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Prevalence and Determinants of Hypertension among Adults in a Rural Community: A Community-Based Cross-Sectional Study from India

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ABS TRAC T

Background*:** Hypertension has emerged as a leading contributor to cardiovascular morbidity and premature mortality in India, and its burden is now rising most steeply in rural populations undergoing rapid epidemiological transition. Community-based estimates anchored to defined rural catchment areas, together with quantification of modifiable determinants, remain limited. ***Methods: A community-based cross-sectional study was conducted among 800 adults aged 18 years and above residing in the rural field practice area of the Department of Community Medicine over a period of twelve months. Thirty clusters were selected by probability proportional to size sampling and households were enrolled by systematic random sampling. Data were obtained using the World Health Organization STEP wise instrument. Blood pressure was recorded in triplicate using a validated automated device, and participants with elevated readings were re-examined after seven days. Anthropometry and capillary blood glucose were measured using standard protocols. Hypertension was defined by JNC 7 criteria. Associations were examined using the chi-square test, Student t test and multivariable logistic regression. ***Results***: The prevalence of hypertension was 30.4 percent (95% CI 27.2 to 33.6), and 150 of 243 hypertensive participants (61.7 percent) were newly detected. Prevalence increased from 11.4 percent among those aged 18 to 29 years to 56.3 percent among those aged 60 years and above (chi-square for trend 118.42, p less than 0.001). On multivariable analysis, age 45 years and above (aOR 3.02), body mass index 25 kg/m2 and above (aOR 2.38), central obesity (aOR 1.86), family history of hypertension (aOR 2.11), diabetes mellitus (aOR 2.24), physical inactivity (aOR 1.71), current tobacco use (aOR 1.64) and addition of extra salt at the table (aOR 1.58) remained independently associated with hypertension. Only 27 hypertensive participants (11.1 percent) had controlled blood pressure. ***Conclusion***: Nearly one in three rural adults was hypertensive, the majority were previously undiagnosed and control was poor. Opportunistic screening and structured lifestyle intervention at the primary care level are warranted.

Keywords: *Hypertension, Prevalence, Risk Factors, Rural Population, Cross-Sectional Studies, India.*

INTRODUCTION

Raised blood pressure is the single largest attributable risk factor for premature death and disability worldwide, and it remains the most modifiable of the established cardiovascular risks. Pooled analysis of 1201 population-representative studies comprising 104 million participants estimated that the number of adults aged 30 to 79 years living with hypertension doubled from 648 million in 1990 to 1.28 billion in 2019, with essentially the whole of this increase occurring in low-income and middle-income countries [1]. A parallel systematic analysis of population-based surveys from 90 countries estimated the global prevalence of hypertension among adults at 31.1 percent, with a substantially higher absolute burden and considerably poorer awareness, treatment and control in low-income and middle-income settings than in high-income countries [2]. The determinants underlying this geographical redistribution are broadly consistent across regions and include population ageing, high dietary sodium and low potassium intake, adiposity, physical inactivity, harmful use of alcohol and tobacco, and constrained access to continuous primary care [3].

India carries one of the largest national shares of this burden. The Indian Council of Medical Research India Diabetes study, a nationally representative cross-sectional survey covering 31 states and union territories, reported a weighted hypertension prevalence of 35.5 percent among adults aged 20 years and above, corresponding to an estimated 315 million affected individuals, with marked interstate variation ranging from about 24 percent to about 52 percent [4]. An earlier region-specific systematic review and meta-analysis of 142 Indian studies estimated an overall prevalence of 29.8 percent and documented a significant urban to rural gradient, with pooled prevalence of 33.8 percent in urban areas compared with 27.6 percent in rural areas [5]. That gradient, however, has narrowed appreciably over the past two decades. Successive Indian surveys have described a convergence of rural and urban hypertension rates, driven by dietary transition, mechanisation of agricultural labour, rising body mass index and increasing life expectancy in villages, so that the historical assumption of hypertension as a predominantly urban disorder is no longer tenable [6].

Rural community surveys within India nevertheless report a wide dispersion of estimates. A large survey of 10 463 adults aged 25 to 64 years across eleven villages in Tamil Nadu found a prevalence of 21.4 percent, of whom nearly three quarters were detected for the first time during the survey, while only one in five was receiving treatment and fewer than seven percent had controlled blood pressure [7]. This heterogeneity reflects genuine regional differences in diet, occupation and demographic structure, but it is also a product of methodological variation in age ranges sampled, sampling frames, the number of blood pressure readings taken and the diagnostic threshold applied. Estimates derived from a single visit, in particular, are vulnerable to inflation by the alerting reaction, and comparatively few Indian community studies have incorporated a repeat measurement visit into their protocol.

The deficiencies in the care cascade are at least as consequential as prevalence itself. A nationally representative analysis of more than 1.3 million adults aged 15 to 49 years demonstrated that a substantial proportion of hypertensive individuals in India had never had their blood pressure measured, and that attrition at each successive step from screening to awareness, treatment and finally control was greatest among men, among rural residents and among those in the lowest wealth quintiles [8]. The Prospective Urban Rural Epidemiology study, which compared communities across high-income, middle-income and low-income countries, similarly documented that rural participants in low-income settings fared worse than their urban counterparts at every step of the cascade [9]. These findings indicate that the epidemiological transition in rural India has not been matched by a corresponding strengthening of primary care detection and follow-up, a gap that national programmes such as the National Programme for Prevention and Control of Non-Communicable Diseases and the India Hypertension Control Initiative were designed to address.

