Caste Disparities in Awareness of Hypertension and Uncontrolled Blood Pressure in India

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Abstract

Hypertension caused most of the brain strokes worldwide. No symptoms at early stages causes unawareness about the disease status. Indian population has a wide variation due to caste system. The minority castes lagged behind in terms of education, wealth and health status - which might have an impact on their awareness about hypertension. To answer this, the current study focuses on the caste disparities in awareness of hypertension and uncontrolled blood pressure (BP) even after being on medication. The study uses the first wave of the Longitudinal Aging Study in India (2017-18) and the fifth wave of National Family Health Survey (2019-21). The awareness of hypertension is defined as (i) self-reporting hypertension while having the disease and (ii) not having hypertension while self-reporting as not having the disease. Trivariate probit model with selection is used for assessing the caste disparities in awareness of hypertension and uncontrolled BP even after being on medication. An extension of Blinder Oaxaca decomposition is used for identifying the driving factors determining the caste disparities in awareness. The minority castes have less awareness. Scheduled tribes have uncontrolled BP even after medication. Education, smoking, alcohol consumption are some driving factors of the caste disparities in awareness.

Keywords: hypertension; disease awareness; trivariate probit with selection; India

1 Introduction

India is currently undergoing a significant epidemiological transition with the shift in the leading causes of death from communicable diseases (CDs) to non-communicable diseases (NCDs). This transition is clearly observed in the country's changing health landscape, with more than 60 percent of total deaths in India attributed to NCDs, particularly cardiovascular diseases (CVDs) and stroke (Mohan et al. 2013; Sathe and Bapat 2013). Also, a 18 year surveillance study from rural communities in northern India shows the decline in deaths due to diarrhoea and increase in deaths due to CVDs over time (Kumar et al. 2012). Hypertension is a significant contributor of stroke. It alone caused more than half of the brain stroke cases (Lin et al. 2022). The prevalence of hypertension in India has been increasing over the past two decades, with recent national estimates indicating rates of up to 30 percent (Gupta et al. 2019; Longkumer et al. 2023). This increase in the prevalence of hypertension aligns with the trends observed in lower-middle-income countries, where over 1 billion

individuals were hypertensive by 2019, representing 82 percent of the global population affected by the condition (Longkumer et al. 2023). An individual with either systolic or diastolic blood pressure (BP) of 140 mm Hg or above and 90 mm Hg or above respectively is said to have uncontrolled BP.

An individual having uncontrolled BP or taking medicines for controlling BP is said to have hypertension. Although there are some symptoms of hypertension in the later stages of the disease (usually with a systolic BP of 180 or more mm Hg or a diastolic BP of 120 or more mm Hg, or higher) such as severe headache, chest pain, dizziness, difficulty in breathing, nausea, vomiting, blurred vision, anxiety, confusion, buzzing in the ears, nosebleeds, abnormal heart rhythm (WHO), there are no symptoms of hypertension in its early stage. Therefore most of the individuals with uncontrolled BP are likely to be unaware of their actual disease status. Unawareness about the status of one's own hypertension leads to an increase in the risk of further outcomes such as stroke or CVD among the individuals as BP goes on increasing without any diagnosis and treatment. Regular check-ups of BP are essential to control and manage hypertension and eventually reduce the risk of its consequent outcomes.

In the large-scale surveys, hypertension is typically measured using both subjective and objective techniques (Whelton 2018). Subjective measures largely involve self-reported data, where individuals are asked about their history of diagnosis with hypertension, their understanding of the condition, and their management strategies, such as lifestyle adjustments or medication (Nwankwo et al. 2013). These measures provide valuable insights into an individual's health status, but they can be influenced by recall bias and may not accurately reflect the true prevalence of hypertension (Pm 2005). On the other hand, objective measures involve clinical assessments, such as the use of sphygmomanometers or automated BP monitors, to directly measure an individual's BP levels (O'brien et al. 2001). Biomarkers, or biological indicators of disease provide more accurate and reliable data on the presence and severity of hypertension (Pickering et al. 2005). However, they require more resources, such as trained personnel and equipment, and may not be feasible in all settings (Mancia et al. 2013). Together, subjective and objective measures provide a comprehensive picture of hypertension prevalence and awareness, informing strategies for prevention and control (Chow et al. 2013).

