org

*Corresponding Author

Address for correspondence:

Ambuj Roy, MD, DM
Additional Professor of Cardiology,
All India Institute of Medical Sciences
New Delhi, India- 110029.
Email:drambujroy@gmail.com
Phone:91-9869393945;
Fax: 91-11-26588663

Word count: 2707

Competing Interests: Nothing to declare

Funding: The study was funded by the Indian Council of Medical Research, New Delhi, India

Contributorship Statement:

Authors Reddy, Tandon, Prabhakaran, Anand Krishnan, Shukla, Sharma and Roy conceptualized and designed the study and revised the manuscript. Reddy, Prabhakaran, Anand Krishnan, Praveen, Amarchand and Roy were involved in execution of the study in the field. Praveen, Prabhakaran and Roy drafted and revised the manuscript. Kondal and Singh did the data analysis. Lakshmy and Gupta coordinated the biochemical analysis and interpreted the data

Data Sharing Statement:

I, the corresponding author of the manuscript, on behalf of all the other authors here by agree to share the study data and additional explanatory materials to fellow researchers.

Key Words: Hypertension; Pre-Hypertension; Secular trends; Cardiovascular disease risk factors; India

Abstract

Background & Objectives: Despite being one of the leading risk factors of cardiovascular mortality, there is limited data on changes in hypertension burden and management from India. This study evaluates trend in the prevalence, awareness, treatment and control of hypertension in the urban and rural areas of India's National Capital Region (NCR).

Design & setting: Two representative cross-sectional surveys were conducted in urban and rural areas [Survey1 (1991-1994); Survey 2 (2010-2012)] of NCR using similar methodologies.

Participants: A total of 3,048 (mean age: 46.8± 9.0; 52.3 % women) and 2,052 (mean age: 46.5±8.4; 54.2 % women) subjects of urban areas and 2,487 (mean age: 46.6±8.8; 57.0% women) and 1,917 (mean age: 46.5±8.5; 51.3 % women) subjects of rural areas were included in Survey 1 & 2 respectively.

Primary and secondary outcome measures: Hypertension was defined as per Joint National Committee VII guidelines. Structure questionnaire was used to measure the awareness and treatment status of hypertension. A mean SBP < 140 mm Hg and DBP < 90 mm Hg was defined as control of hypertension among the participants with hypertension.

Results: The age and sex standardised prevalence of hypertension increased from 23.0% to 42.2% ($p<0.001$) and 11.2% to 28.9% ($p<0.001$) urban and rural NCR respectively. In both surveys, those with high education, alcohol use, obesity and high fasting blood glucose were at a higher risk for hypertension. However, the change in hypertension prevalence between the surveys was independent of these risk factors [adjusted odds ratio (95% C.I): urban [2.4 (2.1, 2.7)]; rural [3.3 (2.5, 4.3)]. Overall there was no improvement in awareness, treatment and control rates of hypertension in the population.

Conclusion: There was marked increase in prevalence of hypertension over two decades with no improvement in management.

Strengths of the study

- One of the first studies to report the trends in the population burden and management of hypertension from the low and middle income countries
- The study surveyed representative samples from the same population using similar methodologies and was adequately powered to compare hypertension burden at two time periods

Limitations of the study

- The Instrument used for blood pressure measurement was different in the two studies. This was inevitable since the apparatus used in first survey was unavailable at the time of the next survey.
- Behavioural risk factors like diet and physical activity were not assessed during the first survey and therefore not reported and they could account for difference in blood pressure levels as discussed.
- The study being restricted to urban and rural NCR of Delhi, may not be generalizable across India.

Introduction

High blood pressure (HBP) is the single largest risk factor for disease burden worldwide[1].In India, HBP has now emerged as a leading risk factor for mortality[1]. Several studies over the years have shown increasing prevalence of hypertension in India[2–4]. Kearney et al in their paper predicted that the burden of hypertension in India is expected to almost double from 118 million in 2000 to 213.5 million by 2025[5]. A recent systematic analysis suggested high prevalence with poor awareness, treatment and control of hypertension in India[6].

At the population level the effect of rise in blood pressure is continuous with increasing cardiovascular risk with rise of blood pressure above 115/75 mmHg. However, data from India on trends of population blood pressure distribution, hypertension prevalence, awareness, treatment and control in representative population over time is scarce due to absence of active surveillance. This data is important to formulate informed policy as high blood pressure is one of the key targets to reduce premature mortality due to cardiovascular diseases (CVD) set by World Health Organisation (WHO) and the Indian government[7,8].

We conducted two surveys on prevalence of cardiovascular risk factors between April 1991 and June 1994 (Survey 1) and August 2010 and January 2012 (Survey 2) in National Capital Region (NCR) of India (urban Delhi and adjoining rural Haryana). These surveys enabled us to estimate the changes in blood pressure epidemiology in this population over this time period.

Methods

The two cross-sectional surveys were carried out in adults aged 35-64 years using a multistage cluster random sampling method in the urban area and a simple random sampling method in the rural area to assess the prevalence of coronary artery disease (CAD) and its risk factors. The sample size was calculated based on estimated prevalence of CAD in the population. The details of sample size calculation were published elsewhere [9]. Based on this 5535 participants were recruited for

survey 1(urban-3048; rural-2487) and 3969 were recruited for survey 2 (urban-2052; rural-1917). In both surveys, all eligible individuals from the primary sampling unit (household) were approached for their consent to participate in the survey. 99% of the participants in both surveys had their blood pressure measured. Among those surveyed, 95% and 78% in Survey 1 and Survey 2 respectively of the urban sample and 51.0% and 64.9% in Survey 1 and Survey 2 respectively of the rural sample agreed to provide a fasting blood sample for biochemical analysis. Both the surveys got ethical clearance from institutional ethics committees of the participating institutions. The data were collected through household visits using a standardized questionnaire. Anthropometric and biochemical data were collected through physician led medical camps using standardized equipments and methods. In survey 1, blood pressure was measured using a random zero sphygmomanometer while in survey 2 an automated blood pressure machine [OMRON (HEM-7080)] was used. In both surveys, two blood pressure readings were recorded in sitting position, five minutes apart. If the difference between the two readings was more than 10mmHg, a third measurement was taken. The mean of the last two measurements were taken for final analysis. Pre hypertension and hypertension were defined using the Joint National Committee VII criteria[10] (systolic blood pressure (SBP) 120-139 mm Hg and/or diastolic blood pressure (DBP) 80-89 mm Hg for pre hypertension and SBP≥ 140 mm Hg and/or DBP ≥ 90 mm Hg or on blood pressure lowering medication for hypertension). Those who were diagnosed with hypertension were further classified in to stage I (SBP140-159 mm Hg and/or DBP 90-99 mm Hg) and stage II (SBP≥ 160 mm Hg and/or DBP ≥ 100mm Hg).

Hypertension awareness, treatment, and control were analysed in hypertensive participants based on questionnaires and blood pressure measurements. Among the hypertensive participants, self-report of any previous clinical diagnosis of hypertension was defined as awareness of hypertension. Self- reported anti-hypertension medication use was defined as on treatment and a mean SBP < 140

mm Hg and DBP < 90 mm Hg was defined as control of hypertension among the participants with hypertension.

Statistical analysis

STATA 12.1 (STATA Corporation, College Station, TX, USA) was used for the statistical analysis. Prevalence of hypertension along with their standard errors and ratios between Survey 1 and Survey 2 and the awareness, treatment and control levels during Survey 1 and 2 are presented. The age and gender adjusted prevalence of hypertension was calculated using Indian census data for 2011 as standard population. Hypertension prevalence was analysed by selected demographic and health characteristics: gender, place of residence (urban/rural), age category (35-44, 45-54, 55-64), educational status, Body Mass Index (BMI), blood glucose level and alcohol use. Educational status was defined as follows: Low (illiterate to primary level), Medium (middle to high school) High (higher secondary and above). South Asian cut offs[11] were used to categorise BMI values (normal- BMI<23 kg/m^2, overweight- BMI 23-28 kg/m^2, obesity-BMI≥28 kg/m^2). Blood glucose levels were categorised as normoglycemic (fasting plasma glucose (FPG) < 100 mg/dl), impaired fasting glucose (FPG 100-<126mg/dl); and diabetes (FPG≥ 126 mg/dl). Alcohol use was defined as any use in the last twelve months of any alcohol product. The difference in proportions between the surveys was evaluated using chi square test. Any p value <0.05 was considered statistically significant. Multivariate logistic regression models were used to examine the effect of potential predictors including gender, age groups, obesity, diabetes and alcohol use on the increase in hypertension prevalence between the surveys. Logistic regression model were constructed for urban and rural populations separately and adjusted odds ratios with 95% confidence intervals (C.I) are presented. Each model has age, gender, obesity, diabetes, alcohol use and time period (Survey1 vs Survey 2) as binary independent variables; and hypertension as a binary dependent variable.

Results

A total of 3,048 (mean (SD) age: 46.8 (9.0) years; 52.3 % females) and 2,052 (mean (SD) age: 46.5 (8.4) years; 54.2 % females) subjects of urban areas and 2,487 (mean (SD) age: 46.6 (8.8) years; 57.0 % females) and 1,917 (mean (SD) age: 46.5 (8.5) years; 51.3 % females) subjects of rural areas were recruited in Survey 1 & 2 respectively.

The prevalence of hypertension increased from 23.0% to 42.2% and 11.2% to 28.9% in urban and rural NCR of Delhi respectively between the two surveys. The increase in prevalence was by 83% in urban NCR and 158% in rural NCR. The rise in prevalence was more in men with a rise of 94% and 73% in urban areas and 191% and 125% in rural areas in men and women receptively (Table 1). The age specific prevalence of hypertension revealed an increase in prevalence at all ages except in the highest age group (55-64 years) of urban men and women. The rise in age specific prevalence was highest in the youngest age group (35-44) with a rise in prevalence of 153%, 115%, 239% and 336%, in urban men, urban women, rural men and rural women respectively.

The distribution of blood pressure in the population (excluding those on anti-hypertensive therapy), changed significantly over the years. In survey 2, there was lesser proportion of the people with optimum blood pressure values (BP <120/80mmhg) and a higher proportion of individuals with pre-hypertension, Stage I and Stage II hypertension (Figure 1)compared to survey1. This change of distribution was similar across men and women in NCR and also both in urban and rural areas.

The prevalence of hypertension was stratified by other known risk factors associated with blood pressure (Figure 2). Hypertension prevalence increased with increasing BMI and education categories in both urban and rural population (Figure 2). The prevalence was highest in diabetics followed by those with impaired fasting blood glucose in both urban and rural areas (Figure 2). Alcohol users had higher prevalence of hypertension (Figure 2). The prevalence increased in each of these categories in survey 2 as compared to Survey 1. This was further evaluated by statistical

modelling (Table 2). The relative increase in hypertension prevalence between the surveys was modelled as if there was no change in the age, gender, obesity, diabetes and alcohol use between the surveys. However the increased odds ratio of hypertension in Survey 2 as compared to Survey 1 persisted even after adjusting for these factors. There was no change in the overall awareness, treatment and control rates of hypertension between the two surveys in the NCR of Delhi (Table 3). When stratified by gender the awareness, treatment and control rates of hypertension in men was lower in the second survey while awareness and treatment but not control rates improved in women. The overall rates of all three parameters were higher in woman than men. Similarly in urban areas there was no change in the overall awareness, treatment and control rates of hypertension between the two surveys though all three parameters decreased in men with no significant change in women with higher overall rates in women. In rural NCR the overall awareness, treatment and control rates of hypertension improved between the two surveys. This was seen in men and women except for control rates in men which did not improve. However, though all three rates improved in rural areas, the overall awareness (46.4% vs26.8%), treatment (40.0vs 20.4%) and control rates (15.9vs 8.0%) in rural areas remained much lower than in urban areas.

Table 1: Age & sex standardized and age-specific prevalence of hypertension: Survey 1 and Survey 2

	Rural							Urban						
	Survey 1			Survey 2				Survey 1			Survey 2			
	N	Prevalence (%)	SE	N	Prevalence (%)	SE	P Value-Difference	Ratio	N	Prevalence (%)	SE	N	Prevalence (%)	SE	P Value-Difference	Ratio
Total	2,469	11.2	0.01	1914	28.9	1	<0.001	2.6	3,041	23	0.01	2026	42.2	1.1	<0.001	1.8
Men	1,065	12.2	0.01	981	32.6	1.5	<0.001	2.9	1,451	22.3	0.01	924	43.3	1.6	<0.001	1.9
Women	1,404	10.2	0.01	933	25.2	1.4	<0.001	2.3	1,590	23.8	0.01	1102	41.1	1.4	<0.001	1.7
Men																
35-44	441	8.1	0.01	459	27.4	0.02	<0.001	3.4	646	13.4	0.01	434	33.9	0.02	<0.001	2.5
45-54	318	12.2	0.02	315	36.1	0.03	<0.001	3	432	21.6	0.02	299	47.9	0.03	<0.001	2.2
55-64	306	21.6	0.02	207	38.6	0.03	<0.001	1.8	373	34.5	0.03	191	42.5	0.02	NS	1
Women																
35-44	667	4.3	0.01	433	18.7	0.02	<0.001	4.4	723	12.8	0.01	521	27.6	0.02	<0.001	2.2
45-54	438	9.4	0.01	277	28.5	0.03	0.001	3	450	25.9	0.02	321	46.9	0.03	<0.001	1.8
55-64	299	23.1	0.02	223	33.3	0.03	0.011	1.4	417	57.6	0.04	260	59.8	0.03	NS	1

N- Sample size; SE- Standard Error; Ratio-Survey2/Survey1: NS-not statistically significant

Table-2: Odds of hypertension in Survey 2 relative to odds for hypertension in Survey 1

	Odds ratio (95% C.I)	
	Rural	Urban
Unadjusted	3.2 (2.7, 3.8)	2.3 (2.0, 2.6)
Adjusted for age	3.4 (2.9, 4.0)	2.6 (2.3, 2.9)
Adjusted for age and gender	3.3 (2.8, 3.9)	2.6 (2.3, 2.9)
Adjusted for age, gender and obesity	3.1 (2.6, 3.6)	2.6 (2.2, 2.9)
Adjusted for age, gender, obesity and diabetes	3.4 (2.7, 4.3)	2.4 (2.1, 2.8)
Adjusted for age, gender, obesity, diabetes and alcohol use	3.3 (2.5, 4.3)	2.4 (2.1, 2.7)

Table-3: Hypertension awareness, treatment and control among hypertensive population in NCR of Delhi: Survey 1 and Survey 2

