Socio-Demographic Inequalities in the Prevalence, Diagnosis and Management of Hypertension in India: Analysis of Nationally-Representative Survey Data

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Abstract

Background: Hypertension is a major contributing factor to the current epidemic of cardiovascular disease in India. Small studies suggest high, and increasing, prevalence especially in urban areas, with poor detection and management, but national data has been lacking. The aim of the current study was to use nationally-representative survey data to examine socio-demographic inequalities in the prevalence, diagnosis and management of hypertension in Indian adults.

Methods: Using data on self-reported diagnosis and treatment, and blood pressure measurement, collected from 12,198 respondents aged 18+ in the 2007 WHO Study on Global Ageing and Adult Health in India, factors associated with prevalence, diagnosis and treatment of hypertension were investigated.

Results: 22% men and 26% women had hypertension; prevalence increased steeply with body mass index (<18.5 kg/m²: 18% men, 21% women; 25-29.9 kg/m²: 35% men, 35% women), was higher in the least poor vs. poorest (men: odds ratio (95%CI) 1.82 (1.20 to 2.76); women: 1.40 (1.08 to 1.81)), urban vs. rural men (1.64 (1.19 to 2.25)), and men recently vs. never using alcohol (1.96 (1.40 to 2.76)). Over half the hypertension in women, and 70% in men, was undetected with particularly poor detection rates in young urban men, and in poorer households. Two-thirds of men and women with detected hypertension were treated. Two-thirds of women treated had their hypertension controlled, irrespective of urban/rural setting or wealth. Adequate blood pressure control was sub-optimal in urban men.

Conclusion: Hypertension is very common in India, even among underweight adults and those of lower socioeconomic position. Improved detection is needed to reduce the burden of disease attributable to hypertension. Levels of treatment and control are relatively good, particularly in women, although urban men require more careful attention.

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Introduction

Hypertension is a major contributing factor to the current epidemic of cardiovascular disease in India and many other low- and middle-income countries [1,2]. The global burden of hypertension was estimated to be close to 1 billion adults in 2000, and predicted to increase to 1.56 billion by 2025 [3]. Worldwide, in excess of 7 million deaths annually may be attributable to hypertension [4] which is the third most important cause of the global burden of disease [5]. There is marked variation in levels of mean systolic blood pressure between countries, with highest levels evident in low- and middle-income countries, and a small decrease in mean systolic blood pressure globally since 1980, although the trends varied across regions [6]. Hypertension tends to be inversely related to socioeconomic position in high income countries [7] with the opposite often being the case in low- and middle-income countries [8]. Only in the later stages of the epidemiological transition does the burden of chronic disease including hypertension shift from higher to lower socioeconomic groups [2,9]. A high and increasing prevalence of hypertension in both rural and urban areas of India has been reported in recent studies [10,11] with higher prevalence in urban than rural areas and intermediate levels among migrants [12]. Detection and effective management of hypertension decreases the risk of stroke, myocardial infarction, chronic kidney disease and heart failure. Knowledge about the prevalence and social patterning of hypertension is essential for informing the public health effort to control hypertension in the community. In the US and other high-income countries in the 1970s what has become known as ‘the rule of halves’ found that only half of adults with hypertension were diagnosed, only half of those diagnosed were treated, and only half of those treated were well controlled [13,14]. While detection and treatment has improved in many high-income countries over recent decades good control remains low [13,16]. Recent small scale and local studies show that the rule of halves applies in India where detection, treatment and control of...
hypertension remain inadequate [11,17–19]. However there is an urgent need for national data to confirm the situation. With the current epidemic in chronic disease, primarily affecting older people, the gap in the evidence base has become only too apparent. The nationally-representative surveys conducted in the WHO Study on Global Ageing and Adult Health (SAGE) programme (http://www.who.int/healthinfo/sage/cohorts/en/index2.html) are beginning to fill this gap by collecting detailed information on the health and well-being of adult populations and the ageing process [20,21]. Using self-reports of hypertension information on the health and well-being of adult populations and index2.html) are beginning to fill this gap by collecting detailed WHO Study on Global Ageing and Adult Health (SAGE) people, the gap in the evidence base has become only too current epidemic in chronic disease, primarily affecting older 1. Blood pressure (BP) measurement at physical examination, measured in the left wrist using a Boso Medistar Wrist Blood Pressure Monitor Model S (which avoids the need for different cuff sizes necessary with blood pressure measured in the upper arm). Validation studies of similar wrist blood pressure monitoring devices indicate they are capable of providing accurate measurements [23,24] but that the position of the arm in relation to the heart is critical (http://www.bhsoc.org/bp-mitters/bp-monitors/bp-monitors/). Respondents were asked to remain seated with legs uncrossed, positioning their arm level with their heart, taking 3 deep slow breaths before measurement started and then remaining relaxed and still while their BP was

### Methods

#### Ethics statement

Ethical approval was not required for this analysis of anonymised secondary data. The 2007 SAGE Wave 1 survey of India received approval from the review board of the International Institute for Population Sciences in Mumbai, India. Respondents provided informed consent to participate in the survey. A standard consent form, approved by the World Health Organization ethics review committee, was read to the respondent in the respondent’s language. If the respondent agreed to participate in the survey, and if s/he was literate, the form was provided to him/her to peruse and sign and was countersigned by the interviewer. If the respondent was illiterate and gave consent to participate, the interviewer confirmed this consent and signed on the form that the form had been read to the respondent, that s/he had understood the study and had agreed to participate. This procedure was approved by the review board of the International Institute for Population Sciences.

This analysis uses data collected in the 2007 SAGE Wave 1 survey of India (conducted by the International Institute for Population Sciences, Mumbai with the World Health Organization, Geneva). The SAGE survey took representative samples of six states in India (Assam, Karnataka, Maharashtra, Rajasthan, Uttar Pradesh and West Bengal) which can be modelled to a nationally representative sample. The survey consisted of a large comparative sample aged 18–49 years, 12,198 respondents (4,717 men, 7,481 women) in total. The SAGE dataset is provided in full elsewhere [20,22] and the questionnaires can be found at http://www.who.int/healthinfo/sage/cohorts/en/index2.html (accessed 23 July 2013). SAGE Wave 1 data are available in the public domain at the same location.