The awareness of hypertension, in this context, means that a person is aware that he/she has hypertension or does not have hypertension. It can be defined in the following two ways. A person self-reports as having hypertension given that he/she actually has the disease according to the BP level (standard definition); or a person is found to be not having the disease according to the BP level given that he/she self-reporting as not having the disease (alternative definition) (Chatterji et al. 2012). Note that the standard definition of awareness can be related to the sensitivity of self-reporting of hypertension and the alternative definition of awareness can be related to the positive predictive value of self-reporting of hypertension. Consequently, unawareness can be related to the probability of false negatives according to the standard definition and can be related to (1-positive predictive value) according to the alternative definition.

Prior to any intervention one needs to know the level of awareness and the severity of the disease in people coming from different background characteristics. The caste system in India has existed since the ancient times. The present caste system in India consists of four broad caste groups. These are scheduled caste (SC), scheduled tribe (ST), other backward caste (OBC) and general. The general caste essentially consists of those people who do not belong to SC, ST and OBC. Different caste groups consists of people from totally different backgrounds. The SC people were ignored to some extent in the society in earlier days. Whereas the ST people used to live far away from the others, in

jungles and mountains. Many of the ST people currently continue the same lifestyle as earlier days. The OBC group consists of the "Sudra" people of earlier times, who used to be involved in the job of cleaning. The OBC also includes the ignored people in the society who converted from Hinduism to some other religion (Nagaraj 2017). The inequalities among ethnic groups are seen in several fields including health and socio-economic status. A narrative review study mentioned that due to the limited access in preventive care, the minority ethnic groups face higher risk of CVD. Earlier study shows that in India at least one third of the income difference between the minority castes and the others is due to the unequal treatment in terms of believing the the minority people to be inferior. Consequently the minority caste groups lagged in terms of education, health and other factors (Borooah 2005). Analysis using the fifth round of the National Family Health Survey (2019-21) shows that the minority castes have significantly higher mortality and fertility levels. Additionally, most of them belong to the lowest two wealth quintiles, poorer and poorest. As the minority caste groups lag behind the others, there is a possibility of caste disparities in several factors including the awareness of the status of hypertension. In addition to awareness, there might be between caste differences in the biomarkers, which is in this case the BP level.

The current study focuses on the caste disparities in the awareness of hypertension status. In the presence of different levels of awareness across the caste groups, there should be different levels of intervention for making the individuals aware of their actual disease status and its consequences. Therefore studying the gap in awareness between caste groups gives an idea about the appropriate level of intervention. There is higher need of intervention within a caste group with lower awareness about the status of hypertension and vice versa. In addition to this, the current study focuses on the caste disparities in the uncontrolled BP even after being on medication for controlling BP. Further, it identifies some driving factors which determine the caste disparities in the awareness of hypertension status.

2 Methods

2.1 Data

This study used the first wave of the Longitudinal Aging Study in India (LASI) data, which is a nationally representative data consisting of over 72,000 individuals, including their spouses, across all states and union territories in India. This data provides a comprehensive resource for understanding the health, economic, and social determinants and consequences of population ageing in India. The collection of data took place in 2017-18. The data encompasses extensive information on health, including conditions such as hypertension, diabetes, heart disease, and other chronic conditions. In addition to subjective measures, it also includes objective measures of health such as biomarkers. In addition, it provides details on family and social networks, income, consumption, and wealth data.