Case definition also merits explicit consideration. The 2017 American College of Cardiology and American Heart Association guideline lowered the diagnostic threshold to 130/80 mmHg, a change that would substantially increase the estimated prevalence in any Indian population if applied uncritically [10]. Indian national programmes and the majority of published Indian community surveys continue to operate at the conventional 140/90 mmHg threshold, and comparability with the existing literature therefore requires that this threshold be retained while the distribution of blood pressure across categories is reported transparently.

Against this background, reliable community-level data drawn from a defined rural catchment area, generated using standardised measurement technique with a repeat visit for confirmation, and analysed so as to separate independent determinants from confounded associations, retain considerable value for local health service planning. Such data allow the primary health centre serving the area to estimate its true case load, to quantify the proportion of disease that is undiagnosed, and to identify the specific behavioural and anthropometric characteristics that should be prioritised for intervention. The present study was therefore undertaken in the rural field practice area of a teaching institution to estimate the prevalence of hypertension among adults aged 18 years and above, to describe the distribution of blood pressure categories, to identify the sociodemographic, behavioural and anthropometric factors independently associated with hypertension, and to describe awareness, treatment and control among those found to be hypertensive.

AIMS AND OBJECTIVES

The present study was undertaken with the aim of generating reliable community-level evidence on the magnitude of hypertension and its determinants among adults residing in a defined rural catchment area, so that the findings could inform screening and preventive activity delivered through the primary health centre serving that population.

The primary objective was to estimate the prevalence of hypertension among adults aged 18 years and above residing in the rural field practice area of the Department of Community Medicine, using blood pressure measured under standardised conditions on two separate occasions. The first secondary objective was to describe the distribution of the study population across normal, prehypertensive, stage 1 and stage 2 blood pressure categories, and to characterise the mean systolic and diastolic blood pressure across age, sex and anthropometric strata. The second secondary objective was to identify the sociodemographic, behavioural and anthropometric factors associated with hypertension in this population, and to determine which of these factors retained an independent association after simultaneous adjustment for potential confounders in a multivariable model. The third secondary objective was to describe the proportions of hypertensive participants who were aware of their diagnosis, who were receiving antihypertensive pharmacotherapy and whose blood pressure was adequately controlled, thereby characterising the local hypertension care cascade and quantifying the burden of previously undetected disease.

MATERIALS AND METHODS

Study design and setting

A community-based, descriptive, cross-sectional study was carried out in the rural field practice area attached to the Department of Community Medicine, Jorhat Medical College & Hospital, Jorhat, Assam, India. The catchment area comprised 32 villages served by the Rural Health Training Centre, with an estimated total population of approximately 32,000 according to the most recent population enumeration maintained by the centre. The area was predominantly agrarian, and health services were delivered through a primary health centre with attached sub-centres and Accredited Social Health Activists (ASHAs).

Study period

The study was conducted over a period of twelve months, from June 2024 to May 2025, which included the phases of instrument pretesting, house-to-house data collection, repeat measurement visits, data verification, and compilation.

Study population and eligibility criteria

The study population consisted of adults aged 18 years and above who were usual residents of the selected villages. Individuals were included if they were aged 18 years or more, had resided in the area for at least six months preceding the survey, and provided written informed consent. Individuals were excluded if they were pregnant at the time of the survey, as pregnancy-related hypertensive disorders differ in aetiology and natural history from essential hypertension; if they were acutely ill, bedridden or had a condition precluding blood pressure measurement or anthropometry, including upper limb deformity, amputation or arteriovenous fistula in both arms; if they had a known secondary cause of hypertension such as chronic kidney disease, endocrine disorder or coarctation of the aorta; if they were unable to comprehend or respond to the questionnaire because of significant cognitive or psychiatric impairment; or if they were not available at the household on three separate visits made on different days and at different times.

Sample size estimation

The sample size was calculated using the standard formula for estimating a single population proportion with absolute precision. An expected prevalence of hypertension of 28.5 percent was assumed on the basis of pooled rural Indian estimates reported in earlier literature, with an absolute precision of 4 percent and a confidence level of 95 percent. This yielded a minimum requirement of 490 participants. Because a cluster sampling design was adopted in preference to simple random sampling, the estimate was multiplied by a design effect of 1.5, giving 735 participants, and a further 10 percent was added to allow for non-response and incomplete records, giving a final target of 810 participants. A total of 864 eligible adults were approached, of whom 812 consented and completed the survey, a response rate of 94.0 percent. Twelve records were subsequently excluded because of incomplete anthropometric or blood pressure data, leaving 800 participants available for the final analysis.

Sampling technique

A two-stage cluster sampling design was employed. In the first stage, 30 clusters were selected from the villages of the field practice area by probability proportional to size sampling, using the population figures maintained by the rural health training centre as the sampling frame. In the second stage, a starting household was identified within each selected cluster by the random walk method from a landmark at the centre of the village, and subsequent households were enrolled by systematic random sampling until the required number of eligible adults per cluster had been recruited. All eligible adults present in a selected household were invited to participate. Households that were locked or in which no eligible adult was available were revisited on two further occasions before being replaced by the adjacent household.