	Awareness			Treatment			Control		
	Survey 1	Survey 2	P value	Survey 1	Survey 2	P value	Survey 1	Survey 2	P value
Total	37.5	38.7	NS	32	32.3	NS	14.4	12.8	NS
Men	33.1	26.8	0.02	28.3	21.1	0.01	13.1	7.1	0.01
Women	41.5	51.1	0.001	35.4	43.9	0.001	15.6	18.7	NS
Urban									
Total	49	46.4	NS	41.6	40	NS	19	15.9	NS
Men	44.3	34.7	0.01	37.8	29.2	0.01	17.6	10.7	0.01
Women	53.2	56.9	NS	45	49.6	NS	20.2	20.4	NS
Rural									
Total	7.2	26.8	0.001	6.8	20.4	0	2.5	8	0.001
Men	5.7	17	0.001	5	11	0.04	2.1	2.5	NS
Women	8.7	40	<0.001	8.7	33.2	<0.001	2.9	15.3	<0.001

NS- not statistically significant

Discussion

The repeat survey in NCR of Delhi done after two decades shows (1) continued gradient in urban rural prevalence of hypertension (2)Significant increases in prevalence of hypertension both in urban and rural areas with a higher increase in rural areas,(3) highest increase in prevalence of hypertension in the youngest age group (35-44 years) surveyed, (4) a rightward shift in the distribution of blood pressure in both urban and rural populations with fewer individuals with optimum blood pressure (<120/80), (5)strong relationship between the prevalence of hypertension and BMI, education level, fasting glucose levels and alcohol use, however, even after adjusting for all the predictor variables the odds of hypertension remained higher in the second survey (6) no change in overall awareness , treatment and control rates of hypertension in NCR

Prevalence of hypertension has been consistently increasing over the years; however, most reviews from India have included old studies. Recent repeat surveys done in other cities have shown varying results. A study from Jaipur revealed no significant change in hypertension prevalence over 2 decades from 1990 with a decrease in mean systolic blood pressure during this period[12]. A repeat survey from Chennai showed rise in self-reported prevalence in hypertension in low and middle income groups[13]. However, both these studies included only urban subjects and utilised convenience sampling and thus were not representative of the population. Our study done on a representative urban and rural sample revealed that the prevalence of hypertension increased in urban and rural areas with a higher rate of rise in the rural population. A recent systematic review of hypertension found a prevalence of 27.6% in rural India though it was only 16.7% in Northern India[6] which was at variance with our findings. However, more recent studies from North India have suggested prevalence of 22% and 32%in similar age groups, which is close to the prevalence in our study of 28.9% and those from other parts of rural India[14,15].

The age stratified prevalence showed increase in all age groups except the oldest in urban areas, with the highest rate of rise of hypertension in the youngest age group (35-44 years). Indirect evidence of high burden of risk factors in young comes from occurrence of cardiovascular diseases at younger age in South Asians as compared the Caucasians[4]. A study among the young individuals (20-30 years) from South India revealed a very high burden of 45.2% of pre-hypertension in the population[16]. However, the rapid rise of the burden of hypertension in young in last two decades has probably been demonstrated for the first time in this study and is worrisome and calls for urgent action to prevent further burden of pre-mature CVD in Indians.

The other important finding was the worsening of population blood pressure levels over two decades with a significantly lower proportion of the population having optimum blood pressure and more of them having pre-hypertension and hypertension. Small shifts in population blood pressure levels is known to lead to large increases in the burden of CVD in the community [17] and thus this also portends future worsening of CVD epidemic in India. It calls for population level intervention like advocacy for salt reduction, weight reduction and increase physical activity. The prevalence of hypertension was expectantly dependant on BMI and fasting glucose levels with higher rates among overweight and obese and those with impaired fasting glucose and diabetes. This finding is consistent across most studies in India and abroad [18–20]. The association of hypertension in India with education is variable. A recent large cohort study from South Asia reported higher prevalence among more educated[21].Some have reported reverse gradient with education[22]while others have reported no relationship[23][24].Alcohol use was associated with higher prevalence of hypertension as seen in other studies[25]. Limited data from South Asia suggests higher blood pressure levels in alcohol users [26]and also higher probability of MI in them than alcohol abstainers[27] unlike other population groups. Interestingly, the rise in prevalence of hypertension in Survey 2 was significant even after adjusting for these factors. This could be due to other lifestyle

factors known to be associated with high blood pressure like diet, physical activity, stress etc not being accounted for as data for this was not available for both studies.

The prevalence, awareness and control rates for hypertension were overall sub-optimal with no improvement between the 2 surveys. The rates of awareness, treatment and control of hypertension were comparable to the pooled estimates reported in systematic reviews with better rates in urban areas as compared to rural areas[2,6]. Additionally these rates were better in women as compared to men, as has been reported consistently in large studies from India and abroad[28,29].This is related to greater health seeking behaviour in women. This study additionally provided insights into the change in these rates over the last two decades which is not available from India earlier. The disturbing fact was that despite rising prevalence of hypertension there was no improvement in these rates with all three rates worsening in men with improvement in awareness, treatment but not control rates in women. When analysed by site and gender all rates except control rates in men improved in rural areas while in urban areas they worsened in men and remained unchanged in women. However, the overall rates in rural areas were still much lower than urban areas and the improvement in rural areas could be attributed to low rates in the first survey.

Strengths and limitations

The strengths of this study is that it surveyed population representative sample in the same population using similar methodologies and was adequately powered, thus providing opportunity to compare hypertension statistics at two time periods. Such temporal trend was not available from urban and rural areas of India earlier. One of the limitations of this study is that the apparatus used for blood pressure measurement was different in the two studies. This was inevitable since the apparatus used in first survey was unavailable at the time of the next survey. The two apparatus have marginal difference and if anything the current method of automated blood pressure monitors is known to underestimate blood pressure[30] and thus the prevalence and shift in blood pressure

levels in the population would only be higher. The other limitation is that behavioural risk factors like diet and physical activity were not assessed during the first survey and therefore not reported and they could account for difference in blood pressure levels as discussed. The study being restricted to urban and rural NCR of Delhi, may not be generalizable across India though similar prevalence rates have been reported across the country.

Conclusions

This two time survey of NCR of Delhi shows marked increase in prevalence of hypertension in the last two decades both in rural and urban areas with higher rates of increase in younger age. This was also associated with fewer individuals with optimum blood pressure and more with pre-hypertension and hypertension. This calls for urgent population and high risk approach to lower blood pressure in the community as the awareness, treatment and control levels showed no improvement over this time frame.

Figure Legend

Figure-1: Distribution of BP categories (%) in untreated population of NCR of Delhi: A) Urban Men; (B) Urban Women; (C) Rural Men; (D) Rural Women

Figure-2: Prevalence (%) of hypertension stratified by risk factors: (A) Education status; (B) Body Mass Index(BMI); (C) Fasting Plasma Glucose; (D) Alcohol Use

References

1 Lim SS, Vos T, Flaxman AD, *et al.* A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;**380**:2224–60. doi:10.1016/S0140-6736(12)61766-8

2 Devi P, Rao M, Sigamani A, *et al.* Prevalence, risk factors and awareness of hypertension in India: a systematic review. *J Hum Hypertens* 2013;**27**:281–7. doi:10.1038/jhh.2012.33

3 Gupta R. Trends in hypertension epidemiology in India. *J Hum Hypertens* 2004;**18**:73–8. doi:10.1038/sj.jhh.1001633

4 Prabhakaran D, Jeemon P, Roy A. Cardiovascular Diseases in India. *Circulation* 2016;**133**:1605–20. doi:10.1161/CIRCULATIONAHA.114.008729

5 Kearney PM, Whelton M, Reynolds K, *et al.* Global burden of hypertension: analysis of worldwide data. *Lancet*;**365**:217–23. doi:10.1016/S0140-6736(05)17741-1

6 Anchala R, Kannuri NK, Pant H, *et al.* Hypertension in India: a systematic review and meta-analysis of prevalence, awareness, and control of hypertension. *J Hypertens* 2014;**32**:1170–7. doi:10.1097/HJH.0000000000000146

7 United Nations. UN General Assembly resolution on the prevention and control of non communicable diseases. 2010.www.un.org (accessed 5 Mar2014).

8 World Health Organization. NCD Global Monitoring Framework. 2013.http://www.who.int/nmh/global_monitoring_framework (accessed 5 Mar2014).

9 Prabhakaran D, A Roy, Praveen PA, Ritvik A, Singh K, Kondal D, Ruby G, Lakshmy R, N Tandon, Reddy K S AK. Twenty year trend in the prevalence of cardiovascular disease risk factors in

the Urban and Rural areas of National Capital Region (NCR), India. *Glob Heart* 2016 (in press).

10 Chobanian A V, Bakris GL, Black HR, *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**:2560–72. doi:10.1001/jama.289.19.2560

11 Misra A, Chowbey P, Makkar BM, *et al.* Consensus statement for diagnosis of obesity, abdominal obesity and the metabolic syndrome for Asian Indians and recommendations for physical activity, medical and surgical management. *J Assoc Physicians India* 2009;**57**:163–70.http://www.ncbi.nlm.nih.gov/pubmed/19582986

12 Gupta R, Guptha S, Gupta VP, *et al.* Twenty-year trends in cardiovascular risk factors in India and influence of educational status. *Eur J Prev Cardiol* 2012;**19**:1258–71. doi:10.1177/1741826711424567

13 Deepa M, Anjana RM, Manjula D, *et al.* Convergence of prevalence rates of diabetes and cardiometabolic risk factors in middle and low income groups in urban India: 10-year follow-up of the Chennai Urban Population Study. *J Diabetes Sci Technol* 2011;**5**:918–27.http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3192599&tool=pmcentrez&rendertype=abstract (accessed 30 May2016).

14 Kishore J, Gupta N, Kohli C, *et al.* Prevalence of Hypertension and Determination of Its Risk Factors in Rural Delhi. *Int J Hypertens* 2016;**2016**:7962595. doi:10.1155/2016/7962595

15 Bansal SK, Saxena V, Kandpal SD, *et al.* The prevalence of hypertension and hypertension risk factors in a rural Indian community: A prospective door-to-door study. *J Cardiovasc Dis Res* 2012;**3**:117–23. doi:10.4103/0975-3583.95365

16 Kini S, Kamath VG, Kulkarni MM, *et al.* Pre-Hypertension among Young Adults (20-30 Years) in Coastal Villages of Udupi District in Southern India: An Alarming Scenario. *PLoS One*

2016;**11**:e0154538. doi:10.1371/journal.pone.0154538

17 Lewington S, Clarke R, Qizilbash N, *et al.* Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *Lancet* 2002;**360**:1903–13.http://www.ncbi.nlm.nih.gov/pubmed/12493255 (accessed 2 Feb2015).

18 Cutler JA, Sorlie PD, Wolz M, *et al.* Trends in hypertension prevalence, awareness, treatment, and control rates in United States adults between 1988-1994 and 1999-2004. *Hypertension* 2008;**52**:818–27. doi:10.1161/HYPERTENSIONAHA.108.113357

19 Menéndez E, Delgado E, Fernández-Vega F, *et al.* Prevalence, Diagnosis, Treatment, and Control of Hypertension in Spain. Results of the Di@bet.es Study. *Rev española Cardiol (English ed)* 2016;**69**:572–8. doi:10.1016/j.rec.2015.11.034

20 Bhadoria AS, Kasar PK, Toppo NA, *et al.* Prevalence of hypertension and associated cardiovascular risk factors in Central India. *J Family Community Med* 2014;**21**:29–38. doi:10.4103/2230-8229.128775

21 Ali MK, Bhaskarapillai B, Shivashankar R, *et al.* Socioeconomic status and cardiovascular risk in urban South Asia: The CARRS Study. *Eur J Prev Cardiol* 2016;**23**:408–19. doi:10.1177/2047487315580891

22 Reddy KS, Prabhakaran D, Jeemon P, *et al.* Educational status and cardiovascular risk profile in Indians. *Proc Natl Acad Sci U S A* 2007;**104**:16263–8. doi:10.1073/pnas.0700933104

23 Samuel P, Antonisamy B, Raghupathy P, *et al.* Socio-economic status and cardiovascular risk factors in rural and urban areas of Vellore, Tamilnadu, South India. *Int J Epidemiol* 2012;**41**:1315–27. doi:10.1093/ije/dys001

24 Kar SS, Thakur JS, Virdi NK, *et al.* Risk factors for cardiovascular diseases: is the social gradient reversing in northern India? *Natl Med J India*;**23**:206–9.http://www.ncbi.nlm.nih.gov/pubmed/21192513 (accessed 30 May2016).

25 Huang X, Zhou Z, Liu J, *et al.* Prevalence, awareness, treatment, and control of hypertension among China's Sichuan Tibetan population: A cross-sectional study. *Clin Exp Hypertens* 2016;**38**:457–63. doi:10.3109/10641963.2016.1163369

26 Roy A, Prabhakaran D, Jeemon P, *et al.* Impact of alcohol on coronary heart disease in Indian men. *Atherosclerosis* 2010;**210**:531–5. doi:10.1016/j.atherosclerosis.2010.02.033

27 Leong DP, Smyth A, Teo KK, *et al.* Patterns of alcohol consumption and myocardial infarction risk: observations from 52 countries in the INTERHEART case-control study. *Circulation* 2014;**130**:390–8. doi:10.1161/CIRCULATIONAHA.113.007627

28 Chow CK, Teo KK, Rangarajan S, *et al.* Prevalence, awareness, treatment, and control of hypertension in rural and urban communities in high-, middle-, and low-income countries. *JAMA* 2013;**310**:959–68. doi:10.1001/jama.2013.184182

29 Irazola VE, Gutierrez L, Bloomfield G, *et al.* Hypertension Prevalence, Awareness, Treatment, and Control in Selected LMIC Communities. *Glob Heart* 2016;**11**:47–59. doi:10.1016/j.gheart.2015.12.008

30 Ostchega Y, Zhang G, Sorlie P, *et al.* Blood pressure randomized methodology study comparing automatic oscillometric and mercury sphygmomanometer devices: National Health and Nutrition Examination Survey, 2009-2010. *Natl Health Stat Report* 2012;:1–15.