2.2 Variables

The primary outcome variables for measuring the awareness of an individual's hypertension status are self-reported hypertension, the actual status of hypertension determined by the information of biomarker and medication, and giving consent for collecting the biomarker data from the individuals. The biomarker consists of systolic and diastolic BP. The participants were asked whether they agree to participate in a medical examination (conducted as a part of data collection) for measuring BP. Giving consent for participating in the medical examinations is used for sample selection, which is discussed in detail in the statistical analysis section. The variables indicating self-reporting, giving

consent and whether on any medication are dichotomous. The biomarkers obtained from the medical examination include systolic and diastolic BP, which are continuous variables. The dichotomous variable for uncontrolled BP is created from the biomarker data by indicating a BP level of 140/90 mm-Hg or higher as uncontrolled and otherwise controlled. The presence of either uncontrolled BP or medication is categorized as the presence of hypertension. Caste is used as the main independent variable, which has four categories, SC, ST, OBC and general. The other independent variables include certain background characteristics such as age, gender, education, employment, marital status, health practices such as physical activity, and smoking, drinking alcohol and health status including self reported overall health status and history of being diagnosed with specific chronic diseases other than hypertension.

2.3 Statistical Analysis

To study whether the minority castes still lag behind, the socio-economic characteristics, mortality and fertility levels of SC, ST and OBC are compared with general caste using the two proportion Z test for large samples. The household characteristics under study are (i) having a separate kitchen, (ii) improved sanitation which consists of flush or pour toilet, pit latrine, compositing toilet - which is not shared with any other household, (iii) improved source of drinking water which consists of piped water, public taps, standpipes, tube well or bore well, dug well, spring water and rain water, (iii) clean fuel for cooking which consists of liquefied petroleum gas, biogas, kerosene and electricity, and (iv) concrete house.

2.3.1 Studying the Disparities in Awareness

Studying the awareness of one's own hypertension status consists of two groups of people who self report either as having hypertension or as not having hypertension. Among them, some agree to participate in the medical examination for checking BP and the others do not agree. The BP of the individuals participating in the medical examination are classified into the following two categories: (i) uncontrolled: $\geq 140/90$, and (ii) controlled: $< 140/90$. People who have either uncontrolled BP or are on medication for controlling BP, or both, are said to have hypertension. Defining the three dichotomous variables associated with one's awareness about his/her own hypertension status as follows, (i) self-report disease denoted as h_1 (1=yes, 0=no), (ii) giving consent for the medical examination denoted as h_2 (1=yes, 0=no), and (iii) actually has the disease denoted as h_3 (1=yes, 0=no). Note that the biomarker data are available for a self-selected sub-sample, based on the individuals' decision on participating in the medical examination. The decision of not participating in the medical examination may or may not be random.

Scenario 1: Model without Sample Selection To study the factors associated with the individuals' awareness of their own status of hypertension, one may model awareness with caste and the other characteristics using a univariate probit model with awareness as the outcome, caste as the primary independent variable, adjusted for the other factors, with the restricted sample, without considering the three associated binary outcomes discussed above. This analysis is appropriate only if giving consent for the medical examination is random, so that the persons not giving consent for the medical examination are not distinguishable from the participants giving consent for the medical examination.

Scenario 2: Model with Sample Selection Giving consent for the medical examination may depend on certain characteristics of the individual. In that case the sub-sample having the biomarker

data becomes self-selected, which is no longer random. It is thus incorrect to use a univariate probit model of awareness on caste and other factors because the results might have been different if the biomarkers of the persons who refused to participate in the medical examination were available. In this scenario the three outcomes, i.e. self-report, consent and disease, are modelled using a trivariate probit model on caste and the other factors. Further, from the trivariate probit model one obtains the estimates of disparities in the awareness of the respondent's state of hypertension primarily by caste, according to the standard and the alternative definitions of awareness. The method is discussed below. Let A be an event denoting that an individual self-reports as having hypertension, agrees to participate in the medical examination and actually has the disease. Let B_1 be an event denoting that an individual self-reports has having hypertension, agrees to participate in the medical examination and actually does not have the disease. Let B_2 be an event denoting that an individual self-reports as not having hypertension, agrees to participate in the medical examination and actually does not have the disease. Let C be an event denoting that an individual self-reports as not having hypertension, agrees to participate in the medical examination and actually has the disease. Let D be an event denoting that an individual self-reports as having hypertension and does not agree to participate in the medical examination. Let E be an event denoting that an individual self-reports as not having hypertension and does not agree to participate in the medical examination. Figure 1 represents the events discussed above.