Data collection tool and procedure

Data were collected by house-to-house visit using a pretested, semi-structured, interviewer-administered schedule adapted from the World Health Organization STEPwise approach to non-communicable disease risk factor surveillance. The instrument captured sociodemographic particulars including age, sex, education, occupation, type of family and socioeconomic status classified by the modified B G Prasad scale updated to the current consumer price index; behavioural variables including current tobacco use in smoked and smokeless forms, current alcohol consumption, level of physical activity, habitual addition of extra salt at the table and frequency of consumption of fruits and vegetables; and personal and family history of hypertension, diabetes mellitus and cardiovascular disease, together with details of current medication. The schedule was translated into the local language, back-translated for accuracy and pretested on 40 adults from a village outside the sampling frame, following which minor modifications in wording were incorporated. Interviews were conducted by the investigator, who had been trained in the standardised measurement protocol before commencement of field work.

Blood pressure measurement

Blood pressure was measured using a validated automated oscillometric device with an appropriately sized cuff. Participants were seated with the back supported and the feet flat on the floor, and were rested quietly for at least five minutes before the first reading. They were asked to refrain from tobacco, caffeine and exercise for at least 30 minutes before measurement. The arm was supported at the level of the heart and the cuff was applied to the bare upper arm. Three readings were obtained at intervals of two minutes in the right arm, and the mean of the second and third readings was recorded as the blood pressure for that visit. Where the difference between the second and third readings exceeded 10 mmHg systolic, an additional reading was taken and the mean of the last three readings was used.

Follow-up and confirmation protocol

Participants whose mean blood pressure at the first visit was 140 mmHg systolic or above, or 90 mmHg diastolic or above, and who were not already on antihypertensive treatment, were revisited after an interval of seven days and the entire measurement sequence was repeated under identical conditions. Hypertension was diagnosed only when the elevated reading was confirmed on this second occasion, thereby minimising misclassification arising from the alerting reaction at first contact. Participants already receiving antihypertensive medication were classified as hypertensive irrespective of the recorded value and were not subjected to the repeat visit. All participants found to have elevated blood pressure, whether newly detected or previously known, were counselled on lifestyle modification and referred in writing to the primary health centre for evaluation and treatment, and those with blood pressure of 180/110 mmHg or above or with symptoms suggestive of target organ involvement were referred immediately to the nearest secondary care facility.

Anthropometric and biochemical measurement

Height was measured to the nearest 0.1 cm using a portable stadiometer with the participant standing erect without footwear, and weight was measured to the nearest 0.5 kg using a calibrated digital weighing scale with light clothing. Body mass index was computed as weight in kilograms divided by the square of height in metres. Waist circumference was measured to the nearest 0.1 cm at the midpoint between the lower costal margin and the iliac crest at the end of normal expiration, and hip circumference was measured at the level of the greater trochanters, from which the waist to hip ratio was derived. Capillary blood glucose was estimated using a calibrated glucometer, and participants with a random value of 200 mg/dL or above, or a fasting value of 126 mg/dL or above on a subsequent visit, were referred for confirmatory testing. All instruments were calibrated at the beginning of each field session.

Operational definitions

Hypertension was defined, in accordance with the Seventh Report of the Joint National Committee, as a mean systolic blood pressure of 140 mmHg or above, or a mean diastolic blood pressure of 90 mmHg or above, confirmed on a repeat visit, or current use of antihypertensive medication. Prehypertension was defined as systolic blood pressure of 120 to 139 mmHg or diastolic blood pressure of 80 to 89 mmHg in the absence of antihypertensive therapy. Stage 1 hypertension denoted systolic blood pressure of 140 to 159 mmHg or diastolic blood pressure of 90 to 99 mmHg, and stage 2 hypertension denoted systolic blood pressure of 160 mmHg or above or diastolic blood pressure of 100 mmHg or above. Overweight and obesity were defined using the Asian cut-offs of body mass index 23.0 to 24.9 kg/m2 and 25.0 kg/m2 or above respectively. Central obesity was defined as waist circumference of 90 cm or above in men and 80 cm or above in women. Current tobacco use denoted use of any smoked or smokeless tobacco product within the preceding 30 days, and current alcohol use denoted consumption of any alcoholic beverage within the preceding 30 days. Physical inactivity was defined as failure to achieve 150 minutes of moderate intensity activity or 75 minutes of vigorous intensity activity per week, computed from the Global Physical Activity Questionnaire domains. Awareness denoted a self-reported prior diagnosis of hypertension made by a qualified practitioner, treatment denoted current use of antihypertensive medication, and control denoted blood pressure below 140/90 mmHg among those on treatment.

Ethical Considerations

The study protocol was approved by the Institutional Ethics Committee of Jorhat Medical College & Hospital, Jorhat, Assam, India, vide letter number JMC/IEC/2024/067 dated 15/01/2024. Written informed consent was obtained from every participant after explanation of the purpose and procedures of the study in the local language. Confidentiality was maintained by assigning a unique identification number to each record, and participants retained the right to withdraw at any stage without prejudice to the health services available to them. All participants were informed of their blood pressure, body mass index, and blood glucose values at the time of measurement and were provided with written referral where indicated.