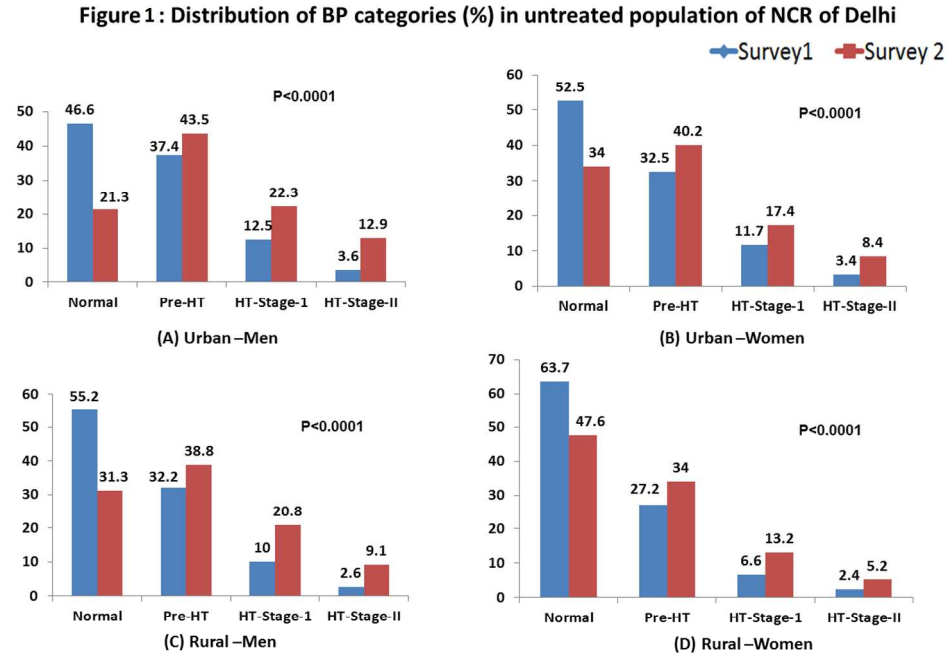

Figure-1: Distribution of BP categories (%) in untreated population of NCR of Delhi: A) Urban Men; (B) Urban Women; (C) Rural Men; (D) Rural Women

260x193mm (300 x 300 DPI)

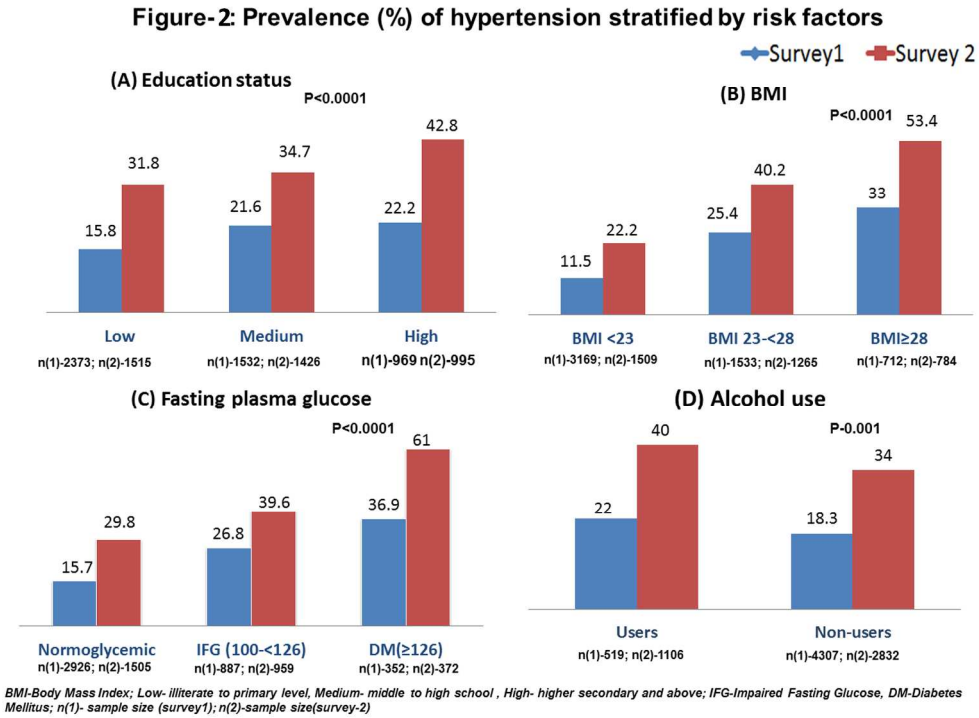

Figure-2: Prevalence (%) of hypertension stratified by risk factors: (A) Education status; (B) Body Mass Index(BMI); (C) Fasting Plasma Glucose; (D) Alcohol Use

130x96mm (600 x 600 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5,6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6.7
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	7
		(*e*) Describe any sensitivity analyses	5
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7,8
		(b) Indicate number of participants with missing data for each variable of interest	10,12
Outcome data	15*	Report numbers of outcome events or summary measures	10,12
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11
		(*b*) Report category boundaries when continuous variables were categorized	7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15,16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13,14
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Changes in Hypertension Prevalence, Awareness, Treatment and Control Rates Over Twenty Years in National Capital Region of India

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2016-015639.R1
Article Type:	Research
Date Submitted by the Author:	24-Mar-2017
Complete List of Authors:	Roy, Ambuj; All India Institute of Medical Sciences, Cardiology Praveen , Pradeep A; All India Institute of Medical Sciences, Endocrinology amd Metabolism Amarchand, Ritvik; All India Institute of Medical Sciences, Ramakrishnan, Lakshmy; All India Institute of Medical Sciences, Cardiac Biochemistry Gupta, Ruby; Public Health Foundation of India Kondal, Dimple; Public Health Foundation of India Singh, Kalpana; Public Health Foundation of India Sharma , Meenakshi; Indian Council of Medical Research Shukla, DK; Indian Council Of Medical Research, Non-communicable Diseases Tandon, Nikhil; All India Institute of Medical Sciences, Endocrinology and Metabolism Reddy, KS; Public Health Foundation of India Anand, Krishnan; All India Institute of Medical Sciences, Center for Community Medicine Prabhakaran, Dorairaj; Public Health Foundation of India
Primary Subject Heading:	Cardiovascular medicine
Secondary Subject Heading:	Epidemiology
Keywords:	Hypertension < CARDIOLOGY, Pre Hypertension, Cardiovascular disease risk factors, Secular trends, India

Title: Changes in Hypertension Prevalence, Awareness, Treatment and Control Rates Over Twenty Years in National Capital Region of India

Sub Title: Change in hypertension burden over 20 years-NCR, India

List of Authors and Affiliations

Ambuj Roy, MD, DM*
Professor of Cardiology, All India Institute of Medical Sciences, New Delhi, India,
Email:drambujroy@gmail.com

Pradeep A Praveen, MPH
Doctoral Student, Department of Endocrinology and Metabolism,
All India Institute of Medical Sciences, New Delhi, India, Email:praveen.aims@gmail.com

Ritvik Amarchand, MBBS, PhD
Centre for Community Medicine, All India Institute of Medical Sciences, New Delhi, India,
Email: drritvik@gmail.com

Lakshmy Ramakrishnan, PhD
Professor, Department of Cardiac Biochemistry, All India Institute of Medical Sciences, New Delhi, India, Email: lakshmy_ram@yahoo.com

Ruby Gupta, PhD
Scientific Officer (Biochemistry), Public Health Foundation of India, Gurgaon, India,
Email: ruby.gupta@phfi.org

Dimple Kondal, PhD
Statistician, Public Health Foundation of India, Gurgaon, India, Email: dimple@ccdcindia.org

Kalpana Singh, MSc
Statistician, Public Health Foundation of India, Gurgaon, India, Email: kalpana.sing@phfi.org

Meenakshi Sharma, PhD
Scientist E, Indian Council of Medical Research, New Delhi, India, Email:smeenakshi@hotmail.com

Deepak Kumar Shukla, PhD
Scientist G & Head, Division of Non Communicable Diseases, Indian Council of Medical Research, New Delhi, India, Email: shukladk@icmr.org.in

Nikhil Tandon, MD, PhD
Professor & Head, Department of Endocrinology and Metabolism, All India Institute of Medical Sciences, New Delhi, India, Email: nikhil_tandon@hotmail.com

Kolli Srinath Reddy, MD, DM, MSc
President, Public Health Foundation of India, Gurgaon, India, Email: ksrinath.reddy@phfi.org

Anand Krishnan, MD, PhD
Professor, Centre for Community Medicine, All India Institute of Medical Sciences, New Delhi, India,
Email: kanandiyer@yahoo.com

Dorairaj Prabhakaran, MD, DM, MSc
Professor& Vice President, Public Health Foundation of India, Gurgaon, India,
Email: dprabhakaran@ccdcindia.org

*Corresponding Author

Address for correspondence:

Ambuj Roy, MD, DM
Professor of Cardiology,
All India Institute of Medical Sciences
New Delhi, India- 110029.
Email: drambujroy@gmail.com
Phone: 91-9869393945;
Fax: 91-11-26588663

Word count: 2869

Competing Interests: Nothing to declare

Funding: The study was funded by the Indian Council of Medical Research, New Delhi, India

Contributorship Statement:

Authors Reddy, Tandon, Prabhakaran, Anand Krishnan, Shukla, Sharma and Roy conceptualized and designed the study and revised the manuscript. Reddy, Prabhakaran, Anand Krishnan, Praveen, Amarchand and Roy were involved in execution of the study in the field. Praveen, Prabhakaran and Roy drafted and revised the manuscript. Kondal and Singh did the data analysis. Lakshmy and Gupta coordinated the biochemical analysis and interpreted the data

Data Sharing Statement:

I, the corresponding author of the manuscript, on behalf of all the other authors here by agree to share the study data and additional explanatory materials to fellow researchers.

Key Words: Hypertension; Pre-Hypertension; Secular trends; Cardiovascular disease risk factors; India

Abstract

Background & Objectives: Despite being one of the leading risk factors of cardiovascular mortality, there is limited data on changes in hypertension burden and management from India. This study evaluates trend in the prevalence, awareness, treatment and control of hypertension in the urban and rural areas of India's National Capital Region (NCR).

Design & setting: Two representative cross-sectional surveys were conducted in urban and rural areas [Survey1 (1991-1994); Survey 2 (2010-2012)] of NCR using similar methodologies.

Participants: A total of 3,048 (mean age: 46.8± 9.0; 52.3 % women) and 2,052 (mean age: 46.5±8.4; 54.2 % women) subjects of urban areas and 2,487 (mean age: 46.6±8.8; 57.0% women) and 1,917 (mean age: 46.5±8.5; 51.3 % women) subjects of rural areas were included in Survey 1 & 2 respectively.

Primary and secondary outcome measures: Hypertension was defined as per Joint National Committee VII guidelines. Structure questionnaire was used to measure the awareness and treatment status of hypertension. A mean SBP < 140 mm Hg and DBP < 90 mm Hg was defined as control of hypertension among the participants with hypertension.

Results: The age and sex standardised prevalence of hypertension increased from 23.0% to 42.2% ($p<0.001$) and 11.2% to 28.9% ($p<0.001$) in urban and rural NCR respectively. In both surveys, those with high education, alcohol use, obesity and high fasting blood glucose were at a higher risk for hypertension. However, the change in hypertension prevalence between the surveys was independent of these risk factors [adjusted odds ratio (95% C.I): urban [2.3 (2.0, 2.7)]; rural [3.1 (2.4, 4.0)]. Overall there was no improvement in awareness, treatment and control rates of hypertension in the population.

Conclusion: There was marked increase in prevalence of hypertension over two decades with no improvement in management.

Strengths of the study

- One of the first studies to report the trends in the population burden and management of hypertension from the low and middle income countries
- The study surveyed representative samples from the same population using similar methodologies and was adequately powered to compare hypertension burden at two time periods

Limitations of the study

- The Instrument used for blood pressure measurement was different in the two studies. This was inevitable since the apparatus used in first survey was unavailable at the time of the next survey.
- Behavioural risk factors like diet and physical activity were not assessed during the first survey and therefore not reported and they could account for difference in blood pressure levels as discussed.
- The study being restricted to urban and rural NCR of Delhi, may not be generalizable across India.

Introduction

High blood pressure (HBP) is the single largest risk factor for disease burden worldwide. In India, HBP has now emerged as a leading risk factor for mortality [1]. Several studies over the years have shown increasing prevalence of hypertension in India [2–4]. Kearney et al in their paper predicted that the burden of hypertension in India is expected to almost double from 118 million in 2000 to 213.5 million by 2025 [5]. A recent systematic analysis suggested high prevalence with poor awareness, treatment and control of hypertension in India [6].

At the population level the effect of rise in blood pressure is continuous with increasing cardiovascular risk with rise of blood pressure above 115/75[7] mmHg. According to the Global Burden of Disease-2015 analysis, the estimated rate of annual deaths associated with SBP of at least 110 to 115 mm Hg between 1990 and 2015 has increased from 135.6 to 145.2 per 100 000 persons[8]. However, data from India on trends of population blood pressure distribution, hypertension prevalence, awareness, treatment and control in representative population over time is scarce due to absence of active surveillance. This data is important to formulate informed policy as high blood pressure is one of the key targets to reduce premature mortality due to cardiovascular diseases (CVD) set by World Health Organisation (WHO) and the Indian government[9,10].

We conducted two surveys on prevalence of cardiovascular risk factors between April 1991 and June 1994 (Survey 1) and August 2010 and January 2012 (Survey 2) in National Capital Region (NCR) of India (urban Delhi and adjoining rural Haryana). These surveys enabled us to estimate the changes in blood pressure prevalence and management in this population over this time period.

Methods

Study population and sample size:

The two cross-sectional surveys were carried out in adults aged 35-64 years using a multistage cluster random sampling method in the urban area and a simple random sampling method in the rural area to assess the prevalence of coronary artery disease (CAD) and its risk factors. The sample size was calculated based on estimated prevalence of CAD in the population. The details of sample size calculation were published elsewhere [11]. Based on this 5535 participants were recruited for survey 1(urban-3048; rural-2487) and 3969 were recruited for survey 2 (urban-2052; rural-1917). In both surveys, all eligible individuals from the primary sampling unit (household) were approached for their consent to participate in the survey.

Data collection:

Both the surveys got ethical clearance from institutional ethics committees of the participating institutions. The data were collected through household visits using a standardized questionnaire. Anthropometric and biochemical data were collected through physician led medical camps using standardized equipments and methods. In survey 1, blood pressure was measured using a random zero sphygmomanometer while in survey 2 an automated blood pressure machine [OMRON (HEM-7080)] was used. In both surveys, two blood pressure readings were recorded in sitting position, five minutes apart. If the difference between the two readings was more than 10mmHg, a third measurement was taken. The mean of the last two measurements were taken for final analysis.