The objective is to obtain the following quantities

$$P(\text{Awareness by standard definition}) = P(\text{self-report} = \text{Yes} | \text{consent} = \text{Yes}, \text{disease} = \text{Yes}) \quad (1)$$

$$P(\text{Awareness by alternative definition}) = P(\text{disease} = \text{No} | \text{consent} = \text{Yes}, \text{self-report} = \text{No}) \quad (2)$$

The probabilities of occurrence of the above events in terms of the observed variables h_1, h_2 and h_3 are shown in equation (3).

$$\begin{aligned} P(A) &= P(h_1 = 1, h_2 = 1, h_3 = 1) \\ P(B_1) &= P(h_1 = 1, h_2 = 1, h_3 = 0) \\ P(B_2) &= P(h_1 = 0, h_2 = 1, h_3 = 0) \\ P(C) &= P(h_1 = 0, h_2 = 1, h_3 = 1) \\ P(D) &= P(h_1 = 1, h_2 = 0) \\ P(E) &= P(h_1 = 0, h_2 = 0) \end{aligned} \quad (3)$$

Consider the latent variables ${h_i}^*; i = 1, 2, 3$ such that

$$h_i = \begin{cases} 1, & \text{if } {h_i}^* \geq 0. \\ 0, & \text{otherwise.} \end{cases}$$

Thus from (3) we have

$$\begin{aligned} P(A) &= P({h_1}^* \geq 0, {h_2}^* \geq 0, {h_3}^* \geq 0) \\ P(B_1) &= P({h_1}^* \geq 0, {h_2}^* \geq 0, {h_3}^* < 0) \\ P(B_2) &= P({h_1}^* < 0, {h_2}^* \geq 0, {h_3}^* < 0) \\ P(C) &= P({h_1}^* < 0, {h_2}^* \geq 0, {h_3}^* \geq 0) \\ P(D) &= P({h_1}^* \geq 0, {h_2}^* < 0) \\ P(E) &= P({h_1}^* < 0, {h_2}^* < 0) \end{aligned} \quad (4)$$

The three equations corresponding to ${h_{ij}}^*$ for individual j and $i = 1, 2, 3$ can be written as follows.

$$ {h_{ij}}^* = {\beta_i}' x_{ij} + \varepsilon_{ij} \tag{5} $$

where ε_{ij} consists of the error terms associated with the equation of ${h_i}^*$ and the individual j, $\forall i$. It is assumed that the error terms $\sim$ trivariate normal distribution with mean $\mathbf{0}$ and correlation matrix $\Omega_3 = \begin{bmatrix} 1 & & \\ \rho_{21} & 1 & \\ \rho_{31} & \rho_{32} & 1 \end{bmatrix}$
The model considers endogeneity if the non-diagonal elements are non-zero. Otherwise, if $\Omega = I$, endogeneity is not considered. Eventually, ${h_i}^* \sim N(0, {\sigma_i}^2)$ independently $\forall i = 1, 2, 3$.