The survey includes 3 types of information on hypertension.

#### Table 1. Characteristics of study population.

|                    | MEN    | WOMEN** | ALL     |
|--------------------|--------|---------|---------|
|                    | %      | (n)     | %       | (n)     | %       | (n)     |
| total              | 100.0  | (4,148) | 100.0   | (6,523) | 100.0   | (10,671) |
| **age group**      |        |         |         |         |         |         |
| 18–29              | 21.2   | (257)   | 27.6    | (1,270) | 24.3    | (1,527)  |
| 30–39              | 25.0   | (345)   | 26.3    | (1,248) | 25.6    | (1,593)  |
| 40–49              | 30.2   | (394)   | 22.0    | (951)   | 26.2    | (1,345)  |
| 50–59              | 11.0   | (1,342) | 10.4    | (1,481) | 10.7    | (2,823)  |
| 60–69              | 7.1    | (1,098) | 7.3     | (1,010) | 7.2     | (2,108)  |
| 70+                | 5.6    | (712)   | 6.5     | (563)   | 6.0     | (1,275)  |
| mean age (95% CI)  | 42.0   | (41.3, 42.8) | 40.0 | (39.5, 40.6) | 41.1 | (40.5, 41.6) |
| **place of residence** |        |         |         |         |         |         |
| rural              | 70.0   | (3,185) | 68.8    | (4,803) | 69.4    | (7,988)  |
| urban              | 30.0   | (963)   | 31.2    | (1,720) | 30.6    | (2,683)  |
| **highest education level** |        |         |         |         |         |         |
| no education       | 21.1   | (1,217) | 49.6    | (3,581) | 35.0    | (4,798)  |
| <primary           | 9.4    | (530)   | 7.5     | (583)   | 8.5     | (1,113)  |
| primary            | 17.2   | (730)   | 16.1    | (904)   | 16.7    | (1,634)  |
| secondary          | 18.8   | (667)   | 12.6    | (681)   | 15.8    | (1,348)  |
| high school        | 20.3   | (625)   | 10.0    | (529)   | 15.3    | (1,154)  |
| >high school       | 13.4   | (379)   | 4.2     | (245)   | 8.9     | (624)    |
| **household wealth index** |        |         |         |         |         |         |
| Q1: poorest quintile | 19.3 | (693) | 20.2 | (1,167) | 19.8 | (1,860) |
| Q2                 | 20.1   | (801)   | 20.9    | (1,227) | 20.5    | (2,028)  |
| Q3                 | 20.7   | (780)   | 19.6    | (1,249) | 20.2    | (2,029)  |
| Q4                 | 18.5   | (896)   | 18.4    | (1,357) | 18.4    | (2,253)  |
| Q5: least poor quintile | 21.4 | (952) | 20.9 | (1,478) | 21.2 | (2,430) |
| **religion**       |        |         |         |         |         |         |
| hindu              | 83.7   | (3,476) | 85.1    | (5,517) | 84.4    | (8,993)  |
| muslim             | 12.7   | (516)   | 11.8    | (770)   | 12.3    | (1,286)  |
| other              | 3.6    | (156)   | 3.1     | (236)   | 3.4     | (392)    |
| caste*             |        |         |         |         |         |         |
| other              | 61.8   | (2,486) | 62.8    | (3,764) | 62.3    | (6,250)  |
| other backward caste | 13.4 | (632) | 13.3 | (1,133) | 13.3 | (1,765) |
| scheduled caste     | 18.9   | (726)   | 17.6    | (1,130) | 18.3    | (1,856)  |
| scheduled tribe     | 5.9    | (285)   | 6.4     | (452)   | 6.1     | (737)    |
| **bmi**            |        |         |         |         |         |         |
| <18.5 kg/m²*       | 34.8   | (1,441) | 35.4    | (2,211) | 35.1    | (3,652)  |
| 18.5–22.9          | 44.1   | (1,816) | 41.1    | (2,585) | 42.6    | (4,401)  |
| 23–24.9            | 11.1   | (417)   | 9.7     | (614)   | 10.4    | (1,031)  |
| 25–29.9            | 8.5    | (369)   | 10.5    | (770)   | 9.5     | (1,139)  |
| 30+                | 1.6    | (72)    | 3.3     | (239)   | 2.4     | (311)    |
| **alcohol**        |        |         |         |         |         |         |
| never use          | 68.8   | (2,923) | 98.6    | (6,371) | 83.3    | (9,294)  |
| not recent use     | 15.1   | (643)   | 0.6     | (54)    | 0.8     | (697)    |
| recent use (in last 30 days) | 16.2 | (582) | 0.9 | (98)    | 0.7 | (880)    |

percentages are weighted; n refers to number in unweighted sample.

*household wealth index missing for 71, caste missing for 63, BMI missing for 137 respondents.

**the sample includes a large number of women aged 18–49 years as part of a nested study.

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Table 2. Mean systolic blood pressure (mm Hg) by sociodemographic characteristics.