Operational definitions:

Pre hypertension and hypertension were defined using the Joint National Committee VII criteria[12] (systolic blood pressure (SBP) 120-139 mm Hg and/or diastolic blood pressure (DBP) 80-89 mm Hg for pre hypertension and SBP≥ 140 mm Hg and/or DBP ≥ 90 mm Hg or on blood pressure lowering medication for hypertension). Those who were diagnosed with hypertension were further classified in to stage I (SBP140-159 mm Hg and/or DBP 90-99 mm Hg) and stage II (SBP≥ 160 mm Hg and/or DBP ≥ 100mm Hg).

Hypertension awareness, treatment, and control were analysed in hypertensive participants based on questionnaires and blood pressure measurements. Among the hypertensive participants, self-report of any previous clinical diagnosis of hypertension was defined as awareness of hypertension. Self- reported anti-hypertension medication use was defined as on treatment and a mean SBP < 140 mm Hg and DBP < 90 mm Hg was defined as control of hypertension among the participants with hypertension.

Statistical analysis

STATA 12.1 (STATA Corporation, College Station, TX, USA) was used for the statistical analysis. Prevalence of hypertension along with their standard errors and ratios between Survey 1 and Survey 2 and the awareness, treatment and control levels during Survey 1 and 2 are presented. The age and gender adjusted prevalence of hypertension was calculated using Indian census data for 2011 as standard population. Hypertension prevalence was analysed by selected demographic and health characteristics: gender, place of residence (urban/rural), age category (35-44, 45-54, 55-64), educational status, Body Mass Index (BMI), blood glucose level and alcohol use. Educational status was defined as follows: Low (illiterate to primary level), Medium (middle to high school) High (higher secondary and above). World Health Organisation cut offs were used to categorise BMI values (normal- BMI<25 kg/m^2, overweight- BMI 25-<30 kg/m^2, obesity-BMI≥30 kg/m^2) and abdominal obesity [Waist to Hip Ratio (WHR) >0.90 for men and >0.85 for women]. Blood glucose levels were categorised as normoglycemic (fasting plasma glucose (FPG) < 100 mg/dl), impaired fasting glucose (FPG 100- <126mg/dl); and diabetes (FPG≥ 126 mg/dl). Alcohol use was defined as any use in the last twelve months of any alcohol product. The difference in proportions between the surveys was evaluated using chi square test. Any p value <0.05 was considered statistically significant. Logistic regression models were constructed for urban and rural populations separately defining prevalence of hypertension as outcome variable and time period (Survey2 vs Survey 1) as exposure variables. We added covariates as categorical variables (age groups, gender, obesity, waist-hip-ratio, diabetes

and alcohol use), stepwise to the logistic regression model. Adjusted odds ratios and 95% CIs were reported. We also assessed the interaction between time (Survey 1; Survey 2) and other covariates mentioned above using likelihood test. If the interaction was found to be significant, then stratified analysis was reported.

Results

A total of 3,048 (mean (SD) age: 46.8 (9.0) years; 52.3 % females) and 2,052 (mean (SD) age: 46.5 (8.4) years; 54.2 % females) subjects of urban areas and 2,487 (mean (SD) age: 46.6 (8.8) years; 57.0 % females) and 1,917 (mean (SD) age: 46.5 (8.5) years; 51.3 % females) subjects of rural areas were recruited in Survey 1 & 2 respectively. Ninety-nine% of the participants in both surveys had their blood pressure measured. Among those surveyed, 95% and 78% in Survey 1 and Survey 2 respectively of the urban sample and 51.0% and 64.9% in Survey 1 and Survey 2 respectively of the rural sample agreed to provide a fasting blood sample for biochemical analysis.

The prevalence of hypertension increased from 23.0% to 42.2% and 11.2% to 28.9% in urban and rural NCR of Delhi respectively between the two surveys. The increase in prevalence was by 83% in urban NCR and 158% in rural NCR. The rise in prevalence was more in men with a rise of 94% and 73% in urban areas and 191% and 125% in rural areas in men and women receptively (Table 1). The age specific prevalence of hypertension revealed an increase in prevalence at all ages except in the highest age group (55-64 years) of urban men and women. The rise in age specific prevalence was highest in the youngest age group (35-44) with a rise in prevalence of 153%, 115%, 239% and 336%, in urban men, urban women, rural men and rural women respectively.

The distribution of blood pressure in the population (excluding those on anti-hypertensive therapy), changed significantly over the years. In survey 2, there was lesser proportion of the people with optimum blood pressure values (BP <120/80mmhg) and a higher proportion of individuals with pre-

hypertension, Stage I and Stage II hypertension (Figure 1)compared to survey1. This change of distribution was similar across men and women in NCR and also both in urban and rural areas.

The prevalence of hypertension was stratified by other known risk factors associated with blood pressure (Figure 2). Hypertension prevalence increased with increasing BMI and education categories in both urban and rural population (Figure 2). The prevalence was highest among those with diabetes followed by those with impaired fasting blood glucose in both urban and rural areas (Figure 2). Alcohol users had higher prevalence of hypertension (Figure 2). The prevalence increased in each of these categories in survey 2 as compared to Survey 1.

The distribution of risk factors in those with and without hypertension in urban and rural areas is as in supplementary table-1. The prevalence of alcohol use, obesity, abdominal obesity and diabetes increased significantly among those with hypertension in survey 2 compared to survey 1. The relative increase in hypertension prevalence between the surveys was modelled as if there was no change in these risk factors and the demographic profile between the surveys. The increased odds ratio of hypertension in Survey 2 as compared to Survey 1 persisted even after adjusting for these factors .On analysis, a significant interaction between time and age was observed. The age stratified models suggested higher odds of change in hypertension prevalence among the youngest age group in both urban and rural areas (Table-2).

There was no change in the overall awareness, treatment and control rates of hypertension between the two surveys in the NCR (Table 3). When stratified by gender the awareness, treatment and control rates of hypertension in men decreased in the second survey while awareness and treatment but not control rates improved in women. The overall rates of all three parameters were higher in woman than men. Similarly in urban areas there was no change in the overall awareness, treatment and control rates of hypertension between the two surveys though all three parameters decreased in men with no significant change in women with higher overall rates in women. In rural NCR the

overall awareness, treatment and control rates of hypertension improved between the two surveys. This was seen in men and women except for control rates in men which did not improve. However, though all three rates improved in rural areas, the overall awareness (46.4% vs26.8%), treatment (40.0vs 20.4%) and control rates (15.9vs 8.0%) in rural areas remained much lower than in urban areas.

Table 1: Age & sex standardized and age-specific prevalence of hypertension: Survey 1 and Survey 2

	Rural							Urban						
	Survey 1			Survey 2				Survey 1			Survey 2			
	N	Prevalence (%)	SE	N	Prevalence (%)	SE	P Value-Difference	Ratio (95% C.I)	N	Prevalence (%)	SE	N	Prevalence (%)	SE	P Value-Difference	Ratio
Total	2,469	11.2	0.01	1914	28.9	1	<0.001	2.6 (2.3, 2.9)	3,041	23	0.01	2026	42.2	1.1	<0.001	1.8 (1.6, 1.9)
Men	1,065	12.2	0.01	981	32.6	1.5	<0.001	2.7 (2.2, 3.3)	1,451	22.3	0.01	924	43.3	1.6	<0.001	1.9 (1.8, 2.3)
Women	1,404	10.2	0.01	933	25.2	1.4	<0.001	2.5 (2.4, 3.6)	1,590	23.8	0.01	1102	41.1	1.4	<0.001	1.7 (1.5, 2.0)
Men																
35-44	441	8.1	0.01	459	27.4	0.02	<0.001	3.4 (2.4, 4.8)	646	13.4	0.01	434	33.9	0.02	<0.001	2.5 (2.0, 3.3)
45-54	318	12.2	0.02	315	36.1	0.03	<0.001	3.0 (2.1, 4.1)	432	21.6	0.02	299	47.9	0.03	<0.001	2.2 (1.8, 2.8)
55-64	306	21.6	0.02	207	38.6	0.03	<0.001	1.8 (1.4, 2.4)	373	34.5	0.03	191	42.5	0.02	NS	1.2 (1.0, 1.6)
Women																
35-44	667	4.3	0.01	433	18.7	0.02	<0.001	4.4 (3.1, 6.9)	723	12.8	0.01	521	27.6	0.02	<0.001	2.2 (1.8, 2.8)
45-54	438	9.4	0.01	277	28.5	0.03	0.001	3.0 (2.2, 4.4)	450	25.9	0.02	321	46.9	0.03	<0.001	1.8 (1.5, 2.2)
55-64	299	23.1	0.02	223	33.3	0.03	0.011	1.4 (1.1, 1.9)	417	57.6	0.04	260	59.8	0.03	NS	1.0 (0.99, 1.6)

N- Sample size; SE- Standard Error; Ratio-Survey2/Survey1: NS-not statistically significant

Table-2: Odds of hypertension in Survey 2 relative to odds for hypertension in Survey 1		
	Odds ratio (95% CI)	
	Rural	Urban
Unadjusted	3.2 (2.7, 3.8)	2.3 (2.0, 2.6)
Model 1: Adjusted for age	3.4 (2.9, 4.0)	2.6 (2.3, 2.9)
Model 2: Adjusted for age and gender	3.3 (2.8, 3.9)	2.6 (2.3, 2.9)
Model 3: Adjusted for age, gender and obesity	3.1 (2.6, 3.6)	2.6 (2.2, 2.9)
Model 4: Adjusted for age, gender and WHR	3.1 (2.6,3.6)	2.4 (2.1,2.8)
Model 5: Adjusted for age, gender, obesity and WHR	2.9 (2.4,3.4)	2.4 (2,1,2.8)
Model 6: Adjusted for age, gender, obesity, WHR and diabetes	3.3(2.6,4.1)	2.4 (2.1,2.7)
Model 7: Adjusted for age, gender, obesity, WHR, diabetes and alcohol use	3.1 (2.4, 4.0)	2.3 (2.0,2.7)
Model 8: Model 7 stratified by age groups		
Age 35-44 years	5.0(3.0,8.4)	2.7(2.1,3.4)
Age 45-54 years	1.6(1.2,2.1)	2.1(1.6,2.6)
Age 55-64 years	2.1(1.6,2.9)	2.6(1.9,3.4)
Obesity- BMI ≥ 30 Kg/m^2; Diabetes- Fasting Plasma Glucose (FPG) ≥ 126 mg/dl or on medication; Abdominal obesity-Waist-hip-ratio >0.90 for men and >0.85 for women; p-value for interaction between time and age (rural) p=0.0001; p-value for interaction between time and age (urban) p=0.0008		

Table-3: Hypertension awareness, treatment and control among hypertensive population in NCR of Delhi: Survey 1 and Survey 2

	Awareness			Treatment			Control		
	Survey 1 (%)	Survey 2 (%)	P value	Survey 1 (%)	Survey 2 (%)	P value	Survey 1 (%)	Survey 2 (%)	P value
Total	37.5	38.7	NS	32.0	32.3	NS	14.4	12.8	NS
Men	33.1	26.8	0.02	28.3	21.1	0.01	13.1	7.1	0.01
Women	41.5	51.1	0.001	35.4	43.9	0.001	15.6	18.7	NS
Urban									
Total	49.0	46.4	NS	41.6	40.0	NS	19.0	15.9	NS
Men	44.3	34.7	0.01	37.8	29.2	0.01	17.6	10.7	0.01
Women	53.2	56.9	NS	45.0	49.6	NS	20.2	20.4	NS
Rural									
Total	7.2	26.8	0.001	6.8	20.4	0.01	2.5	8.0	0.001
Men	5.7	17.0	0.001	5.0	11.0	0.04	2.1	2.5	NS
Women	8.7	40	<0.001	8.7	33.2	<0.001	2.9	15.3	<0.001

NS- not statistically significant

Discussion

The repeat survey in NCR of Delhi done after two decades shows (1) continued gradient in urban rural prevalence of hypertension (2) Significant increases in prevalence of hypertension both in urban and rural areas with a higher increase in rural areas,(3) highest increase in prevalence of hypertension in the youngest age group (35-44 years) surveyed, (4) a rightward shift in the distribution of blood pressure in both urban and rural populations with fewer individuals with optimum blood pressure (<120/80), (5)strong relationship between hypertension and BMI, education level, fasting glucose levels and alcohol use, however, even after adjusting for all these predictor variables the odds of hypertension prevalence remained higher in the second survey (6) no change in overall awareness , treatment and control rates of hypertension in NCR

Prevalence of hypertension has been consistently increasing over the years; however, most reviews from India have included old studies. Recent repeat surveys done in other cities have shown varying results. A study from Jaipur revealed no significant change in hypertension prevalence over 2 decades from 1990 with a decrease in mean systolic blood pressure during this period [13]. A repeat survey from Chennai showed rise in self-reported prevalence in hypertension in low and middle income groups [14]. However, these studies included only urban subjects and utilised convenience sampling and thus were not representative of the population. Our study done on a representative urban and rural sample revealed that the prevalence of hypertension increased in urban and rural areas with a higher rate of rise in the rural population. A recent systematic review of hypertension found a prevalence of 27.6% in rural India though it was only 16.7% in rural Northern India [6] which was at variance with our findings. However, more recent studies from North India have suggested prevalence of 22% and 32%in similar age groups, which is close to the prevalence in our study of 28.9% and those from other parts of rural India[15][16].

The age stratified prevalence showed increase in all age groups except the oldest in urban areas, with the highest rate of rise of hypertension in the youngest age group (35-44 years). Indirect evidence of high burden of risk factors in young comes from occurrence of cardiovascular diseases at younger age in South Asians as compared the Caucasians [4]. A study among the young individuals (20-30 years) from South India revealed a very high burden of 45.2% of pre-hypertension in the population [17]. However, the rapid rise of the burden of hypertension in young in last two decades has probably been demonstrated for the first time in this study and is worrisome and calls for urgent action to prevent further burden of pre-mature CVD in Indians.