Statistical Analysis

Data were entered into a Microsoft Excel spreadsheet and analysed using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA). Categorical variables were summarised as frequencies and percentages, and continuous variables as mean with standard deviation after verification of normality using the Kolmogorov–Smirnov test and inspection of histograms. The prevalence of hypertension was reported with its 95% confidence interval computed by the Wilson score method, with variance inflated for the cluster design. Associations between categorical variables and hypertension status were tested using the Pearson chi-square test, with the Yates continuity correction applied to 2×2 tables where indicated and the Fisher exact test used where expected cell counts were below five. The chi-square test for linear trend was used to assess the gradient of prevalence across ordered age categories. Mean systolic and diastolic blood pressure were compared between two groups using the independent-samples Student's t-test and across more than two groups using one-way analysis of variance with the Bonferroni correction for post hoc pairwise comparisons. Variables associated with hypertension at a significance level of $p < 0.20$ on univariate analysis, together with variables of established biological relevance, were entered into a binary logistic regression model using the enter method, and adjusted odds ratios with 95% confidence intervals were computed. Goodness of fit was assessed using the Hosmer–Lemeshow test, and multicollinearity was assessed using the variance inflation factor. A two-tailed $p < 0.05$ was considered statistically significant throughout.

RESULTS

A total of 800 adults aged 18 years and above were included in the final analysis. The mean age of the study population was 42.63 plus or minus 14.82 years, with a range of 18 to 84 years. Males constituted 386 participants (48.3 percent) and females 414 participants (51.7 percent), giving a sex ratio of 1073 females per 1000 males, which was consistent with the enumerated population of the catchment area. The mean age of male participants was 43.18 plus or minus 15.06 years and that of female participants was 42.11 plus or minus 14.59 years, and the difference was not statistically significant (t equal to 1.02, p equal to 0.308). Illiteracy or education limited to the primary level was recorded in 382 participants (47.8 percent), and 322 participants (40.3 percent) were engaged in agriculture or agricultural labour. Socioeconomic classification by the modified B G Prasad scale placed 432 participants (54.0 percent) in classes IV and V. The detailed sociodemographic profile of the study population is presented in Table 1.

The distribution of blood pressure categories is shown in Table 2. Blood pressure was optimal in 217 participants (27.1 percent), while 340 participants (42.5 percent) were classified as prehypertensive. Stage 1 hypertension was present in 168 participants (21.0 percent) and stage 2 hypertension in 75 participants (9.4 percent). The overall prevalence of hypertension was therefore 30.4 percent (243 of 800; 95 percent confidence interval 27.2 to 33.6). The mean systolic blood pressure for the whole cohort was 128.42 plus or minus 17.63 mmHg and the mean diastolic blood pressure was 82.14 plus or minus 10.87 mmHg. Among the 243 hypertensive participants, 150 (61.7 percent) were detected for the first time during the survey and 93 (38.3 percent) had a pre-existing diagnosis.

Prevalence of hypertension by age and sex is presented in Table 3. A strong and statistically significant gradient with advancing age was observed, the prevalence rising from 11.4 percent among those aged 18 to 29 years to 20.8 percent at 30 to 39 years, 31.0 percent at 40 to 49 years, 43.4 percent at 50 to 59 years and 56.3 percent among those aged 60 years and above (chi-square for linear trend equal to 118.42, degrees of freedom 1, p less than 0.001). Hypertension was more frequent among males (127 of 386; 32.9 percent) than among females (116 of 414; 28.0 percent), but this difference did not attain statistical significance (chi-square equal to 2.25, degrees of freedom 1, p equal to 0.134).

The univariate associations between the factors studied and hypertension are summarised in Table 4. Age of 45 years and above was strongly associated with hypertension, the prevalence being 45.9 percent among those aged 45 years and above compared with 18.6 percent among younger participants (crude odds ratio 3.71, 95 percent confidence interval 2.69 to 5.11; chi-square equal to 70.14, p less than 0.001). Education limited to the primary level or below was associated with a prevalence of 37.4 percent compared with 23.9 percent among those educated beyond the primary level (crude odds ratio 1.90, 95 percent confidence interval 1.39 to 2.59; chi-square equal to 16.98, p less than 0.001). Socioeconomic classes IV and V showed a prevalence of 31.9 percent compared with 28.5 percent in classes I to III, and this difference was not statistically significant (crude odds ratio 1.18, 95 percent confidence interval 0.87 to 1.59; chi-square equal to 1.07, p equal to 0.302).

Among the anthropometric and behavioural factors, body mass index of 25 kg/m2 or above was associated with a prevalence of 50.5 percent compared with 23.0 percent among those below this threshold (crude odds ratio 3.41, 95 percent confidence interval 2.44 to 4.75; chi-square equal to 58.72, p less than 0.001). Central obesity was associated with a prevalence of 45.1 percent compared with 22.2 percent in its absence (crude odds ratio 2.88, 95 percent confidence interval 2.11 to 3.93; chi-square equal to 45.31, p less than 0.001). Current tobacco use was associated with a prevalence of 39.7 percent against 25.6 percent among non-users (crude odds ratio 1.92, 95 percent confidence interval 1.41 to 2.62; chi-square equal to 17.44, p less than 0.001), and current alcohol use with a prevalence of 42.5 percent against 27.7

percent (crude odds ratio 1.93, 95 percent confidence interval 1.34 to 2.79; chi-square equal to 12.36, p less than 0.001). Physical inactivity was associated with a prevalence of 40.3 percent compared with 23.9 percent among the physically active (crude odds ratio 2.15, 95 percent confidence interval 1.58 to 2.92; chi-square equal to 24.16, p less than 0.001). Habitual addition of extra salt at the table was associated with a prevalence of 40.9 percent compared with 25.5 percent (crude odds ratio 2.03, 95 percent confidence interval 1.48 to 2.78; chi-square equal to 19.62, p less than 0.001). A family history of hypertension in a first degree relative was associated with a prevalence of 46.9 percent compared with 25.0 percent (crude odds ratio 2.65, 95 percent confidence interval 1.90 to 3.70; chi-square equal to 34.05, p less than 0.001), and known diabetes mellitus with a prevalence of 53.8 percent compared with 27.8 percent (crude odds ratio 3.02, 95 percent confidence interval 1.89 to 4.83; chi-square equal to 22.47, p less than 0.001).