|                  | MEN                     |                      | WOMEN                  |                      |
|------------------|-------------------------|----------------------|------------------------|----------------------|
|                  | unadjusted              | full adj* (excl caste)| unadjusted             | full adj* (excl caste)|
|                  | mean (95% CI)           | diff from baseline (95% CI) | mean (95% CI)         | diff from baseline (95% CI) |
| age group        |                         |                      |                         |                      |
| 18–29            | 114.8 (113.4, 116.2)   | ref                  | 110.7 (109.4, 112.0)   | ref                  |
| 30–39            | 117.3 (115.6, 119.0)   | 1.0 (−1.0, 3.1)      | 113.7 (112.6, 114.9)   | 1.3 (−0.5, 3.1)      |
| 40–49            | 117.1 (114.9, 119.3)   | 1.6 (−0.8, 4.0)      | 118.0 (116.6, 119.5)   | 5.2 (3.1, 7.3)       |
| 50–59            | 120.4 (119.1, 121.8)   | 5.1 (3.3, 6.9)       | 123.0 (121.4, 124.6)   | 10.1 (7.8, 12.3)     |
| 60–69            | 122.2 (120.3, 124.1)   | 7.1 (4.6, 9.6)       | 127.3 (125.7, 129.0)   | 15.2 (12.8, 17.5)    |
| 70+              | 125.4 (122.7, 128.0)   | 11.0 (8.1, 13.9)     | 129.2 (126.8, 131.5)   | 16.8 (14.1, 19.6)    |
| age effect per 10 years | 1.84 (1.39, 2.30) |                      | 3.80 (3.45, 4.15)      |                      |
| place of residence |                         |                      |                         |                      |
| rural            | 116.5 (115.6, 117.5)   | ref                  | 116.7 (115.9, 117.4)   | ref                  |
| urban            | 120.9 (118.8, 123.0)   | 3.2 (0.9, 5.5)       | 117.0 (115.3, 118.8)   | −0.1 (−1.8, 1.7)     |
| age effect per 10 years: rural | 1.72 (1.20, 2.23) |                      | 3.65 (3.28, 4.01)      |                      |
| urban            | 2.25 n/a**              |                      | 4.16 n/a**             |                      |
| highest education level |                   |                      |                         |                      |
| no education     | 118.0 (116.2, 119.9)   | ref                  | 118.6 (117.6, 119.6)   | ref                  |
| ≤ primary        | 118.5 (116.0, 121.0)   | 1.0 (−1.9, 3.9)      | 117.0 (115.1, 118.9)   | −0.4 (−2.4, 1.6)     |
| primary          | 118.4 (116.0, 120.7)   | −0.2 (−3.0, 2.6)     | 117.2 (115.1, 119.2)   | 1.0 (−0.9, 3.0)      |
| secondary        | 115.9 (114.0, 117.8)   | −1.9 (−4.4, 0.6)     | 114.4 (112.8, 116.0)   | 0.6 (−1.3, 2.4)      |
| high school      | 117.1 (115.0, 119.3)   | −2.1 (−4.8, 0.7)     | 112.3 (110.2, 114.5)   | −2.0 (−4.5, 0.6)     |
| > high school    | 120.2 (117.6, 122.7)   | −0.2 (−3.2, 2.7)     | 110.6 (107.7, 113.6)   | −4.2 (−7.4, −1.1)    |
| household wealth index |                   |                      |                         |                      |
| Q1: poorest quintile | 115.8 (113.4, 118.1) | ref                  | 117.1 (115.5, 118.7)   | ref                  |
| Q2               | 116.7 (114.7, 118.7)   | 0.1 (−2.6, 2.8)      | 117.4 (115.6, 119.2)   | −0.6 (−2.5, 1.4)     |
| Q3               | 117.6 (115.7, 119.6)   | 0.3 (−2.6, 3.3)      | 115.7 (114.3, 117.1)   | −2.6 (−4.7, −0.5)    |
| Q4               | 117.8 (115.7, 119.9)   | −0.9 (−4.0, 2.2)     | 116.3 (114.9, 117.6)   | −1.9 (−3.9, 0.0)     |
| Q5: least poor quintile | 121.0 (119.3, 122.8) | 1.0 (−2.2, 4.1)      | 117.3 (116.0, 118.6)   | −1.7 (−4.0, 0.6)     |
| religion         |                         |                      |                         |                      |
| hindu            | 118.2 (117.2, 119.2)   | ref                  | 116.5 (115.8, 117.3)   | ref                  |
| muslim           | 116.1 (113.6, 118.7)   | −1.5 (−4.0, 1.0)     | 117.2 (114.9, 119.5)   | 0.4 (−1.9, 2.7)      |
| other            | 115.6 (110.1, 121.1)   | −2.1 (−7.3, 3.2)     | 122.2 (118.6, 125.9)   | 5.2 (1.4, 9.1)       |
| caste            |                         |                      |                         |                      |
| other            | 118.1 (116.8, 119.3)   | ref                  | 116.7 (115.8, 117.7)   | ref                  |
| other backward caste | 119.7 (117.3, 122.1) |                      | 116.5 (115.2, 117.8)   |                      |
| scheduled caste  | 115.5 (113.4, 117.6)   | ref                  | 116.2 (114.7, 117.6)   | ref                  |
| scheduled tribe  | 119.1 (116.0, 122.2)   | ref                  | 118.7 (116.1, 121.2)   | ref                  |
| bmi              | 112.7 (111.4, 113.9)   | ref                  | 113.9 (112.7, 115.0)   | ref                  |
| < 18.5 kg/m²     | 118.4 (117.2, 119.6)   | 5.8 (3.9, 7.7)       | 116.7 (115.6, 117.7)   | 3.6 (2.4, 4.7)       |
| 18.5–22.9        | 123.7 (120.8, 126.5)   | 11.5 (8.7, 14.4)     | 119.3 (117.0, 121.6)   | 6.4 (4.0, 8.9)       |
| 23–24.9          | 126.9 (123.1, 130.7)   | 14.2 (10.0, 18.4)    | 122.7 (120.7, 124.8)   | 9.0 (6.6, 11.4)      |
| 25–29.9          | 122.4 (116.0, 128.8)   | 10.4 (3.6, 17.1)     | 123.9 (120.5, 127.3)   | 10.0 (6.3, 13.7)     |
| alcohol use      |                         |                      |                         |                      |
| never use        | 117.1 (116.1, 118.1)   | ref                  | 116.7 (115.9, 117.4)   | ref                  |
measured three times with at least one minute between each measurement [22].