The other important finding was the worsening of population blood pressure levels over two decades with a significantly lower proportion of the population having optimum blood pressure and more of them having pre-hypertension and hypertension. Small shifts in population blood pressure levels is known to lead to large increases in the burden of CVD in the community [18] and thus this also portends future worsening of CVD epidemic in India. It calls for population level intervention like advocacy for salt reduction, weight reduction and increase physical activity. The prevalence of hypertension was expectantly dependant on BMI and fasting glucose levels with higher rates among overweight and obese and those with impaired fasting glucose and diabetes. This finding is consistent across most studies in India and abroad [19–21]. The association of hypertension in India with education is variable. A recent large cohort study from South Asia reported higher prevalence among more educated [22]**.** Some have reported reverse gradient with education [23] while others have reported no relationship[24,25].Alcohol use was associated with higher prevalence of hypertension as seen in other studies[26]. Limited data from South Asia suggests higher blood pressure levels in alcohol users [27]and also higher probability of MI in them than alcohol abstainers[28]unlike other population groups. Interestingly, the rise in prevalence of hypertension in Survey 2 was significant even after adjusting for these factors. This could be due to other

unmeasured lifestyle factors known to be associated with high blood pressure like diet, physical activity, stress etc, data for which was not available for both studies.

The prevalence, awareness and control rates for hypertension were overall sub-optimal with no improvement between the 2 surveys. The rates of awareness, treatment and control of hypertension were comparable to the pooled estimates reported in systematic reviews with better rates in urban areas as compared to rural areas [2,6]. Additionally these rates were better in women as compared to men, as has been reported consistently in large studies from India and abroad[29,30]. This is related to greater health seeking behaviour in women [30]. This study additionally provided insights into the change in these rates over the last two decades which is not available from India earlier. The disturbing fact was that despite rising prevalence of hypertension there was no improvement in these rates with all three rates worsening in men with improvement in awareness, treatment but not control rates in women. When analysed by site and gender all rates except control rates in men improved in rural areas while in urban areas they worsened in men and remained unchanged in women. However, the overall rates in rural areas were still much lower than urban areas and the improvement in rural areas could be attributed to low rates in the first survey.

Strengths and limitations

The strengths of this study is that it surveyed population representative sample in the same population using similar methodologies and was adequately powered, thus providing opportunity to compare hypertension statistics at two time periods. Such temporal trend was not available from urban and rural areas of India earlier. One of the limitations of this study is that the apparatus used for blood pressure measurement was different in the two studies. This was inevitable since the apparatus used in first survey was unavailable at the time of the next survey. The two apparatus have marginal difference and if anything the current method of automated blood pressure monitors is known to underestimate blood pressure [31]and thus the prevalence and shift in blood pressure

levels in the population would only be higher. The other limitation is that behavioural risk factors like diet and physical activity were not assessed during the first survey and therefore not reported and they could account for difference in blood pressure levels as discussed. In addition macro level changes in the population like socio-economic transition, urbanisation, policy etc. are not accounted for in our study. The study being restricted to urban and rural NCR of Delhi, may not be generalizable across India though similar prevalence rates have been reported across the country.

Conclusions

This two time survey of NCR of Delhi shows marked increase in prevalence of hypertension in the last two decades both in rural and urban areas with higher rates of increase in younger age. This was also associated with fewer individuals with optimum blood pressure and more with pre-hypertension and hypertension. This calls for urgent population and high risk approach to lower blood pressure in the community as the overall awareness, treatment and control levels showed no improvement over this time frame.

Figure Legend

Figure-1: Distribution of BP categories (%) in untreated population of NCR of Delhi: A) Urban Men; (B) Urban Women; (C) Rural Men; (D) Rural Women

Figure-2: Prevalence (%) of hypertension stratified by risk factors: (A) Education status; (B) Body Mass Index(BMI); (C) Fasting Plasma Glucose; (D) Alcohol Use

References

1 Lim SS, Vos T, Flaxman AD, *et al.* A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;**380**:2224–60. doi:10.1016/S0140-6736(12)61766-8

2 Devi P, Rao M, Sigamani A, *et al.* Prevalence, risk factors and awareness of hypertension in India: a systematic review. *J Hum Hypertens* 2013;**27**:281–7. doi:10.1038/jhh.2012.33

3 Gupta R. Trends in hypertension epidemiology in India. *J Hum Hypertens* 2004;**18**:73–8. doi:10.1038/sj.jhh.1001633

4 Prabhakaran D, Jeemon P, Roy A. Cardiovascular Diseases in India. *Circulation* 2016;**133**:1605–20. doi:10.1161/CIRCULATIONAHA.114.008729

5 Kearney PM, Whelton M, Reynolds K, *et al.* Global burden of hypertension: analysis of worldwide data. *Lancet*;**365**:217–23. doi:10.1016/S0140-6736(05)17741-1

6 Anchala R, Kannuri NK, Pant H, *et al.* Hypertension in India: a systematic review and meta-analysis of prevalence, awareness, and control of hypertension. *J Hypertens* 2014;**32**:1170–7. doi:10.1097/HJH.0000000000000146

7 Lewington S, Clarke R, Qizilbash N, *et al.* Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *Lancet (London, England)* 2002;**360**:1903–13.

8 Forouzanfar MH, Liu P, Roth GA, *et al.* Global Burden of Hypertension and Systolic Blood Pressure of at Least 110 to 115 mm Hg, 1990-2015. *JAMA* 2017;**317**:165. doi:10.1001/jama.2016.19043

9 United Nations. UN General Assembly resolution on the prevention and control of non communicable diseases. 2010.www.un.org (accessed 5 Mar2014).

10 World Health Organization. NCD Global Monitoring Framework. 2013.http://www.who.int/nmh/global_monitoring_framework (accessed 5 Mar2014).

11 Prabhakaran D, A Roy, Praveen PA, Ritvik A, Singh K, Kondal D, Ruby G, Lakshmy R, N Tandon, Reddy K S AK. Twenty year trend in the prevalence of cardiovascular disease risk factors in the Urban and Rural areas of National Capital Region (NCR), India. *Glob Heart* 2017(in press).

12 Chobanian A V, Bakris GL, Black HR, *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**:2560–72. doi:10.1001/jama.289.19.2560

13 Gupta R, Guptha S, Gupta VP, *et al.* Twenty-year trends in cardiovascular risk factors in India and influence of educational status. *Eur J Prev Cardiol* 2012;**19**:1258–71. doi:10.1177/1741826711424567

14 Deepa M, Anjana RM, Manjula D, *et al.* Convergence of prevalence rates of diabetes and cardiometabolic risk factors in middle and low income groups in urban India: 10-year follow-up of the Chennai Urban Population Study. *J Diabetes Sci Technol* 2011;**5**:918–27.http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3192599&tool=pmcentrez&rendertype=abstract (accessed 30 May2016).

15 Kishore J, Gupta N, Kohli C, *et al.* Prevalence of Hypertension and Determination of Its Risk Factors in Rural Delhi. *Int J Hypertens* 2016;**2016**:7962595. doi:10.1155/2016/7962595

16 Bansal SK, Saxena V, Kandpal SD, *et al.* The prevalence of hypertension and hypertension risk factors in a rural Indian community: A prospective door-to-door study. *J Cardiovasc Dis Res* 2012;**3**:117–23. doi:10.4103/0975-3583.95365

17 Kini S, Kamath VG, Kulkarni MM, *et al.* Pre-Hypertension among Young Adults (20-30 Years) in Coastal Villages of Udupi District in Southern India: An Alarming Scenario. *PLoS One* 2016;**11**:e0154538. doi:10.1371/journal.pone.0154538

18 Lewington S, Clarke R, Qizilbash N, *et al.* Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *Lancet* 2002;**360**:1903–13.http://www.ncbi.nlm.nih.gov/pubmed/12493255 (accessed 2 Feb2015).

19 Cutler JA, Sorlie PD, Wolz M, *et al.* Trends in hypertension prevalence, awareness, treatment, and control rates in United States adults between 1988-1994 and 1999-2004. *Hypertension* 2008;**52**:818–27. doi:10.1161/HYPERTENSIONAHA.108.113357

20 Menéndez E, Delgado E, Fernández-Vega F, *et al.* Prevalence, Diagnosis, Treatment, and Control of Hypertension in Spain. Results of the Di@bet.es Study. *Rev española Cardiol (English ed)* 2016;**69**:572–8. doi:10.1016/j.rec.2015.11.034

21 Bhadoria AS, Kasar PK, Toppo NA, *et al.* Prevalence of hypertension and associated cardiovascular risk factors in Central India. *J Family Community Med* 2014;**21**:29–38. doi:10.4103/2230-8229.128775

22 Ali MK, Bhaskarapillai B, Shivashankar R, *et al.* Socioeconomic status and cardiovascular risk in urban South Asia: The CARRS Study. *Eur J Prev Cardiol* 2016;**23**:408–19. doi:10.1177/2047487315580891

23 Reddy KS, Prabhakaran D, Jeemon P, *et al.* Educational status and cardiovascular risk profile in Indians. *Proc Natl Acad Sci U S A* 2007;**104**:16263–8. doi:10.1073/pnas.0700933104

24 Samuel P, Antonisamy B, Raghupathy P, *et al.* Socio-economic status and cardiovascular risk factors in rural and urban areas of Vellore, Tamilnadu, South India. *Int J Epidemiol*

2012;**41**:1315–27. doi:10.1093/ije/dys001

25 Kar SS, Thakur JS, Virdi NK, *et al.* Risk factors for cardiovascular diseases: is the social gradient reversing in northern India? *Natl Med J India*;**23**:206–9.http://www.ncbi.nlm.nih.gov/pubmed/21192513 (accessed 30 May2016).

26 Huang X, Zhou Z, Liu J, *et al.* Prevalence, awareness, treatment, and control of hypertension among China's Sichuan Tibetan population: A cross-sectional study. *Clin Exp Hypertens* 2016;**38**:457–63. doi:10.3109/10641963.2016.1163369

27 Roy A, Prabhakaran D, Jeemon P, *et al.* Impact of alcohol on coronary heart disease in Indian men. *Atherosclerosis* 2010;**210**:531–5. doi:10.1016/j.atherosclerosis.2010.02.033

28 Leong DP, Smyth A, Teo KK, *et al.* Patterns of alcohol consumption and myocardial infarction risk: observations from 52 countries in the INTERHEART case-control study. *Circulation* 2014;**130**:390–8. doi:10.1161/CIRCULATIONAHA.113.007627

29 Chow CK, Teo KK, Rangarajan S, *et al.* Prevalence, awareness, treatment, and control of hypertension in rural and urban communities in high-, middle-, and low-income countries. *JAMA* 2013;**310**:959–68. doi:10.1001/jama.2013.184182

30 Irazola VE, Gutierrez L, Bloomfield G, *et al.* Hypertension Prevalence, Awareness, Treatment, and Control in Selected LMIC Communities. *Glob Heart* 2016;**11**:47–59. doi:10.1016/j.gheart.2015.12.008

31 Ostchega Y, Zhang G, Sorlie P, *et al.* Blood pressure randomized methodology study comparing automatic oscillometric and mercury sphygmomanometer devices: National Health and Nutrition Examination Survey, 2009-2010. *Natl Health Stat Report* 2012;:1–15.

Figure 1 : Distribution of BP categories (%) in untreated population of NCR of Delhi

*HT: Hypertension; Normal: BP<120mmHg and DBP<80 mmHg; Pre hypertension: BP 120-139 mmHg or DBP 80-89 mmHg; Hypertension Stage I: SBP 140-159or DBP 90-99; Hypertension Stage II: SBP≥160 or DBP≥ 100; S1: Survey-1; S2: Survey-2; * Difference in distribution of blood pressure categories of Survey 1 &2*

Figure-1: Distribution of BP categories (%) in untreated population of NCR of Delhi: A) Urban Men; (B) Urban Women; (C) Rural Men; (D) Rural Women

260x193mm (300 x 300 DPI)

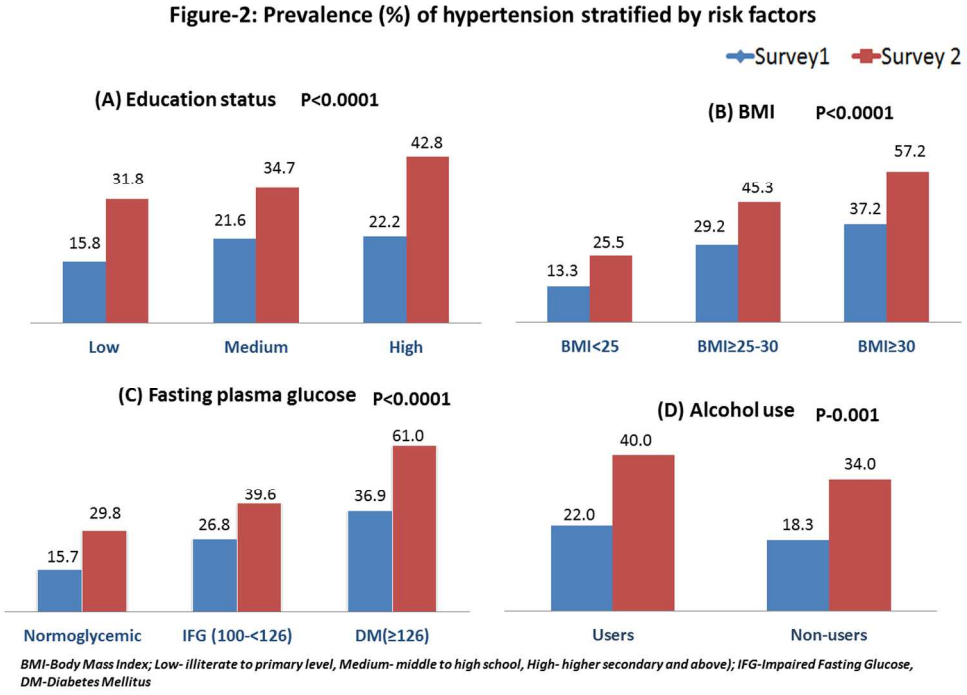

Figure-2: Prevalence (%) of hypertension stratified by risk factors: (A) Education status; (B) Body Mass Index(BMI); (C) Fasting Plasma Glucose; (D) Alcohol Use

250x178mm (300 x 300 DPI)

Supplementary table-1: Characteristics of study population according to hypertension status								
	Urban				Rural			
	Survey 1		Survey 2		Survey 1		Survey 2	
	Without hypertension	With hypertension	Without hypertension	With hypertension	Without hypertension	With hypertension	Without hypertension	With hypertension
Age [Mean ± SEM]	45.6±0.2	52.0±0.3	44.7±0.2	48.9±0.3	46.0±0.2	51.9±0.5	45.8±0.2	48.2±0.4
Gender Women[%(95% C.I)]	52.0 (50.0, 54.0)	53.2 (49.5, 56.8)	55.5 (52.6, 58.3)	52.9 (49.5, 56.2)	57.8 (55.7, 59.8)	49.6 (43.8, 55.5)	51.3 (48.6, 53.9)	42.5 (38.4, 46.7)
Alcohol use (Yes) [%(95% C.I)]	14.0 (12.6, 15.5)	14.2 (11.8, 17.0)	20.8 (18.5, 23.2)	26.1 (23.2, 29.1)	5.5 (4.5, 6.7)	7.6 (4.7, 12.0)	30.9 (28.5, 33.4)	39.8 (35.8, 43.9)
Obesity [%(95% C.I)]	9.9 (8.8, 11.2)	19.3 (16.5, 22.3)	13.8 (11.8, 16.2)	27.9 (24.7, 31.3)	1.2 (0.8, 1.8)	4.0 (2.2, 7.1)	5.0 (4.0, 6.3)	12.1 (9.7, 15.1)
Abdominal obesity [%(95% C.I)]	62.0 (60.0, 64.0)	72.3 (68.9, 75.4)	67.4 (64.6, 70.0)	83.2 (80.6, 85.6)	50.9 (48.7, 53.0)	72.8 (67.0, 77.9)	67.7 (65.1, 70.1)	82.4 (79.0, 85.4)
Diabetes Mellitus [%(95% C.I)]	10.3 (9.1, 11.7)	21.1 (18.2, 24.2)	12.5 (10.5, 14.8)	30.2 (26.9, 33.7)	2.5 (1.7, 3.5)	6.9 (3.6, 12.8)	6.6 (5.2, 8.5)	16.0 (12.6, 20.1)

Obesity- BMI ≥ 30 Kg/m^2; Abdominal obesity-Waist-hip-ratio >0.90 for men and >0.85 for women; Diabetes- Fasting Plasma Glucose (FPG) ≥ 126 mg/dl or on medication; SEM-Standard Error of Mean

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5,6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6.7
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	7
		(*e*) Describe any sensitivity analyses	5
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	10,11
Outcome data	15*	Report numbers of outcome events or summary measures	10,11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12
		(*b*) Report category boundaries when continuous variables were categorized	7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15,16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14,15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Changes in Hypertension Prevalence, Awareness, Treatment and Control Rates over Twenty Years in National Capital Region of India- Results from a repeat cross-sectional study.