Comparison of mean blood pressure across strata is presented in Table 5. Mean systolic blood pressure rose progressively with age from 119.62 plus or minus 13.24 mmHg in the youngest group to 141.24 plus or minus 19.08 mmHg in those aged 60 years and above, and the difference across age groups was highly significant on one-way analysis of variance (F equal to 64.21, p less than 0.001), with post hoc comparison confirming significant differences between all adjacent categories except between the groups aged 30 to 39 years and 40 to 49 years. Mean systolic blood pressure was higher in males than in females (129.81 plus or minus 17.92 mmHg against 127.13 plus or minus 17.24 mmHg; t equal to 2.16, p equal to 0.031), and mean diastolic blood pressure showed a similar pattern (83.06 plus or minus 11.02 mmHg against 81.28 plus or minus 10.67 mmHg; t equal to 2.32, p equal to 0.021). Participants with a body mass index of 25 kg/m2 or above had substantially higher mean systolic and diastolic pressures than those below this threshold (135.18 plus or minus 18.36 mmHg against 125.95 plus or minus 16.61 mmHg, t equal to 6.85, p less than 0.001; and 86.42 plus or minus 11.13 mmHg against 80.58 plus or minus 10.29 mmHg, t equal to 6.97, p less than 0.001). Current tobacco users also had higher mean systolic blood pressure than non-users (131.64 plus or minus 18.21 mmHg against 126.76 plus or minus 17.02 mmHg; t equal to 3.72, p less than 0.001).

The results of the multivariable binary logistic regression are presented in Table 6. After simultaneous adjustment, age of 45 years and above retained the strongest independent association with hypertension (adjusted odds ratio 3.02, 95 percent confidence interval 2.10 to 4.34, p less than 0.001), followed by body mass index of 25 kg/m2 or above (adjusted odds ratio 2.38, 95 percent confidence interval 1.62 to 3.50, p less than 0.001), known diabetes mellitus (adjusted odds ratio 2.24, 95 percent confidence interval 1.32 to 3.80, p equal to 0.003), family history of hypertension (adjusted odds ratio 2.11, 95 percent confidence interval 1.44 to 3.09, p less than 0.001), central obesity (adjusted odds ratio 1.86, 95 percent confidence interval 1.28 to 2.71, p equal to 0.001), physical inactivity (adjusted odds ratio 1.71, 95 percent confidence interval 1.20 to 2.44, p equal to 0.003), current tobacco use (adjusted odds ratio 1.64, 95 percent confidence interval 1.13 to 2.38, p equal to 0.009) and habitual addition of extra salt (adjusted odds ratio 1.58, 95 percent confidence interval 1.10 to 2.27, p equal to 0.013). Male sex, education level, socioeconomic class and current alcohol use lost statistical significance after adjustment, with adjusted odds ratios of 1.21 (p equal to 0.336), 1.28 (p equal to 0.196), 1.09 (p equal to 0.638) and 1.42 (p equal to 0.114) respectively. The model demonstrated adequate fit on the Hosmer Lemeshow test (chi-square equal to 6.42, degrees of freedom 8, p equal to 0.600), explained 28.6 percent of the variance by the Nagelkerke R square statistic and correctly classified 74.6 percent of cases, and no variance inflation factor exceeded 1.9.

With regard to the care cascade, of the 243 participants identified as hypertensive, 93 (38.3 percent) were aware of their diagnosis before the survey, 71 (29.2 percent) were currently receiving antihypertensive pharmacotherapy and 27 (11.1 percent) had blood pressure controlled below 140/90 mmHg. Among those on treatment, control was achieved in 27 of 71 participants (38.0 percent). Awareness was significantly higher among women than among men (46.6 percent against 30.7 percent; chi-square equal to 6.34, p equal to 0.012) and among participants aged 45 years and above compared with younger participants (44.9 percent against 26.2 percent; chi-square equal to 7.52, p equal to 0.006).

Table 1: Sociodemographic profile of the study population (n = 800)

Variable	Category	Frequency (n)	Percentage (%)
Age group (years)	18 to 29	176	22.0
	30 to 39	192	24.0
	40 to 49	168	21.0
	50 to 59	136	17.0
	60 and above	128	16.0
Sex	Male	386	48.3
	Female	414	51.7
Education	Illiterate	168	21.0

	Primary	214	26.8
	Secondary	268	33.5
	Higher secondary and above	150	18.7
Occupation	Agriculture or agricultural labour	322	40.3
	Homemaker	246	30.7
	Skilled or semi-skilled worker	122	15.3
	Service or business	68	8.5
	Unemployed or retired	42	5.2
Socioeconomic class (modified B G Prasad)	Class I (upper)	46	5.8
	Class II (upper middle)	118	14.7
	Class III (middle)	204	25.5
	Class IV (lower middle)	264	33.0
	Class V (lower)	168	21.0
Type of family	Nuclear	438	54.8
	Joint or three generation	362	45.2

Percentages are rounded to one decimal place and may not total exactly 100.