2. Later in the interview respondents were asked: Have you ever been diagnosed with high BP (hypertension)?

3. Those answering ‘yes’ were asked: Have you been taking any medications or other treatment for it during a) the last 2 weeks? b) the last 12 months? (The questionnaire stated ‘Other treatment might include weight loss program or change in eating habits’). We calculated mean systolic and diastolic BP using all three BP readings and where systolic \( \geq 140 \text{mmHg} \) and/or diastolic \( \geq 90 \text{mmHg} \) respondents were classified as having high BP at exam in accordance with guidelines [25]. We defined hypertension as high BP at exam and/or self-reported diagnosis; this included all those on treatment as only respondents reporting diagnosis were asked about treatment. Treatment was defined as being on medication or other treatment in the past 12 months. For respondents reporting diagnosis, or diagnosis and treatment, we examined whether their hypertension was controlled, defined as systolic BP \(<140 \text{mmHg} \) and diastolic \(<90 \text{mmHg} \). The rule of halves for detection, treatment and control was assessed by splitting hypertension into the following proportions i) undiagnosed and uncontrolled (i.e. high BP at exam, but diagnosis not reported), ii) diagnosed but uncontrolled (i.e. high BP, diagnosis reported), and iii) controlled (i.e. diagnosis reported, BP not high). Both ii) and iii) were further sub-divided into those reporting being on treatment or not.

Socio-demographic and risk factors considered were respondents’ area of residence (urban; rural); age; sex; religion (Hindu; Muslim; other religion); caste (scheduled tribe; scheduled caste; other backward caste; other); highest level of education completed (no formal education; less than primary school; primary school completed; secondary school completed; high school (or equivalent) completed; above high school); body mass index (BMI, \(<18.5, 18.5–, 23.0–, 25.0–, 30.0+ \text{kg/m}^2 \) [26]) calculated from height and weight measurements where both values were non-missing; alcohol consumption (recent use (in last 30 days), used but not recently, never used); household wealth index (provided in dataset, derived using WHO standard approach to estimating permanent income from survey data on household ownership of durable goods, neighbourhood and dwelling characteristics, and access to water, sanitation, electricity etc [27]).

Survey response was high with 92% of the eligible persons contacted completing the interviews. Respondents with complete interviews and complete hypertension data were included in the analysis. Hypertension data was considered complete if the respondent had all three BP measurements and had answered yes or no when asked if ever diagnosed with high BP (hypertension). We examined whether respondents with complete hypertension data differed from those with incomplete hypertension data.

Outcome variables were mean systolic and diastolic BP, high BP at examination, self-reported diagnosis and treatment of hypertension, any indication of hypertension (that is, high BP at exam and/or self-reported diagnosis of hypertension), and control of hypertension. We explored the association between outcome variables and age, sex and other socio-demographic characteristics. Age-standardisation was conducted using the United Nations 2005 population of India (both sexes combined) as the standard [28]. Associations with socio-demographic characteristics were examined using linear regression for mean BP adjusted for age and socio-demographic variables, and logistic regression for the prevalence of hypertension adjusted for age. STATA statistical software version 10.0 was used. The analysis took account of the cluster sampling design. Supplied weighting factors were used throughout the analysis, including the regression analyses, to correct for the unequal probability of selection resulting from the sampling design. Detailed information on the survey weighting is available at http://apps.who.int/healthinfo/systems/surveydata/index.php/catalog/65#page = sampling&tab = study-desc. Numerators and denominators given in the text and tables refer to the unweighted sample.

**Results**

Of the 12,198 survey respondents 12% (1,462) did not have complete interviews (494 partial interviews, 968 refusals, no contacts etc) and were excluded from further analysis. Of the remaining 10,736, a further 65 were excluded as they had incomplete hypertension data. Respondents with complete hypertension data were more likely to live in a rural area than the 65 with incomplete hypertension data (69.4% vs. 42.8%, \( p = 0.03 \)). The mean age of those with complete hypertension data did not differ significantly from those with incomplete data, nor did the two groups differ in their composition by sex \( (p = 0.75) \), education level \( (p = 0.33) \) or household wealth \( (p = 0.74) \). In general, all further analyses were conducted on the 10,671 respondents (4,148 men, 6,523 women) with complete hypertension data. However as three further variables - household wealth index, caste, and BMI - contained missing data for 71, 63 and 137 respondents respectively, analyses including these variables were conducted on a
Table 3. Prevalence of hypertension* by sociodemographic characteristics.