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2016-015639.R2
Article Type:	Research
Date Submitted by the Author:	09-May-2017
Complete List of Authors:	Roy, Ambuj; All India Institute of Medical Sciences, Cardiology Praveen , Pradeep A; All India Institute of Medical Sciences, Endocrinology amd Metabolism Amarchand, Ritvik; All India Institute of Medical Sciences, Ramakrishnan, Lakshmy; All India Institute of Medical Sciences, Cardiac Biochemistry Gupta, Ruby; Public Health Foundation of India Kondal, Dimple; Public Health Foundation of India Singh, Kalpana; Public Health Foundation of India Sharma , Meenakshi; Indian Council of Medical Research Shukla, DK; Indian Council Of Medical Research, Non-communicable Diseases Tandon, Nikhil; All India Institute of Medical Sciences, Endocrinology and Metabolism Reddy, KS; Public Health Foundation of India Anand, Krishnan; All India Institute of Medical Sciences, Center for Community Medicine Prabhakaran, Dorairaj; Public Health Foundation of India
Primary Subject Heading:	Cardiovascular medicine
Secondary Subject Heading:	Epidemiology
Keywords:	Hypertension < CARDIOLOGY, Pre hypertension, Secular Trends, Cardiovasclar Disease Risk Factors, India

Title: Changes in Hypertension Prevalence, Awareness, Treatment and Control Rates over Twenty Years in National Capital Region of India- Results from a repeat cross-sectional study.

Sub Title: Change in hypertension burden over 20 years-NCR, India

List of Authors and Affiliations

Ambuj Roy, MD, DM*
Professor of Cardiology, All India Institute of Medical Sciences, New Delhi, India,
Email:drambujroy@gmail.com

Pradeep A Praveen, MPH
Doctoral Student, Department of Endocrinology and Metabolism,
All India Institute of Medical Sciences, New Delhi, India, Email:praveen.aims@gmail.com

Ritvik Amarchand, MBBS, PhD
Centre for Community Medicine, All India Institute of Medical Sciences, New Delhi, India,
Email: drritvik@gmail.com

Lakshmy Ramakrishnan, PhD
Professor, Department of Cardiac Biochemistry, All India Institute of Medical Sciences, New Delhi, India, Email: lakshmy_ram@yahoo.com

Ruby Gupta, PhD
Scientific Officer (Biochemistry), Public Health Foundation of India, Gurgaon, India,
Email: ruby.gupta@phfi.org

Dimple Kondal, PhD
Statistician, Public Health Foundation of India, Gurgaon, India, Email: dimple@ccdcindia.org

Kalpana Singh, MSc
Statistician, Public Health Foundation of India, Gurgaon, India, Email: kalpana.singh@phfi.org

Meenakshi Sharma, PhD
Scientist E, Indian Council of Medical Research, New Delhi, India, Email:smeenakshi@hotmail.com

Deepak Kumar Shukla, PhD
Scientist G & Head, Division of Non Communicable Diseases, Indian Council of Medical Research, New Delhi, India, Email: shukladk@icmr.org.in

Nikhil Tandon, MD, PhD
Professor & Head, Department of Endocrinology and Metabolism, All India Institute of Medical Sciences, New Delhi, India, Email: nikhil_tandon@hotmail.com

Kolli Srinath Reddy, MD, DM, MSc
President, Public Health Foundation of India, Gurgaon, India, Email: ksrinath.reddy@phfi.org

Anand Krishnan, MD, PhD
Professor, Centre for Community Medicine, All India Institute of Medical Sciences, New Delhi, India,
Email: kanandiyer@yahoo.com

Dorairaj Prabhakaran, MD, DM, MSc
Professor& Vice President, Public Health Foundation of India, Gurgaon, India,
Email: dprabhakaran@ccdcindia.org

*Corresponding Author

Address for correspondence:

Ambuj Roy, MD, DM
Professor of Cardiology,
All India Institute of Medical Sciences
New Delhi, India- 110029.
Email: drambujroy@gmail.com
Phone: 91-9869393945;
Fax: 91-11-26588663

Word count: 3007

Competing Interests: Nothing to declare

Funding: The study was funded by the Indian Council of Medical Research, New Delhi, India

Contributorship Statement:

Authors Kolli Srinath Reddy, Nikhil Tandon, Dorairaj Prabhakaran, Anand Krishnan, Deepak Kumar Shukla, Meenakshi Sharma and Ambuj Roy conceptualized and designed the study and revised the manuscript. Kolli Srinath Reddy, Dorairaj Prabhakaran, Anand Krishnan, Pradeep A Praveen, Ritvik Amarchand and Ambuj Roy were involved in execution of the study in the field. Pradeep A Praveen, Dorairaj Prabhakaran and Ambuj Roy drafted and revised the manuscript. Dimple Kondal and Kalpana Singh did the data analysis. Lakshmy Ramakrishnan and Ruby Gupta coordinated the biochemical analysis and interpreted the data

Data Sharing Statement:

I, the corresponding author of the manuscript, on behalf of all the other authors here by agree to share the study data and additional explanatory materials to fellow researchers.

Key Words: Hypertension; Pre-Hypertension; Secular trends; Cardiovascular disease risk factors; India

Abstract

Background & Objectives: Despite being one of the leading risk factors of cardiovascular mortality, there is limited data on changes in hypertension burden and management from India. This study evaluates trend in the prevalence, awareness, treatment and control of hypertension in the urban and rural areas of India's National Capital Region (NCR).

Design & setting: Two representative cross-sectional surveys were conducted in urban and rural areas [Survey1 (1991-1994); Survey 2 (2010-2012)] of NCR using similar methodologies.

Participants: A total of 3,048 (mean age: 46.8± 9.0; 52.3 % women) and 2,052 (mean age: 46.5±8.4; 54.2 % women) subjects of urban areas and 2,487 (mean age: 46.6±8.8; 57.0% women) and 1,917 (mean age: 46.5±8.5; 51.3 % women) subjects of rural areas were included in Survey 1 & 2 respectively.

Primary and secondary outcome measures: Hypertension was defined as per Joint National Committee VII guidelines. Structure questionnaire was used to measure the awareness and treatment status of hypertension. A mean SBP < 140 mm Hg and DBP < 90 mm Hg was defined as control of hypertension among the participants with hypertension.

Results: The age and sex standardised prevalence of hypertension increased from 23.0% to 42.2% ($p<0.001$) and 11.2% to 28.9% ($p<0.001$) in urban and rural NCR respectively. In both surveys, those with high education, alcohol use, obesity and high fasting blood glucose were at a higher risk for hypertension. However, the change in hypertension prevalence between the surveys was independent of these risk factors [adjusted odds ratio (95% C.I): urban [2.3 (2.0, 2.7)]; rural [3.1 (2.4, 4.0)]. Overall there was no improvement in awareness, treatment and control rates of hypertension in the population.

Conclusion: There was marked increase in prevalence of hypertension over two decades with no improvement in management.

Strengths of the study

- One of the first studies to report the trends in the population burden and management of hypertension from the low and middle income countries
- The study surveyed representative samples from the same population using similar methodologies and was adequately powered to compare hypertension burden at two time periods

Limitations of the study

- The Instrument used for blood pressure measurement was different in the two studies. This was inevitable since the apparatus used in first survey was unavailable at the time of the next survey.
- Behavioural risk factors like diet and physical activity were not assessed during the first survey and therefore not reported and they could account for difference in blood pressure levels as discussed.
- The study being restricted to urban and rural NCR of Delhi, may not be generalizable across India.

Introduction

High blood pressure (HBP) is the single largest risk factor for disease burden worldwide. In India, HBP has now emerged as a leading risk factor for mortality [1]. Several studies over the years have shown increasing prevalence of hypertension in India [2–4]. Kearney et al in their paper predicted that the burden of hypertension in India is expected to almost double from 118 million in 2000 to 213.5 million by 2025[5] . A recent systematic analysis suggested high prevalence with poor awareness, treatment and control of hypertension in India [6].

At the population level the effect of rise in blood pressure is continuous with increasing cardiovascular risk with rise of blood pressure above 115/75 mmHg[7]. According to the Global Burden of Disease-2015 analysis, the estimated rate of annual deaths associated with SBP of at least 110 to 115 mm Hg between 1990 and 2015 has increased from 135.6 to 145.2 per 100 000 persons[8]. However, data from India on trends of population blood pressure distribution, hypertension prevalence, awareness, treatment and control in representative population over time is scarce due to absence of active surveillance. This data is important to formulate informed policy as high blood pressure is one of the key targets to reduce premature mortality due to cardiovascular diseases (CVD) set by World Health Organisation (WHO) and the Indian government[9,10].

We conducted two surveys on prevalence of cardiovascular risk factors between April 1991 and June 1994 (Survey 1) and August 2010 and January 2012 (Survey 2) in National Capital Region (NCR) of India (urban Delhi and adjoining rural Haryana). These surveys enabled us to estimate the changes in blood pressure prevalence and management in this population over this time period.

Methods

Study population and sample size:

The two cross-sectional surveys were carried out in adults aged 35-64 years using a multistage cluster random sampling method in the urban area and a simple random sampling method in the rural area to assess the prevalence of coronary artery disease (CAD) and its risk factors. The sample size was calculated based on estimated prevalence of CAD in the population. The details of sample size calculation were published elsewhere [11]. Based on this 5535 participants were recruited for survey 1(urban-3048; rural-2487) and 3969 were recruited for survey 2 (urban-2052; rural-1917). In both surveys, all eligible individuals from the primary sampling unit (household) were approached for their consent to participate in the survey.

Data collection:

Both the surveys got ethical clearance from institutional ethics committees of the participating institutions. The data were collected through household visits using a standardized questionnaire. Blood sampling was done through physician led medical camps using standardized equipments and methods. In survey 1, blood pressure was measured using a random zero sphygmomanometer while in survey 2 an automated blood pressure machine [OMRON (HEM-7080)] was used. In both surveys, two blood pressure readings were recorded in sitting position, five minutes apart. If the difference between the two readings was more than 10mmHg, a third measurement was taken. The mean of the last two measurements were taken for final analysis. Operational definitions:

Pre hypertension and hypertension were defined using the Joint National Committee VII criteria[12](systolic blood pressure (SBP) 120-139 mm Hg and/or diastolic blood pressure (DBP) 80-89 mm Hg for pre hypertension and SBP≥ 140 mm Hg and/or DBP ≥ 90 mm Hg or on blood pressure lowering medication for hypertension). Those who were diagnosed with hypertension were further classified in to stage I (SBP140-159 mm Hg and/or DBP 90-99 mm Hg) and stage II (SBP≥ 160 mm Hg and/or DBP ≥ 100mm Hg).

Hypertension awareness, treatment, and control were analysed in hypertensive participants based on questionnaires and blood pressure measurements. Among the hypertensive participants, self-report of any previous clinical diagnosis of hypertension was defined as awareness of hypertension. Self- reported anti-hypertension medication use was defined as on treatment and a mean SBP < 140 mm Hg and DBP < 90 mm Hg was defined as control of hypertension among the participants with hypertension.

Statistical analysis

STATA 12.1 (STATA Corporation, College Station, TX, USA) was used for the statistical analysis. Prevalence of hypertension along with their standard errors and ratios between Survey 1 and Survey 2 and the awareness, treatment and control levels during Survey 1 and 2 are presented. The age and gender adjusted prevalence of hypertension was calculated using Indian census data for 2011 as standard population. Hypertension prevalence was analysed by selected demographic and health characteristics: gender, place of residence (urban/rural), age category (35-44, 45-54, 55-64), educational status, Body Mass Index (BMI), blood glucose level and alcohol use. Educational status was defined as follows: Low (illiterate to primary level), Medium (middle to high school) High (higher secondary and above). World Health Organisation cut offs were used to categorise BMI values (normal- BMI<25 kg/m^2, overweight- BMI 25-<30 kg/m^2, obesity-BMI≥30 kg/m^2) and abdominal obesity [Waist to Hip Ratio (WHR) >0.90 for men and >0.85 for women]. Blood glucose levels were categorised as normoglycemic (fasting plasma glucose (FPG) < 100 mg/dl), impaired fasting glucose (FPG 100- <126mg/dl); and diabetes (FPG≥ 126 mg/dl). Alcohol use was defined as any use in the last twelve months of any alcohol product. The difference in proportions between the surveys was evaluated using chi square test. Any p value <0.05 was considered statistically significant. Logistic regression models were constructed for urban and rural populations separately defining prevalence of hypertension as outcome variable and time period (Survey2 vs Survey 1) as exposure variables. We added covariates as categorical variables (age groups, gender, obesity, waist-hip-ratio, diabetes

and alcohol use), stepwise to the logistic regression model. Adjusted odds ratios and 95% CIs were reported. We also assessed the interaction between time (Survey 1; Survey 2) and other covariates mentioned above using likelihood test. If the interaction was found to be significant, then stratified analysis was reported. We additionally conducted a sensitivity analysis to account for suboptimal response for biochemical data in survey 1 (<65%) by applying inverse probability weighting (IPW)[13]. Those who did not participate for blood collection were more likely to be females, lesser educated, smokers and with low BMI. The IPW approach weighted the analysis by the inverse of the predicted probability of being observed at a given time point. This was computed based on a logistic model with gender, education, smoking status and BMI as predictors for non-response bias for Survey 1 and gender, education, smoking status, BMI, time of survey and site as predictors for both survey together.