Table 2: Distribution of study participants by blood pressure category (n = 800)

Blood pressure category	Criterion (mmHg)	Frequency (n)	Percentage (%)	95% CI
Normal	SBP < 120 and DBP < 80	217	27.1	24.1 to 30.3
Prehypertension	SBP 120 to 139 or DBP 80 to 89	340	42.5	39.1 to 46.0
Stage 1 hypertension	SBP 140 to 159 or DBP 90 to 99	168	21.0	18.3 to 23.9
Stage 2 hypertension	SBP >= 160 or DBP >= 100	75	9.4	7.5 to 11.6
Hypertension (overall)	Stage 1 + Stage 2 + on treatment	243	30.4	27.2 to 33.6

SBP: systolic blood pressure; DBP: diastolic blood pressure; CI: confidence interval. Blood pressure categories follow JNC 7 criteria.

Table 3: Prevalence of hypertension by age group and sex (n = 800)

Age group (years)	Total (n)	Male hypertensive n/N (%)	Female hypertensive n/N (%)	Total hypertensive n (%)	95% CI
18 to 29	176	11/82 (13.4)	9/94 (9.6)	20 (11.4)	7.5 to 16.9
30 to 39	192	22/90 (24.4)	18/102 (17.6)	40 (20.8)	15.7 to 27.1
40 to 49	168	28/82 (34.1)	24/86 (27.9)	52 (31.0)	24.5 to 38.3
50 to 59	136	31/68 (45.6)	28/68 (41.2)	59 (43.4)	35.3 to 51.8
60 and above	128	35/64 (54.7)	37/64 (57.8)	72 (56.3)	47.6 to 64.6
Total	800	127/386 (32.9)	116/414 (28.0)	243 (30.4)	27.2 to 33.6

Chi-square for linear trend across age groups = 118.42, df = 1, p < 0.001. Male versus female comparison: chi-square = 2.25, df = 1, p = 0.134.

Table 4: Univariate association of sociodemographic, behavioural and anthropometric factors with hypertension (n = 800)

Factor	Total (n)	Hypertensive n (%)	Crude OR (95% CI)	Chi-square	p value
Age >= 45 years	344	158 (45.9)	3.71 (2.69 to 5.11)	70.14	< 0.001
Age < 45 years	456	85 (18.6)	Reference		
Male sex	386	127 (32.9)	1.26 (0.93 to 1.71)	2.25	0.134
Female sex	414	116 (28.0)	Reference		
Education <= primary	382	143 (37.4)	1.90 (1.39 to 2.59)	16.98	< 0.001
Education > primary	418	100 (23.9)	Reference		
SES class IV or V	432	138 (31.9)	1.18 (0.87 to 1.59)	1.07	0.302
SES class I to III	368	105 (28.5)	Reference		
BMI >= 25 kg/m2	214	108 (50.5)	3.41 (2.44 to 4.75)	58.72	< 0.001
BMI < 25 kg/m2	586	135 (23.0)	Reference		

Central obesity present	286	129 (45.1)	2.88 (2.11 to 3.93)	45.31	< 0.001
Central obesity absent	514	114 (22.2)	Reference		
Current tobacco use	272	108 (39.7)	1.92 (1.41 to 2.62)	17.44	< 0.001
No tobacco use	528	135 (25.6)	Reference		
Current alcohol use	146	62 (42.5)	1.93 (1.34 to 2.79)	12.36	< 0.001
No alcohol use	654	181 (27.7)	Reference		
Physically inactive	318	128 (40.3)	2.15 (1.58 to 2.92)	24.16	< 0.001
Physically active	482	115 (23.9)	Reference		
Extra salt at table	254	104 (40.9)	2.03 (1.48 to 2.78)	19.62	< 0.001
No extra salt	546	139 (25.5)	Reference		
Family history present	196	92 (46.9)	2.65 (1.90 to 3.70)	34.05	< 0.001
Family history absent	604	151 (25.0)	Reference		
Diabetes mellitus present	78	42 (53.8)	3.02 (1.89 to 4.83)	22.47	< 0.001
Diabetes mellitus absent	722	201 (27.8)	Reference		

OR: odds ratio; CI: confidence interval; SES: socioeconomic status; BMI: body mass index. Central obesity defined as waist circumference >= 90 cm in men and >= 80 cm in women.

Table 5: Mean systolic and diastolic blood pressure across selected strata (n = 800)

Stratum	n	Mean SBP (mmHg) +/- SD	Mean DBP (mmHg) +/- SD	Test statistic, p value
Age 18 to 29 years	176	119.62 +/- 13.24	76.48 +/- 9.12	F = 64.21, p < 0.001
Age 30 to 39 years	192	125.11 +/- 15.03	80.32 +/- 9.87	
Age 40 to 49 years	168	129.84 +/- 16.42	83.16 +/- 10.24	
Age 50 to 59 years	136	135.42 +/- 17.88	85.71 +/- 11.06	
Age 60 years and above	128	141.24 +/- 19.08	87.94 +/- 11.63	
Male	386	129.81 +/- 17.92	83.06 +/- 11.02	t = 2.16, p = 0.031 (SBP)
Female	414	127.13 +/- 17.24	81.28 +/- 10.67	t = 2.32, p = 0.021 (DBP)
BMI >= 25 kg/m2	214	135.18 +/- 18.36	86.42 +/- 11.13	t = 6.85, p < 0.001 (SBP)
BMI < 25 kg/m2	586	125.95 +/- 16.61	80.58 +/- 10.29	t = 6.97, p < 0.001 (DBP)
Current tobacco user	272	131.64 +/- 18.21	84.11 +/- 11.28	t = 3.72, p < 0.001 (SBP)
Non-user of tobacco	528	126.76 +/- 17.02	81.12 +/- 10.48	t = 3.76, p < 0.001 (DBP)
Whole cohort	800	128.42 +/- 17.63	82.14 +/- 10.87	

SBP: systolic blood pressure; DBP: diastolic blood pressure; SD: standard deviation; BMI: body mass index. Age group comparison by one-way analysis of variance; all other comparisons by independent samples t test.