|                                                                 | MEN |                                                                 | WOMEN |                                                                 |
|----------------------------------------------------------------|-----|----------------------------------------------------------------|--------|----------------------------------------------------------------|
|                                                                 | no. with | crude (age-standardised) | odds ratios | no. with | crude (age-standardised) | odds ratios |
| hypertension prevalence % | 1,390 | 25.2 (22.9) | | 2,030 | 27.1 (25.7) | |
| age group | | | | | | |
| 18–29 | 38 | 12.3 | | 161 | 13.0 | |
| 30–39 | 82 | 24.6 | | 268 | 22.0 | |
| 40–49 | 101 | 27.4 | | 314 | 34.1 | |
| 50–59 | 472 | 32.0 | | 571 | 39.5 | |
| 60–69 | 392 | 31.5 | | 440 | 43.5 | |
| 70+ | 305 | 42.5 | | 276 | 45.2 | |
| place of residence | | | | | | |
| rural | 992 | 22.5 (21.2) | 1.00 | 1,407 | 26.1 (25.0) | 1.00 |
| urban | 398 | 31.4 (27.9) | **1.70 (1.21, 2.38)** | 623 | 29.2 (27.2) | **1.16 (0.93, 1.44)** |
| highest education level | | | | | | |
| no education | 383 | 24.0 (23.0) | 1.00 | 1,188 | 30.1 (26.1) | 1.00 |
| < primary | 178 | 25.3 (23.4) | 1.07 (0.66, 1.72) | 184 | 25.2 (24.2) | 0.94 (0.70, 1.26) |
| primary | 232 | 28.6 (28.8) | 1.48 (0.98, 2.24) | 267 | 27.5 (27.7) | 1.19 (0.92, 1.55) |
| secondary | 223 | 21.2 (20.2) | 1.03 (0.67, 1.59) | 188 | 21.0 (28.3) | 1.10 (0.78, 1.56) |
| high school | 220 | 23.5 (22.2) | 1.25 (0.82, 1.92) | 146 | 22.1 (28.9) | 1.23 (086, 1.77) |
| > high school | 154 | 30.6 (31.2) | **1.96 (1.21, 3.16)** | 57 | 22.8 (26.2) | 1.19 (0.75, 1.59) |
| household wealth index | | | | | | |
| Q1: poorest quintile | 188 | 21.4 (19.5) | 1.00 | 311 | 24.2 (24.4) | 1.00 |
| Q2 | 237 | 21.3 (22.5) | 1.01 (0.65, 1.59) | 339 | 25.5 (23.8) | 1.07 (0.76, 1.49) |
| Q3 | 250 | 25.7 (21.3) | 1.36 (0.88, 2.11) | 378 | 25.9 (25.3) | 1.13 (0.86, 1.47) |
| Q4 | 335 | 26.0 (22.6) | 1.26 (0.81, 1.96) | 442 | 28.7 (27.2) | 1.30 (0.97, 1.73) |
| Q5: least poor quintile | 373 | 31.4 (30.6) | **1.95 (1.27, 3.00)** | 543 | 30.9 (28.4) | **1.40 (1.07, 1.84)** |
| religion | | | | | | |
| hindu | 1,182 | 25.8 (23.3) | 1.00 | 1,662 | 26.3 (24.9) | 1.00 |
| muslim | 147 | 21.5 (19.6) | 0.79 (0.49, 1.28) | 278 | 30.2 (29.5) | 1.28 (0.95, 1.72) |
| other | 61 | 24.0 (24.0) | 0.93 (0.48, 1.82) | 90 | 36.1 (31.6) | **1.62 (1.02, 2.56)** |
| caste | | | | | | |
| other | 795 | 25.1 (22.6) | 1.00 | 1,210 | 28.2 (26.7) | 1.00 |
| other backward caste | 266 | 29.0 (25.5) | 1.24 (0.85, 1.80) | 376 | 25.1 (23.8) | 0.87 (0.71, 1.06) |
| scheduled caste | 213 | 20.6 (19.8) | 0.81 (0.55, 1.19) | 303 | 24.6 (23.6) | 0.86 (0.67, 1.10) |
| scheduled tribe | 108 | 32.5 (29.8) | 1.52 (0.90, 2.57) | 130 | 26.3 (25.3) | 0.95 (0.66, 1.38) |
### Table 3. Cont.

| bmi | MEN | WOMEN |
|-----|-----|-------|
| <18.5 kg/m² | 370 | 18.8 (18.1) | 1.00 | 527 | 21.6 (20.6) | 1.00 |
| 18.5–23.0 | 595 | 23.3 (20.9) | 1.39 | 771 | 25.4 (24.9) | 1.28 |
| 23.0–25.0 | 186 | 33.8 (32.2) | 2.42 | 223 | 34.1 (31.5) | 1.86 |
| 25.0–30.0 | 185 | 46.6 (36.7) | 3.78 | 356 | 38.7 (34.9) | 2.03 |
| 30.0+ | 39 | 37.1 (26.1) | 2.88 | 120 | 48.7 (40.0) | 3.17 |

*defined as > = 140/90 mmHg and/or diagnosis.*

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### Table 4. Prevalence, diagnosis, treatment and control of hypertension by age and sex.

| age group | MEN | crude (age-standardised) | odds ratios | WOMEN | crude (age-standardised) | odds ratios |
|-----------|-----|--------------------------|-------------|--------|--------------------------|-------------|
| 18–29     | 257 | 345 | 394 | 1,342 | 1,098 | 712 | 4,148 | 1,270 | 1,248 | 951 | 1,481 | 1,010 | 563 | 6,523 |
| 30–39     | 13.6 (10.9) | 510 | 35 | 70 | 49 | 75 | 85 | 70 | 65 |
| 40–49     | 19.2 (18.3) | 197 | 95 | 79 | 69 | 54 | 49 | 66 | 402 |
| 50–59     | 20.8 (19.0) | 234 | 50 | 48 | 70 | 29 | 273 |
| 60–69     | 19.2 (18.3) | 45 | 15 | 15 | 32 | 32 | 52 | 52 | 894 |
| 70+       | 20.8 (19.0) | 234 | 50 | 48 | 70 | 29 | 273 |

percentages are weighted; n refers to number in unweighted sample. subgroups are not mutually exclusive.
doi:10.1371/journal.pone.0086043.t004
slightly reduced (up to a maximum of 206) number of respondents. Study characteristics are shown in Table 1. The mean age was 41 years, with over two-thirds living in rural areas. One-third of either sex had a BMI below 18.5 kg/m² while 24% of women and 21% of men had a BMI of 23 kg/m² or above. Two-thirds of men and 99% of women reported never consuming alcohol.

In general, findings for mean diastolic BP mirrored those of systolic BP so only systolic BP data are shown in Table 2. Mean systolic BP increased with age for both sexes, with a steeper and smoother gradient in women than men. After full adjustment, mean systolic BP increased with BMI in both sexes, and recent users of alcohol had higher mean BP than never users. No wealth differentials were apparent in either sex. While no urban-rural differential was apparent in women, in men systolic BP was higher in urban than rural residents by 4.4 mmHg which attenuated after full adjustment to 3.2 mmHg.

The age-standardised prevalence of hypertension was 23% in men and 26% in women increasing, in both sexes, with age from 13% under age 30 to over 40% at ages 70 and over (Table 3). In men, hypertension was more prevalent in urban than rural areas (age-standardised prevalence, 28% vs. 21%) with the age-adjusted odds of men in urban areas having hypertension 1.70 (95%CI 1.21 to 2.38) times that of men in rural areas. In both sexes the odds of having hypertension was higher in the least poor as compared with the poorest wealth quintile, and increased steeply with BMI. Although hypertension was more prevalent in overweight and less poor groups, even groups with very low BMI and groups in the poorest wealth category had appreciable levels of hypertension (BMI <18.5: 18% men, 21% women; poorest: 20% men, 24% women). In men, the odds of having hypertension was high in those with high BP at examination, with the rate increasing from 10% under age 30 to around one-third at ages 70 and over. The proportion of men with high BP at exam doubled between the 18–29 and 30–39 age groups, then remained at 20–25% through the 30 s to 60 s. Only a small proportion of those with high BP at exam reported being diagnosed with hypertension, with proportions particularly low at younger ages; none of the men under 30 with high BP, and only 4% of those in their 30 s, reported being diagnosed. The situation was slightly better among women, but in no age group in either sex did the proportion of those with high BP reporting diagnosis exceed one-third; this indicates detection rates far worse than the 50% suggested by the rule of halves. Among both men and women reporting diagnosis with hypertension, two-thirds reported treatment in the past 12 months; half the men and two-thirds of the women treated had their BP controlled.