Results

A total of 3,048 (mean (SD) age: 46.8 (9.0) years; 52.3 % females) and 2,052 (mean (SD) age: 46.5 (8.4) years; 54.2 % females) subjects of urban areas and 2,487 (mean (SD) age: 46.6 (8.8) years; 57.0 % females) and 1,917 (mean (SD) age: 46.5 (8.5) years; 51.3 % females) subjects of rural areas were recruited in Survey 1 & 2 respectively. Ninety-nine% of the participants in both surveys had their blood pressure measured. Among those surveyed, 95% and 78% in Survey 1 and Survey 2 respectively of the urban sample and 51% and 65% in Survey 1 and Survey 2 respectively of the rural sample agreed to provide a fasting blood sample for biochemical analysis.

The prevalence of hypertension increased from 23.0% to 42.2% and 11.2% to 28.9% in urban and rural NCR of Delhi respectively between the two surveys. The increase in prevalence was by 83% in urban NCR and 158% in rural NCR. The rise in prevalence was more in men with a rise of 94% and 73% in urban areas and 191% and 125% in rural areas in men and women receptively (Table 1). The age specific prevalence of hypertension revealed an increase in prevalence at all ages except in the

highest age group (55-64 years) of urban men and women. The rise in age specific prevalence was highest in the youngest age group (35-44) with a rise in prevalence of 153%, 115%, 239% and 336%, in urban men, urban women, rural men and rural women respectively.

The distribution of blood pressure in the population (excluding those on anti-hypertensive therapy), changed significantly over the years. In survey 2, there was lesser proportion of the people with optimum blood pressure values (BP <120/80mmhg) and a higher proportion of individuals with pre-hypertension, Stage I and Stage II hypertension (Figure 1)compared to survey1. This change of distribution was similar across men and women in NCR and also both in urban and rural areas.

The prevalence of hypertension was stratified by other known risk factors associated with blood pressure (Figure 2). Hypertension prevalence increased with increasing BMI and education categories in both urban and rural population (Figure 2). The prevalence was highest among those with diabetes followed by those with impaired fasting blood glucose in both urban and rural areas (Figure 2). Alcohol users had higher prevalence of hypertension (Figure 2). The prevalence increased in each of these categories in survey 2 as compared to Survey 1.

The distribution of risk factors in those with and without hypertension in urban and rural areas is as in supplementary table-1. The prevalence of alcohol use, obesity, abdominal obesity and diabetes increased significantly among those with hypertension in survey 2 compared to survey 1. The relative increase in hypertension prevalence between the surveys was modelled as if there was no change in these risk factors and the demographic profile between the surveys. The increased odds ratio of hypertension in Survey 2 as compared to Survey 1 persisted even after adjusting for these factors .On analysis, a significant interaction between time and age was observed. The age stratified models suggested higher odds of change in hypertension prevalence among the youngest age group in both urban and rural areas (Table-2). The sensitivity analysis using IPW did not show any

significant difference in the estimates after accounting for the suboptimal response for blood sampling in survey 1 (data not shown).

There was no change in the overall awareness, treatment and control rates of hypertension between the two surveys in the NCR (Table 3). When stratified by gender the awareness, treatment and control rates of hypertension in men decreased in the second survey while awareness and treatment but not control rates improved in women. The overall rates of all three parameters were higher in woman than men. Similarly in urban areas there was no change in the overall awareness, treatment and control rates of hypertension between the two surveys though all three parameters decreased in men with no significant change in women with higher overall rates in women. In rural NCR the overall awareness, treatment and control rates of hypertension improved between the two surveys. This was seen in men and women except for control rates in men which did not improve. However, though all three rates improved in rural areas, the overall awareness (46.4% vs26.8%), treatment (40.0vs 20.4%) and control rates (15.9vs 8.0%) in rural areas remained much lower than in urban areas.

Table 1: Age & sex standardized and age-specific prevalence of hypertension: Survey 1 and Survey 2

	Rural							Urban						
	Survey 1			Survey 2				Survey 1			Survey 2			
	N	Prevalence (%)	SE	N	Prevalence (%)	SE	P Value-Difference	Ratio (95% C.I)	N	Prevalence (%)	SE	N	Prevalence (%)	SE	P Value-Difference	Ratio
Total	2,469	11.2	0.01	1914	28.9	1	<0.001	2.6 (2.3, 2.9)	3,041	23	0.01	2026	42.2	1.1	<0.001	1.8 (1.6, 1.9)
Men	1,065	12.2	0.01	981	32.6	1.5	<0.001	2.7 (2.2, 3.3)	1,451	22.3	0.01	924	43.3	1.6	<0.001	1.9 (1.8, 2.3)
Women	1,404	10.2	0.01	933	25.2	1.4	<0.001	2.5 (2.4, 3.6)	1,590	23.8	0.01	1102	41.1	1.4	<0.001	1.7 (1.5, 2.0)
Men																
35-44	441	8.1	0.01	459	27.4	0.02	<0.001	3.4 (2.4, 4.8)	646	13.4	0.01	434	33.9	0.02	<0.001	2.5 (2.0, 3.3)
45-54	318	12.2	0.02	315	36.1	0.03	<0.001	3.0 (2.1, 4.1)	432	21.6	0.02	299	47.9	0.03	<0.001	2.2 (1.8, 2.8)
55-64	306	21.6	0.02	207	38.6	0.03	<0.001	1.8 (1.4, 2.4)	373	34.5	0.03	191	42.5	0.02	NS	1.2 (1.0, 1.6)
Women																
35-44	667	4.3	0.01	433	18.7	0.02	<0.001	4.4 (3.1, 6.9)	723	12.8	0.01	521	27.6	0.02	<0.001	2.2 (1.8, 2.8)
45-54	438	9.4	0.01	277	28.5	0.03	0.001	3.0 (2.2, 4.4)	450	25.9	0.02	321	46.9	0.03	<0.001	1.8 (1.5, 2.2)
55-64	299	23.1	0.02	223	33.3	0.03	0.011	1.4 (1.1, 1.9)	417	57.6	0.04	260	59.8	0.03	NS	1.0 (0.99, 1.6)

N- Sample size; SE- Standard Error; Ratio-Survey2/Survey1: NS-not statistically significant

Table-2: Odds of hypertension in Survey 2 relative to odds for hypertension in Survey 1		
	Odds ratio (95% CI)	
	Rural	Urban
Unadjusted	3.2 (2.7, 3.8)	2.3 (2.0, 2.6)
Model 1: Adjusted for age	3.4 (2.9, 4.0)	2.6 (2.3, 2.9)
Model 2: Adjusted for age and gender	3.3 (2.8, 3.9)	2.6 (2.3, 2.9)
Model 3: Adjusted for age, gender and obesity	3.1 (2.6, 3.6)	2.6 (2.2, 2.9)
Model 4: Adjusted for age, gender and WHR	3.1 (2.6,3.6)	2.4 (2.1,2.8)
Model 5: Adjusted for age, gender, obesity and WHR	2.9 (2.4,3.4)	2.4 (2,1,2.8)
Model 6: Adjusted for age, gender, obesity, WHR and diabetes	3.3(2.6,4.1)	2.4 (2.1,2.7)
Model 7: Adjusted for age, gender, obesity, WHR, diabetes and alcohol use	3.1 (2.4, 4.0)	2.3 (2.0,2.7)
Model 8: Model 7 stratified by age groups		
Age 35-44 years	5.0(3.0,8.4)	2.7(2.1,3.4)
Age 45-54 years	1.6(1.2,2.1)	2.1(1.6,2.6)
Age 55-64 years	2.1(1.6,2.9)	2.6(1.9,3.4)
Obesity- BMI ≥ 30 Kg/m^2; Diabetes- Fasting Plasma Glucose (FPG) ≥ 126 mg/dl or on medication; Abdominal obesity-Waist-hip-ratio >0.90 for men and >0.85 for women; p-value for interaction between time and age (rural) p=0.0001; p-value for interaction between time and age (urban) p=0.0008		

Table-3: Hypertension awareness, treatment and control among hypertensive population in NCR of Delhi: Survey 1 and Survey 2

	Awareness			Treatment			Control		
	Survey 1 (%)	Survey 2 (%)	P value	Survey 1 (%)	Survey 2 (%)	P value	Survey 1 (%)	Survey 2 (%)	P value
Total	37.5	38.7	NS	32.0	32.3	NS	14.4	12.8	NS
Men	33.1	26.8	0.02	28.3	21.1	0.01	13.1	7.1	0.01
Women	41.5	51.1	0.001	35.4	43.9	0.001	15.6	18.7	NS
Urban									
Total	49.0	46.4	NS	41.6	40.0	NS	19.0	15.9	NS
Men	44.3	34.7	0.01	37.8	29.2	0.01	17.6	10.7	0.01
Women	53.2	56.9	NS	45.0	49.6	NS	20.2	20.4	NS
Rural									
Total	7.2	26.8	0.001	6.8	20.4	0.01	2.5	8.0	0.001
Men	5.7	17.0	0.001	5.0	11.0	0.04	2.1	2.5	NS
Women	8.7	40	<0.001	8.7	33.2	<0.001	2.9	15.3	<0.001

NS- not statistically significant

Discussion

The repeat survey in NCR of Delhi done after two decades shows (1) continued gradient in urban rural prevalence of hypertension (2) Significant increases in prevalence of hypertension both in urban and rural areas with a higher increase in rural areas,(3) highest increase in prevalence of hypertension in the youngest age group (35-44 years) surveyed, (4) a rightward shift in the distribution of blood pressure in both urban and rural populations with fewer individuals with optimum blood pressure (<120/80), (5)strong relationship between hypertension and BMI, education level, fasting glucose levels and alcohol use, however, even after adjusting for all these predictor variables the odds of hypertension prevalence remained higher in the second survey (6) no change in overall awareness , treatment and control rates of hypertension in NCR

Prevalence of hypertension has been consistently increasing over the years; however, most reviews from India have included old studies. Recent repeat surveys done in other cities have shown varying results. A study from Jaipur revealed no significant change in hypertension prevalence over 2 decades from 1990 with a decrease in mean systolic blood pressure during this period[14]. A repeat survey from Chennai showed rise in self-reported prevalence in hypertension in low and middle income groups[15]. However, these studies included only urban subjects and utilised convenience sampling and thus were not representative of the population. Our study done on a representative urban and rural sample revealed that the prevalence of hypertension increased in urban and rural areas with a higher rate of rise in the rural population. A recent systematic review of hypertension found a prevalence of 27.6% in rural India though it was only 16.7% in rural Northern India[6]which was at variance with our findings. However, more recent studies from North India have suggested prevalence of 22% and 32%in similar age groups, which is close to the prevalence in our study of 28.9% and those from other parts of rural India[16][17].

The age stratified prevalence showed increase in all age groups except the oldest in urban areas, with the highest rate of rise of hypertension in the youngest age group (35-44 years). Indirect evidence of high burden of risk factors in young comes from occurrence of cardiovascular diseases at younger age in South Asians as compared the Caucasians [4]. A study among the young individuals (20-30 years) from South India revealed a very high burden of 45.2% of pre-hypertension in the population[18]. However, the rapid rise of the burden of hypertension in young in last two decades has probably been demonstrated for the first time in this study and is worrisome and calls for urgent action to prevent further burden of pre-mature CVD in Indians.

The other important finding was the worsening of population blood pressure levels over two decades with a significantly lower proportion of the population having optimum blood pressure and more of them having pre-hypertension and hypertension. Small shifts in population blood pressure levels is known to lead to large increases in the burden of CVD in the community[7] and thus this also portends future worsening of CVD epidemic in India. It calls for population level intervention like advocacy for salt reduction, weight reduction and increase physical activity. The prevalence of hypertension was expectantly dependant on BMI and fasting glucose levels with higher rates among overweight and obese and those with impaired fasting glucose and diabetes. This finding is consistent across most studies in India and abroad[19–21]. The association of hypertension in India with education is variable. A recent large cohort study from South Asia reported higher prevalence among more educated[22]**.** Some have reported reverse gradient with education[23]while others have reported no relationship[24][25]Alcohol use was associated with higher prevalence of hypertension as seen in other studies[26]. Limited data from South Asia suggests higher blood pressure levels in alcohol users[27] and also higher probability of MI in them than alcohol abstainers[28]unlike other population groups. Interestingly, the rise in prevalence of hypertension in Survey 2 was significant even after adjusting for these factors. This could be due to other

unmeasured lifestyle factors known to be associated with high blood pressure like diet, physical activity, stress etc, data for which was not available for both studies.

The prevalence, awareness and control rates for hypertension were overall sub-optimal with no improvement between the 2 surveys. The rates of awareness, treatment and control of hypertension were comparable to the pooled estimates reported in systematic reviews with better rates in urban areas as compared to rural areas [2,6]. Additionally these rates were better in women as compared to men, as has been reported consistently in large studies from India and abroad[29,30]. This is related to greater health seeking behaviour in women [30]. This study additionally provided insights into the change in these rates over the last two decades which is not available from India earlier. The disturbing fact was that despite rising prevalence of hypertension there was no improvement in these rates with all three rates worsening in men with improvement in awareness, treatment but not control rates in women. When analysed by site and gender all rates except control rates in men improved in rural areas while in urban areas they worsened in men and remained unchanged in women. However, the overall rates in rural areas were still much lower than urban areas and the improvement in rural areas could be attributed to low rates in the first survey.