Table 6: Multivariable binary logistic regression analysis of factors independently associated with hypertension (n = 800)

Variable	Beta coefficient	Adjusted OR (95% CI)	Wald statistic	p value
Age >= 45 years	1.106	3.02 (2.10 to 4.34)	35.62	< 0.001
Male sex	0.191	1.21 (0.82 to 1.79)	0.93	0.336
Education <= primary	0.247	1.28 (0.88 to 1.86)	1.67	0.196
SES class IV or V	0.086	1.09 (0.76 to 1.56)	0.22	0.638
BMI >= 25 kg/m2	0.867	2.38 (1.62 to 3.50)	19.48	< 0.001
Central obesity	0.621	1.86 (1.28 to 2.71)	10.62	0.001
Current tobacco use	0.495	1.64 (1.13 to 2.38)	6.83	0.009
Current alcohol use	0.351	1.42 (0.92 to 2.19)	2.50	0.114
Physical inactivity	0.536	1.71 (1.20 to 2.44)	8.86	0.003
Extra salt at table	0.457	1.58 (1.10 to 2.27)	6.14	0.013
Family history of hypertension	0.747	2.11 (1.44 to 3.09)	14.62	< 0.001
Diabetes mellitus	0.806	2.24 (1.32 to 3.80)	8.94	0.003
Constant	-2.914	0.054	128.41	< 0.001

OR: odds ratio; CI: confidence interval; SES: socioeconomic status; BMI: body mass index. Model fit: Hosmer Lemeshow chi-square = 6.42, df = 8, p = 0.600; Nagelkerke R square = 0.286; overall correct classification = 74.6 percent; maximum variance inflation factor = 1.87.

DISCUSSION

The present community-based survey found that 30.4 percent of rural adults aged 18 years and above were hypertensive, that nearly three fifths of these individuals were unaware of their condition until the survey, and that only about one in nine achieved blood pressure control. Advancing age, generalised and central adiposity, physical inactivity, tobacco use, habitual addition of extra salt, family history of hypertension and coexistent diabetes mellitus were independently associated with the condition. Taken together, these findings place the study community firmly within the pattern of advanced epidemiological transition now described across rural India.

The observed prevalence is closely comparable with the pooled rural estimate of 27.6 percent reported in the largest Indian meta-analysis and lies within the range described by contemporary rural surveys, although it exceeds several older estimates.[5] A community-based study of 1005 adults in rural Delhi using the World Health Organization STEPS approach reported a broadly similar burden and identified age, obesity and dysglycaemia as principal correlates, which corresponds closely with the determinant profile observed here [11]. By contrast, an earlier survey of 924 adults aged 30 years and above in a rural community of central India documented a considerably lower prevalence of 19.04 percent, with a female preponderance of 23.4 percent against 14.4 percent in men [12]. Similarly, work from rural Himachal Pradesh reported lower figures with correspondingly poor awareness and control [13]. The discrepancy is most plausibly explained by a genuine secular increase over the intervening decade in conjunction with methodological differences, since the lower estimates derive from surveys conducted in populations with lower mean body mass index and more physically demanding agricultural work patterns, and in some instances from single visit measurement in cohorts restricted to narrower age bands.

Estimates from other rural Indian settings occupy a similar range. A prospective door-to-door study in a rural Indian community documented prevalence and risk factor patterns comparable with the present findings, with obesity and age emerging as the dominant correlates [14]. A survey in rural Maharashtra reported a period prevalence broadly consistent with our own and likewise found a marked age gradient [15]. The large survey of 10 463 adults across eleven Tamil Nadu villages reported a lower prevalence of 21.4 percent, but the population studied was restricted to those aged 25 to 64 years and therefore excluded the elderly stratum in whom prevalence in our cohort exceeded 56 percent, which would be expected to lower the crude estimate substantially [7]. That study nevertheless reported that 74.9 percent of hypertensive participants were newly detected, a figure remarkably close to the 61.7 percent observed here and one that underlines the persistence of a large undiagnosed reservoir in rural India despite the intervening expansion of screening services.

The independent association of adiposity with hypertension observed in this study, with adjusted odds ratios of 2.38 for a body mass index of 25 kg/m2 or above and 1.86 for central obesity, is consistent with the wider Indian literature. A community-based cohort study from rural Kerala identified overweight and central obesity as leading predictors of incident hypertension, indicating that the relationship observed in cross-sectional data reflects a genuine temporal sequence rather than reverse causation [16]. Analyses of sociodemographic patterning of non-communicable disease risk factors in rural India have similarly shown that increasing body mass index and reduced occupational physical activity accompany rising socioeconomic position in villages, which explains why the crude association of low socioeconomic class with hypertension in our data was weak and lost significance entirely after adjustment [17]. This contrasts with the pattern seen in urban India, where hypertension is increasingly concentrated in lower socioeconomic strata, and the divergence indicates that the social gradient of hypertension in India is still in the process of inverting and differs by place of residence.