Urban-rural differences

One-quarter of urban men and 17% of rural men had high BP at examination, with no urban-rural differential observed in women (18%) (Table 5). The expected increase in prevalence of high BP with age was not apparent for urban men; a very high proportion, 30–40%, of those in their 30 s and 40 s had high BP, although these figures were based on relatively small numbers. A greater proportion of those with high BP reported diagnosis in urban than rural areas (men: 18% urban, 11% rural; women: 27%, 16%). Among men there was no urban-rural differential in the proportion of those with any indication of hypertension who were diagnosed, although in both settings, at around 30%, detection rates were low (Figure 2). The situation was better for women. In either sex two-thirds of those diagnosed were treated, with little evidence of an urban-rural differential. Control among those treated was sub-optimal in urban men, only one-third of whom had their BP controlled.

Wealth differences

In both sexes, the proportion reporting diagnosis of hypertension showed marked positive gradients from poorest to least poor quintiles of household wealth (Table 6). The prevalence of high BP at examination in men showed a less pronounced gradient and among women there was no gradient with household wealth. However, of those with high BP at exam the proportion reporting diagnosis increased steeply with wealth (poorest: 3% men, 7% women; least poor: 26%, 29%). When considering any indication of hypertension, the proportion reporting diagnosis was twice as high in the least poor as the poorest quintile (39% vs. 19% men; 56% vs. 25% women) (Table 6, Figure 3), but, excepting women in

![Figure 1. Percentage of hypertension that is diagnosed, treated, controlled, by age and sex.](http://dx.doi.org/10.1371/journal.pone.0086043.g001)
### Table 5. Prevalence, diagnosis, treatment and control of hypertension by urban-rural residence, age and sex.

|          | MEN                                                                 | RURAL                                                                |
|----------|----------------------------------------------------------------------|----------------------------------------------------------------------|
|          | URBAN                                                                | crude (age-standardised) rate | RURAL                                                                | crude (age-standardised) rate |
|          | 18–29 30–39 40–49 50–59 60–69 70+ | n | 18–29 30–39 40–49 50–59 60–69 70+ | n |
| age group|                                                                     | 72 | 185 | 339 | 1,012 | 856 | 544 | 3,185 |
| n        |                                                                     | 76 | 269 | 319 | 1,012 | 856 | 544 | 3,185 |
| Reporting diagnosis of hypertension (%) | 0.0 2.8 12.8 14.8 36.4 | 8.8 (7.4) | 0.0 2.8 12.8 14.8 36.4 | 6.7 (5.8) |
| of those reporting diagnosis, % reporting treatment in past 12 months | 0 0 70 84 94 | 71 | 146 | 38 58 65 67 76 70 | 64 | 242 |
| of those reporting diagnosis & treatment, % controlled at exam (<140/90) | 0 0 13 44 62 | 34 | 77 100 59 62 52 49 59 | 59 | 120 |
| High BP at examination +140/90 (%) | 8.7 31.8 40.4 30.1 20.6 37.2 | 27.6 (24.5) | 8.7 31.8 40.4 30.1 20.6 37.2 | 17.8 (17.1) |
| of those with high BP at exam, % reporting diagnosis | 0 3 19 34 27 53 | 18 | 80 5 12 17 23 21 | 11 | 154 |
| of those with high BP at exam, % reporting diagnosis & treatment | 0 0 19 17 23 52 | 15 | 69 0 5 12 14 17 17 | 10 | 122 |
| Any indication of hypertension (%) | 8.7 33.7 45.4 34.3 29.7 54.0 | 31.4 (27.9) | 8.7 33.7 45.4 34.3 29.7 54.0 | 22.5 (21.2) |
| of those with any indication of hyp, % reporting diagnosis | 0 8 28 42 50 67 | 28 | 173 18 20 35 34 36 43 | 30 | 337 |
| percentages are weighted; n refers to number in unweighted sample. subgroups are not mutually exclusive. doi:10.1371/journal.pone.0086043.t005 | | | |
Discussion

These analyses indicate that over one-fifth of Indian adults had hypertension, most of which - half in women, 70% in men - went undetected and therefore remained untreated and uncontrolled. Less than one-quarter of adults with measured high BP were aware of their condition, with diagnosis rates at younger ages particularly bad. On the other hand the data suggest that of the hypertension that was detected, treatment rates, and control among those treated, generally exceeded 50% which, although sub-optimal, is comparable with the situation in more affluent countries [15,16].

There were differentials across population groups. Although hypertension was particularly prevalent in the least poor and the overweight, prevalence in the poor and the underweight was also high. These findings do not support the idea that hypertension is a condition only of affluence [29] and therefore of low priority for health and development programmes in India and other low- and middle-income countries. The lack of the usual age gradient in the prevalence of measured high BP in men is surprising. In our study recent alcohol use was much higher in underweight than overweight men, in rural than urban areas, and highest among men in their 30 s and 40 s. This, and other recent exposures such as increased dietary salt intake and low levels of physical activity in younger people, may be contributing to our findings [30,31].

There were important differences between the sexes. The higher overall rates of diagnosis seen in women, especially those in urban locations and in better off households, probably result from contact with health services around childbirth. National Family Health Survey data for 2005-06 indicate that 77% of women attended an antenatal clinic for their most recent birth, and 64% of attendees had their BP measured [32]; attendance was much less common in rural than urban areas, and in poorer households, as was the proportion of attendees who had their BP measured. Our data show for women, but not men, a lack of patterning of treatment and control of hypertension across urban-rural or household wealth categories suggesting that the quality of care is more of an issue for men than women. The failure to detect hypertension in younger men, and the poor control in urban men, is of particular importance, suggesting a need for more proactive surveillance.