Strengths and limitations

The strengths of this study is that it surveyed population representative sample in the same population using similar methodologies and was adequately powered, thus providing opportunity to compare hypertension statistics at two time periods. Such temporal trend was not available from urban and rural areas of India earlier. One of the limitations of this study is that the apparatus used for blood pressure measurement was different in the two studies. This was inevitable since the apparatus used in first survey was unavailable at the time of the next survey. The two apparatus have marginal difference and if anything the current method of automated blood pressure monitors is known to underestimate blood pressure[31]and thus the prevalence and shift in blood pressure

levels in the population would only be higher. The other limitation is that behavioural risk factors like diet and physical activity were not assessed during the first survey and therefore not reported and they could account for difference in blood pressure levels as discussed. In addition macro level changes in the population like socio-economic transition, urbanisation, policy etc. are not accounted for in our study. The study being restricted to urban and rural NCR of Delhi, may not be generalizable across India though similar prevalence rates have been reported across the country.

Conclusions

This two time survey of NCR of Delhi shows marked increase in prevalence of hypertension in the last two decades both in rural and urban areas with higher rates of increase in younger age. This was also associated with fewer individuals with optimum blood pressure and more with pre-hypertension and hypertension. This calls for urgent population and high risk approach to lower blood pressure in the community as the overall awareness, treatment and control levels showed no improvement over this time frame.

Figure Legend

Figure-1: Distribution of BP categories (%) in untreated population of NCR of Delhi: A) Urban Men; (B) Urban Women; (C) Rural Men; (D) Rural Women

Figure-2: Prevalence (%) of hypertension stratified by risk factors: (A) Education status; (B) Body Mass Index(BMI); (C) Fasting Plasma Glucose; (D) Alcohol Use

References

1 Lim SS, Vos T, Flaxman AD, *et al.* A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;**380**:2224–60. doi:10.1016/S0140-6736(12)61766-8

2 Devi P, Rao M, Sigamani A, *et al.* Prevalence, risk factors and awareness of hypertension in India: a systematic review. *J Hum Hypertens* 2013;**27**:281–7. doi:10.1038/jhh.2012.33

3 Gupta R. Trends in hypertension epidemiology in India. *J Hum Hypertens* 2004;**18**:73–8. doi:10.1038/sj.jhh.1001633

4 Prabhakaran D, Jeemon P, Roy A. Cardiovascular Diseases in India. *Circulation* 2016;**133**:1605–20. doi:10.1161/CIRCULATIONAHA.114.008729

5 Kearney PM, Whelton M, Reynolds K, *et al.* Global burden of hypertension: analysis of worldwide data. *Lancet*;**365**:217–23. doi:10.1016/S0140-6736(05)17741-1

6 Anchala R, Kannuri NK, Pant H, *et al.* Hypertension in India: a systematic review and meta-analysis of prevalence, awareness, and control of hypertension. *J Hypertens* 2014;**32**:1170–7. doi:10.1097/HJH.0000000000000146

7 Lewington S, Clarke R, Qizilbash N, *et al.* Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *Lancet* 2002;**360**:1903–13.http://www.ncbi.nlm.nih.gov/pubmed/12493255 (accessed 2 Feb2015).

8 Forouzanfar MH, Liu P, Roth GA, *et al.* Global Burden of Hypertension and Systolic Blood Pressure of at Least 110 to 115 mm Hg, 1990-2015. *JAMA* 2017;**317**:165.

doi:10.1001/jama.2016.19043

9 United Nations. UN General Assembly resolution on the prevention and control of non communicable diseases. 2010.www.un.org (accessed 5 Mar2014).

10 World Health Organization. NCD Global Monitoring Framework. 2013.http://www.who.int/nmh/global_monitoring_framework (accessed 5 Mar2014).

11 Prabhakaran D, Roy A, Praveen PA, *et al.* 20-Year Trend of Cardiovascular Disease Risk Factors: Urban and Rural National Capital Region of Delhi, India. *Glob Heart* Published Online First: 11 April 2017. doi:10.1016/j.gheart.2016.11.004

12 Chobanian A V, Bakris GL, Black HR, *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**:2560–72. doi:10.1001/jama.289.19.2560

13 Seaman SR, White IR. Review of inverse probability weighting for dealing with missing data. *Stat Methods Med Res* 2013;**22**:278–95. doi:10.1177/0962280210395740

14 Gupta R, Guptha S, Gupta VP, *et al.* Twenty-year trends in cardiovascular risk factors in India and influence of educational status. *Eur J Prev Cardiol* 2012;**19**:1258–71. doi:10.1177/1741826711424567

15 Deepa M, Anjana RM, Manjula D, *et al.* Convergence of prevalence rates of diabetes and cardiometabolic risk factors in middle and low income groups in urban India: 10-year follow-up of the Chennai Urban Population Study. *J Diabetes Sci Technol* 2011;**5**:918–27.http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3192599&tool=pmcentrez&rendertype=abstract (accessed 30 May2016).

16 Kishore J, Gupta N, Kohli C, *et al.* Prevalence of Hypertension and Determination of Its Risk

Factors in Rural Delhi. *Int J Hypertens* 2016;**2016**:7962595. doi:10.1155/2016/7962595

17 Bansal SK, Saxena V, Kandpal SD, *et al.* The prevalence of hypertension and hypertension risk factors in a rural Indian community: A prospective door-to-door study. *J Cardiovasc Dis Res* 2012;**3**:117–23. doi:10.4103/0975-3583.95365

18 Kini S, Kamath VG, Kulkarni MM, *et al.* Pre-Hypertension among Young Adults (20-30 Years) in Coastal Villages of Udupi District in Southern India: An Alarming Scenario. *PLoS One* 2016;**11**:e0154538. doi:10.1371/journal.pone.0154538

19 Cutler JA, Sorlie PD, Wolz M, *et al.* Trends in hypertension prevalence, awareness, treatment, and control rates in United States adults between 1988-1994 and 1999-2004. *Hypertension* 2008;**52**:818–27. doi:10.1161/HYPERTENSIONAHA.108.113357

20 Menéndez E, Delgado E, Fernández-Vega F, *et al.* Prevalence, Diagnosis, Treatment, and Control of Hypertension in Spain. Results of the Di@bet.es Study. *Rev española Cardiol (English ed)* 2016;**69**:572–8. doi:10.1016/j.rec.2015.11.034

21 Bhadoria AS, Kasar PK, Toppo NA, *et al.* Prevalence of hypertension and associated cardiovascular risk factors in Central India. *J Family Community Med* 2014;**21**:29–38. doi:10.4103/2230-8229.128775

22 Ali MK, Bhaskarapillai B, Shivashankar R, *et al.* Socioeconomic status and cardiovascular risk in urban South Asia: The CARRS Study. *Eur J Prev Cardiol* 2016;**23**:408–19. doi:10.1177/2047487315580891

23 Reddy KS, Prabhakaran D, Jeemon P, *et al.* Educational status and cardiovascular risk profile in Indians. *Proc Natl Acad Sci U S A* 2007;**104**:16263–8. doi:10.1073/pnas.0700933104

24 Samuel P, Antonisamy B, Raghupathy P, *et al.* Socio-economic status and cardiovascular risk

factors in rural and urban areas of Vellore, Tamilnadu, South India. *Int J Epidemiol* 2012;**41**:1315–27. doi:10.1093/ije/dys001

25 Kar SS, Thakur JS, Virdi NK, *et al.* Risk factors for cardiovascular diseases: is the social gradient reversing in northern India? *Natl Med J India*;**23**:206–9.http://www.ncbi.nlm.nih.gov/pubmed/21192513 (accessed 30 May2016).

26 Huang X, Zhou Z, Liu J, *et al.* Prevalence, awareness, treatment, and control of hypertension among China's Sichuan Tibetan population: A cross-sectional study. *Clin Exp Hypertens* 2016;**38**:457–63. doi:10.3109/10641963.2016.1163369

27 Roy A, Prabhakaran D, Jeemon P, *et al.* Impact of alcohol on coronary heart disease in Indian men. *Atherosclerosis* 2010;**210**:531–5. doi:10.1016/j.atherosclerosis.2010.02.033

28 Leong DP, Smyth A, Teo KK, *et al.* Patterns of alcohol consumption and myocardial infarction risk: observations from 52 countries in the INTERHEART case-control study. *Circulation* 2014;**130**:390–8. doi:10.1161/CIRCULATIONAHA.113.007627

29 Chow CK, Teo KK, Rangarajan S, *et al.* Prevalence, awareness, treatment, and control of hypertension in rural and urban communities in high-, middle-, and low-income countries. *JAMA* 2013;**310**:959–68. doi:10.1001/jama.2013.184182

30 Irazola VE, Gutierrez L, Bloomfield G, *et al.* Hypertension Prevalence, Awareness, Treatment, and Control in Selected LMIC Communities. *Glob Heart* 2016;**11**:47–59. doi:10.1016/j.gheart.2015.12.008

31 Ostchega Y, Zhang G, Sorlie P, *et al.* Blood pressure randomized methodology study comparing automatic oscillometric and mercury sphygmomanometer devices: National Health and Nutrition Examination Survey, 2009-2010. *Natl Health Stat Report* 2012;:1–15.

Figure 1 : Distribution of BP categories (%) in untreated population of NCR of Delhi

*HT: Hypertension; Normal: BP<120mmHg and DBP<80 mmHg; Pre hypertension: BP 120-139 mmHg or DBP 80-89 mmHg; Hypertension Stage I: SBP 140-159or DBP 90-99; Hypertension Stage II: SBP≥160 or DBP≥ 100; S1: Survey-1; S2: Survey-2; * Difference in distribution of blood pressure categories of Survey 1 &2*

Figure-1: Distribution of BP categories (%) in untreated population of NCR of Delhi: A) Urban Men; (B) Urban Women; (C) Rural Men; (D) Rural Women

260x193mm (300 x 300 DPI)

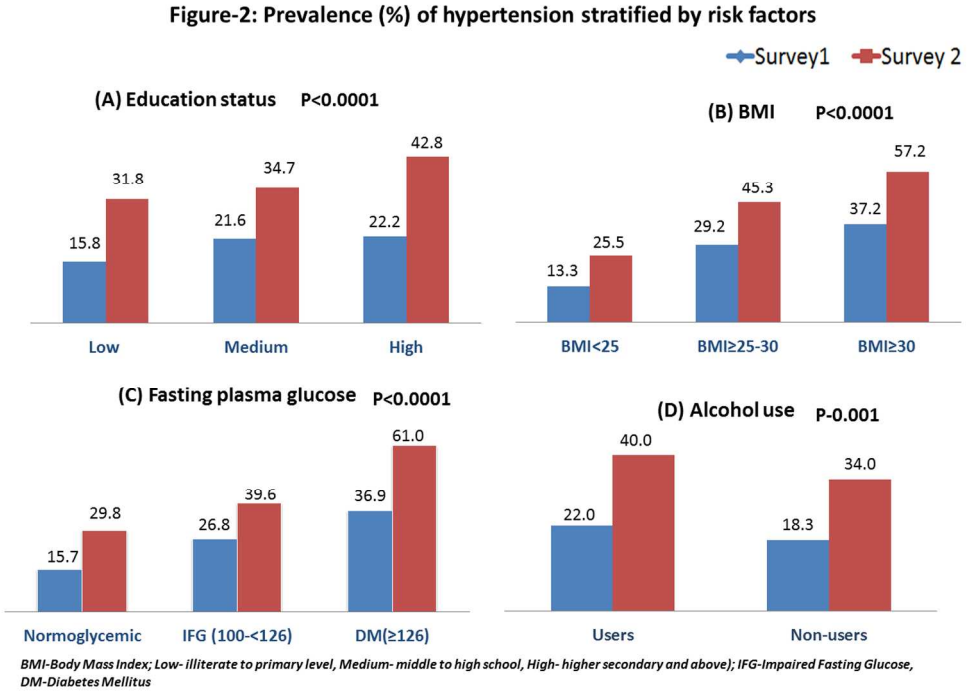

Figure-2: Prevalence (%) of hypertension stratified by risk factors: (A) Education status; (B) Body Mass Index(BMI); (C) Fasting Plasma Glucose; (D) Alcohol Use

250x178mm (300 x 300 DPI)

Supplementary table-1: Characteristics of study population according to hypertension status								
	Urban				Rural			
	Survey 1		Survey 2		Survey 1		Survey 2	
	Without hypertension	With hypertension	Without hypertension	With hypertension	Without hypertension	With hypertension	Without hypertension	With hypertension
Age [Mean ± SEM]	45.6±0.2	52.0±0.3	44.7±0.2	48.9±0.3	46.0±0.2	51.9±0.5	45.8±0.2	48.2±0.4
Gender Women[%(95% C.I)]	52.0 (50.0, 54.0)	53.2 (49.5, 56.8)	55.5 (52.6, 58.3)	52.9 (49.5, 56.2)	57.8 (55.7, 59.8)	49.6 (43.8, 55.5)	51.3 (48.6, 53.9)	42.5 (38.4, 46.7)
Alcohol use (Yes) [%(95% C.I)]	14.0 (12.6, 15.5)	14.2 (11.8, 17.0)	20.8 (18.5, 23.2)	26.1 (23.2, 29.1)	5.5 (4.5, 6.7)	7.6 (4.7, 12.0)	30.9 (28.5, 33.4)	39.8 (35.8, 43.9)
Obesity [%(95% C.I)]	9.9 (8.8, 11.2)	19.3 (16.5, 22.3)	13.8 (11.8, 16.2)	27.9 (24.7, 31.3)	1.2 (0.8, 1.8)	4.0 (2.2, 7.1)	5.0 (4.0, 6.3)	12.1 (9.7, 15.1)
Abdominal obesity [%(95% C.I)]	62.0 (60.0, 64.0)	72.3 (68.9, 75.4)	67.4 (64.6, 70.0)	83.2 (80.6, 85.6)	50.9 (48.7, 53.0)	72.8 (67.0, 77.9)	67.7 (65.1, 70.1)	82.4 (79.0, 85.4)
Diabetes Mellitus [%(95% C.I)]	10.3 (9.1, 11.7)	21.1 (18.2, 24.2)	12.5 (10.5, 14.8)	30.2 (26.9, 33.7)	2.5 (1.7, 3.5)	6.9 (3.6, 12.8)	6.6 (5.2, 8.5)	16.0 (12.6, 20.1)

Obesity- BMI ≥ 30 Kg/m^2; Abdominal obesity-Waist-hip-ratio >0.90 for men and >0.85 for women; Diabetes- Fasting Plasma Glucose (FPG) ≥ 126 mg/dl or on medication; SEM-Standard Error of Mean

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5,6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6.7
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	7
		(*e*) Describe any sensitivity analyses	5
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	10,11
Outcome data	15*	Report numbers of outcome events or summary measures	10,11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12
		(*b*) Report category boundaries when continuous variables were categorized	7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15,16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14,15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.