The finding that male sex was associated with hypertension on univariate analysis but not after adjustment merits comment. National data from more than 1.3 million adults have shown higher crude prevalence in men in most Indian states, and the attenuation observed in the present analysis is attributable to the concentration of tobacco use, alcohol consumption and physical activity differentials among men, which mediated much of the apparent sex effect [18]. The independent association of current tobacco use with hypertension in our data, with an adjusted odds ratio of 1.64, is concordant with analysis of the fifth National Family Health Survey, which demonstrated a significant association between smoking and hypertension among Indian men after adjustment for confounders [19]. It should be noted, however, that the acute pressor effect of nicotine and the chronic association of tobacco with hypertension are not identical phenomena, and some Indian surveys have reported null or inverse associations, most often where smokeless tobacco predominates and where residual confounding by body mass index has not been fully addressed.

The association between habitual addition of extra salt and hypertension, with an adjusted odds ratio of 1.58, is biologically coherent and consistent with community data from rural India relating discretionary salt use to blood pressure [20]. This variable is nonetheless a crude proxy, since it captures only discretionary salt added at the table and not total dietary sodium, the greater part of which in rural Indian diets derives from salt used in cooking and from preserved foods. The magnitude of association reported here should therefore be regarded as an underestimate of the true sodium effect, and 24 hour urinary sodium estimation would be required for accurate quantification.

The care cascade documented in this study, with awareness of 38.3 percent, treatment of 29.2

percent and control of 11.1 percent, closely mirrors the pooled rural Indian figures of 25.3 percent, 25.1 percent and 10.7 percent respectively and remains far short of national targets [5]. The nationally representative analysis of individuals aged 15 to 49 years found progressive attrition at each step of the cascade, with rural residence, male sex and lower household wealth predicting loss at every stage, and the pattern observed in the present cohort, in which awareness was significantly lower in men and in younger adults, reproduces this finding at the community level [8]. The Great India Blood Pressure Survey, a large multicentre screening exercise, similarly reported that a substantial fraction of participants were unaware of elevated blood pressure at the time of screening [21]. Analyses of older Indian adults have further shown that awareness and treatment improve with age but that control remains poor even among those in regular contact with health services, indicating that the principal deficiency lies not only in detection but in the continuity and intensity of treatment thereafter [22]. The findings of this study therefore support a shift in emphasis from episodic screening camps towards sustained follow-up, single pill regimens and structured drug supply at the sub-centre and health and wellness centre level, in line with the approach adopted by the India Hypertension Control Initiative and with current global recommendations on pharmacological management [23, 24].

Several limitations warrant acknowledgement. First, the cross-sectional design permits identification of associations but does not establish temporality, and the direction of the relationship between physical inactivity and hypertension in particular may be bidirectional. Second, behavioural exposures including tobacco use, alcohol consumption, physical activity and salt intake were self-reported and are therefore subject to recall and social desirability bias, the latter likely to have produced underreporting of alcohol use among women. Third, biochemical assessment was limited to capillary blood glucose, and lipid profile, serum creatinine and urinary sodium were not estimated, precluding evaluation of dyslipidaemia, renal function and objective sodium intake as covariates. Fourth, although a confirmatory second visit was incorporated, blood pressure was measured on two occasions only, whereas ambulatory or home monitoring would have permitted more precise classification and identification of white coat and masked hypertension. Fifth, the study was conducted in a single field practice area and the findings, while internally valid, are generalisable principally to rural populations of comparable demographic and agricultural profile. Offsetting these limitations are several strengths, namely the community-based cluster design with high response rate, the use of a standardised international instrument, triplicate measurement with a validated automated device, the incorporation of a repeat confirmatory visit and the use of multivariable modelling to distinguish independent determinants from confounded associations.

The prevalence documented here also carries direct programmatic implications for the primary health centre serving the study area. Applying the observed prevalence to the adult population of the catchment area indicates a substantial expected case load, of which the greater part is presently undetected and therefore invisible to the health system. The strong independent contribution of modifiable factors, particularly adiposity, inactivity, tobacco use and discretionary salt, indicates that a considerable proportion of this burden is amenable to intervention through community-level measures that do not require specialist infrastructure, and national reporting of hypertension prevalence and its determinants supports the prioritisation of exactly these targets in rural settings [25].

CONCLUSION

Nearly one in three adults in this rural community was hypertensive, and the burden rose steeply with age to affect more than half of those aged 60 years and above. The majority of hypertensive individuals were identified for the first time during the survey, fewer than one third were receiving treatment and barely one in nine had adequately controlled blood pressure, indicating substantial attrition at every step of the local care cascade. Advancing age, generalised obesity, central obesity, family history of hypertension, diabetes mellitus, physical inactivity, current tobacco use and habitual addition of extra salt were independently associated with hypertension, and the predominance of modifiable factors among these determinants is the most actionable finding of the study.

These results indicate that rural populations can no longer be regarded as being at lower risk of hypertension than their urban counterparts, and that the assumption underlying the historical concentration of non-communicable disease services in urban areas requires revision. Systematic opportunistic screening of all adults attending the primary health centre and its sub-centres, combined with structured community-level counselling on weight reduction, physical activity, tobacco cessation and salt restriction, and supported by an uninterrupted supply of first line antihypertensive medication with defined follow-up intervals, would be expected to yield measurable improvement in detection and control. Longitudinal studies incorporating objective measurement of sodium intake and prospective follow-up are recommended to quantify incidence and to evaluate the effectiveness of such interventions in this setting.

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