These analyses, based on recent nationally-representative survey data, provide up to date national estimates of the prevalence, diagnosis, treatment and control of hypertension amongst adults in India. This is important new information as, to date, most evidence on hypertension, and chronic disease more generally, in India has come from small scale and/or local studies.

The SAGE survey has the strength of containing blood pressure measurements and self-reported information on diagnosis and treatment of hypertension thus providing the opportunity to compare and contrast clinical measurements with self-reported data. The accuracy and reliability of Boso BP instruments, widely used in Germany, has been recognised by the German consumer safety organisation with the Medistar S coming top in the wrist category and the German Hypertension Society also confirms their high accuracy [33]. Self-reported information may be affected by recall biases and reporting errors which may vary by socio-demographic characteristics. As the survey question on treatment did not differentiate taking medication, weight loss program or change in eating habits, it was not possible to identify the subgroup taking hypertension medication, as recommended by the JNC guidelines as a diagnostic criteria for hypertension [25]. The adequacy of assessing prevalence of high BP using measurements made at a single clinic visit has been questioned [34] as it does not mirror clinical guidance of making repeated measurements over several weeks in order to avoid regression to the mean effects. These effects lead to over-estimation of the prevalence of high BP as the within-person fluctuations in blood pressure will tend to underestimate the “usual” level of blood pressure [35]. However, measurements made on a single occasion do have strong predictive power for cardiovascular disease in epidemiological studies [36,37].
Table 6. Prevalence, diagnosis, treatment and control of hypertension by wealth quintile and sex.

|                  | Q1: POOREST | Q2 | Q3 | Q4 | Q5: LEAST POOR |
|------------------|-------------|----|----|----|----------------|
| **MEN**          |             |    |    |    |                |
| Reporting diagnosis of hypertension (%) | 4.1 (3.8) | 5.1 (5.3) | 7.7 (6.8) | 7.3 (5.5) | 12.2 (10.8) |
| of those reporting diagnosis, % reporting treatment in past 12 months | 46 | 30 | 34 | 63 | 101 |
| of those reporting diagnosis & treatment, % controlled at exam (<140/<90) | 70 | 14 | 20 | 31 | 41 |
| High BP at examination +140+90 (%) | 17.9 (16.3) | 17.8 (19.2) | 20.3 (16.3) | 21.8 (19.3) | 25.9 (25.5) |
| of those with high BP at exam, % reporting diagnosis | 3 | 17 | 9 | 35 | 67 |
| of those with high BP at exam, % reporting diagnosis & treatment | 3 | 16 | 4 | 12 | 26 |
| Any indication of hypertension (%) | 21.4 (19.5) | 21.3 (22.5) | 25.7 (21.3) | 26.0 (22.6) | 31.4 (30.6) |
| of those with any indication of hyp, % reporting diagnosis | 19 | 41 | 24 | 61 | 140 |
| **WOMEN**        |             |    |    |    |                |
| Reporting diagnosis of hypertension (%) | 6.1 (5.9) | 9.8 (8.4) | 12.1 (11.7) | 12.8 (12.3) | 17.3 (15.9) |
| of those reporting diagnosis, % reporting treatment in past 12 months | 64 | 54 | 88 | 65 | 118 |
| of those reporting diagnosis & treatment, % controlled at exam (<140/<90) | 72 | 35 | 46 | 54 | 61 |
| High BP at examination +140+90 (%) | 19.5 (19.9) | 19.3 (18.6) | 23.1 (18.1) | 18.8 (18.0) | 18.9 (19.3) |
| of those with high BP at exam, % reporting diagnosis | 7 | 23 | 19 | 51 | 26 |
| of those with high BP at exam, % reporting diagnosis & treatment | 6 | 19 | 13 | 42 | 19 |
| Any indication of hypertension (%) | 24.2 (24.4) | 25.5 (23.8) | 25.9 (25.3) | 28.7 (27.2) | 30.9 (28.4) |
| of those with any indication of hyp, % reporting diagnosis | 25 | 77 | 39 | 117 | 47 |

Percentages are weighted; n refers to number in unweighted sample. Subgroups are not mutually exclusive. doi:10.1371/journal.pone.0086043.t006
This nationally-representative study shows high rates of hypertension in adults in India affecting both the poor and the better off and with sub-optimal detection particularly among young urban men and poorer households. Tackling low detection rates is the priority as, once detected, the results indicate that rates of treatment and control of hypertension are relatively good. Substantial effort – both in improving clinical practice and in preventing high BP in the first place - is needed to reduce the high rates of hypertension, and the resulting large burden of cardiovascular disease, in India.

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Author Contributions
Conceived and designed the experiments: SE KM. Analyzed the data: KM. Wrote the paper: KM SA GDS SE. Interpreted data: KM SA GDS KM. Contributed reagents/materials/analysis tools: SJ. Drafted the paper: SJ KM SE. Contributed to the writing of the manuscript: KM SE. Managed the process of data collection: SE KM. Conceived and designed the experiments: SE KM. Analyzed the data: SJ KM SE. Contributed reagents/materials/analysis tools: SJ. Drafted the paper: SJ KM SE. Interpreted data: KM SA GDS SE. Wrote the paper: KM SA GDS SE. Interpreted data: KM SA GDS SE.

References
1. Reddy KS, Shah B, Varghese C, Ramadoss A (2005) Responding to the threat of chronic diseases in India. Lancet 366:1744–1749.
2. Patel V, Chatterji S, Chisholm D, Ebrahim S, Gopalakrishna G, et al. (2011) Chronic diseases and injuries in India. Lancet 377:419–429.
3. Kearney PM, Whelton M, Reynolds K, Muntner P, Whelton PK, et al. (2005) Global burden of hypertension: analysis of worldwide data. Lancet 365:217–223.
4. World Health Organisation (2002) The World Health Report 2002 - Reducing risks, promoting healthy life. Geneva: WHO.
5. Ezzati M, Lopez AD, Rodgers A, Vander Hoorn S, Murray CJ, et al. (2002) Selected major risk factors and global and regional burden of disease. Lancet 360:1347–60.
6. Danaei G, Finucane MM, Lin JK, Singh GM, Paciorek CJ, et al on behalf of the Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group (Blood Pressure) (2011) National, regional, and global trends in systolic blood pressure since 1980: systematic analysis of health examination surveys and epidemiological studies with 786 country-years and 5.4 million participants. Lancet 377:568–77.
7. Colhoun HM, Hemingway H, Poulter NR (1998) Socio-economic status and blood pressure: an overview analysis. J Hum Hypertens 12:91–110.
8. Addo J, Smeeth L, Leon DA (2009) Socioeconomic position and hypertension: a study of urban civil servants in Ghana. J Epidemiol Comm Health 63:646–650.
9. Reddy KS, Yusuf S (1996) Emerging epidemic of cardiovascular disease in developing countries. Circulation 97:596–601.
10. Gupta R (2004) Trends in hypertension epidemiology in India. J Hum Hypertens 18:73–78.
11. Hypertension Study Group (2001) Prevalence, awareness, treatment and control of hypertension among the elderly in Bangladesh and India: a multicentre study. Bull World Health Organ 79:490–500.
12. Ebrahim S, Kira S, Bowen L, Andersen E, Ben-Shlomo Y, et al (2010) The effect of rural-to-urban migration on obesity and diabetes in India: a cross-sectional study. PLoS Medicine 7(4):e1000268. doi: 10.1371/journal.pmed.1000268.
13. Wilber JA, Barrow JG (1972) Hypertension – a community problem. Am J Med 52(5):653–663.
14. Hart JT (1992) Rule of halves: implications of increasing diagnosis and reducing dropout for future workload and prescribing costs in primary care. Brit J Gen Practice 42(356):116–119.
15. Patel R, Landsor DA, Whincup P, Montaner D, Papacosta O, et al. (2006) The detection, treatment and control of high blood pressure in older British adults: cross-sectional findings from the British Women’s Heart and Health Study and the British Regional Heart Study. J Hum Hypertens 20:733–741.
16. Egan BM, Zhao Y, Aznom RN (2010) US trends in prevalence, awareness, treatment and control of hypertension, 1968-2008. JAMA 303(20):2043–2050.
17. Chaturvedi S, Pant M, Neelam MD, Yadav G (2007) Hypertension in Delhi: prevalence, awareness, treatment and control. Tropical Doctor 37:142–145.
18. Joshi SR, Shah SN (2003) Control of blood pressure in India: rule of halves still very much valid. J Assoc Physicians India 51:151–2.
19. Mohan V, Deepa M, Farooq S, Datta M, Deepa R (2007) Prevalence, awareness and control of hypertension in Chennai: the Chennai Urban Rural Epidemiology Study (CURES-52). J Assoc Physicians India 55:326–332.
20. Kowal P, Chatterji S, Naikoo N, Birirswam R, Fau W, et al. (2012) Data Resource Profile: The World Health Organization Study on global AGEng and adult health (SAGE). Int J Epidemiol 41:1639–1649.
21. Bau S, Millett C (2013) Social epidemiology of hypertension in middle-income countries: determinants of prevalence, diagnosis, treatment, and control in the WHO SAGE study. Hypertension 62:18–26.
22. World Health Organisation (2006) WHO SAGE Survey Manual: The WHO Study on Global AGEng and Adult Health (SAGE). Geneva, WHO.
23. Altunkan S, Oztas K, Altunkan E (2006) Validation of the Omron 637IT wrist blood pressure measuring device with a position sensor according to the International Protocol in adults and obese adults. Blood Press Monit 11(2):79–85.
24. Tian HY, Liu WJ, Li SG, Song Z, Gong W (2010) Validation of the Transtek TMB-988 wrist blood pressure monitor for home blood pressure monitoring according to the International protocol. Blood Press Monit 15:326–3.
25. Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (2003) The seventh report of the Joint National...
Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (JNC-7). JAMA 289:2560–2571.

26. WHO Expert consultation (2004) Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 363:157–63.

27. Ferguson BD, Tandon A, Gakidou E, Murray CJL (2005) Estimating permanent income using indicator variables. In: Murray CJL, Evans DB, editors. Health Systems Performance Assessment: Debates, Methods and Empiricism. Geneva: WHO.

28. United Nations Population Division (2009) World Population Prospects: The 2008 Revision. Available: http://esa.un.org/wpp/unpp/panel_population.htm. Accessed 12 June 2013.

29. Olshansky SJ, Ault AB (1986) The fourth stage of the epidemiological transition: The age of delayed degenerative diseases. Milbank Mem Fund Q 64: 355–391.

30. Dobe M (2013) Hypertension: The prevention paradox. Indian J Public Health 57:1–3

31. Yadav K, Krishnan A (2008) Changing patterns of diet, physical activity and obesity among urban, rural and slum populations in north India. Obes Rev 9: 400–408.

32. International Institute for Population Sciences (IIPS) and Macro International (2007) National Family Health Survey (NFHS-3), 2005–06: India: Volume I. Chapter 8: Maternal Health. Mumbai: IIPS.

33. Boso, Bosch & Sohn, Germany. Blood pressure instrument brochure and specification. Available at: http://www.boso.de/produkte/blutdruckmessgeraete-fuer-die-selbstmessung.html. Accessed 12 June 2013.

34. Bovet P, Gervasoni JP, Ross AG, Mkamba M, Mtasiwa DM, et al. (2003) Assessing the prevalence of hypertension in populations: are we doing it right? J Hypertension 21:509–517.

35. MacMahon S, Petro R, Cutler J, Collins R, Sorlie P, et al. (1990) Blood pressure, stroke, and coronary heart disease. Part 1, prolonged differences in blood pressure: prospective observational studies corrected for the regression dilution bias. Lancet 335:763–774.

36. Society of Actuaries (1959) Build & Blood Pressure Study 1959. Chicago: Society of Actuaries.

37. Prospective Studies Collaboration (2002) 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 360:1903–13.