Using equation (5), the probabilities in (4) can be written as follows.

$$ \begin{aligned} P(A) &= P({h_1}^* \geq 0, {h_2}^* \geq 0, {h_3}^* \geq 0) = \Phi_3({h_1}^*, {h_2}^*, {h_3}^*, \Omega_3) = \Phi_3(\beta_1 x_{1j}, \beta_2 x_{2j}, \beta_3 x_{3j}, \Omega_3) \\ P(B_1) &= P({h_1}^* \geq 0, {h_2}^* \geq 0, {h_3}^* < 0) = \Phi_3({h_1}^*, {h_2}^*, -{h_3}^*, \Omega_3) = \Phi_3(\beta_1 x_{1j}, \beta_2 x_{2j}, -\beta_3 x_{3j}, \Omega_3) \\ P(B_2) &= P({h_1}^* < 0, {h_2}^* \geq 0, {h_3}^* < 0) = \Phi_3(-{h_1}^*, {h_2}^*, -{h_3}^*, \Omega_3) = \Phi_3(-\beta_1 x_{1j}, \beta_2 x_{2j}, -\beta_3 x_{3j}, \Omega_3) \\ P(C) &= P({h_1}^* < 0, {h_2}^* \geq 0, {h_3}^* > 0) = \Phi_3(-{h_1}^*, {h_2}^*, {h_3}^*, \Omega_3) = \Phi_3(-\beta_1 x_{1j}, \beta_2 x_{2j}, \beta_3 x_{3j}, \Omega_3) \\ P(D) &= P({h_1}^* < 0, {h_2}^* < 0) = \Phi_2({h_1}^*, -{h_2}^*, \Omega_{21}) = \Phi_2(\beta_1 x_{1j}, -\beta_2 x_{2j}, \Omega_{21}) \\ P(E) &= P({h_1}^* < 0, {h_2}^* < 0) = \Phi_2(-{h_1}^*, -{h_2}^*, \Omega_{21}) = \Phi_2(-\beta_1 x_{1j}, -\beta_2 x_{2j}, \Omega_{21}) \end{aligned} \tag{6} $$

where Ω_{21} is the 2×2 submatrix of Ω_3 involving ρ_{21}.

The log likelihood function, which is evaluated using the probabilities simulated by the GHK Monte Carlo simulator (Cappellari and Jenkins 2003), is given by

$$ \begin{aligned} L = &\sum_{j \in A} \ln P({h_1}^* \geq 0, {h_2}^* \geq 0, {h_3}^* \geq 0) \\ &+ \sum_{j \in B_1} \ln P({h_1}^* \geq 0, {h_2}^* \geq 0, {h_3}^* < 0) \\ &+ \sum_{j \in B_2} \ln P({h_1}^* < 0, {h_2}^* \geq 0, {h_3}^* < 0) \\ &+ \sum_{j \in C} \ln P({h_1}^* < 0, {h_2}^* \geq 0, {h_3}^* \geq 0) \\ &+ \sum_{j \in D} \ln P({h_1}^* \geq 0, {h_2}^* < 0) \\ &+ \sum_{j \in E} \ln P({h_1}^* < 0, {h_2}^* < 0) \end{aligned} \tag{7} $$

In the absence of endogeneity, i.e., if the the unobserved factors associated with the three outcomes are uncorrelated, h_1, h_2 and h_3 independently follow normal distributions. The log likelihood function would be as follows.

$$
\begin{aligned}
L = & \sum_{j \in B_2 \cup C \cup E} \ln P(h_{1j}^* < 0) \\
& + \sum_{j \in A \cup B_1 \cup D} \ln P(h_{1j}^* \geq 0) \\
& + \sum_{j \in D \cup E} \ln P(h_{2j}^* < 0) \\
& + \sum_{j \in B_1 \cup B_2 \cup C \cup A} \ln P(h_{2j}^* \geq 0) \\
& + \sum_{j \in B_1 \cup B_2} \ln P(h_{3j}^* < 0) \\
& + \sum_{j \in A \cup C} \ln P(h_{3j}^* \geq 0)
\end{aligned} \tag{8}
$$

From the estimates obtained from the trivariate probit model, the probability that a person is aware of his/her own hypertension status, according to the standard definition, is given by

$$
\begin{aligned}
& P(\text{self-report=Yes}|\text{consent=Yes,disease=Yes}) \\
& = P(h_{1j} = 1 | h_{2j} = 1, h_{3j} = 1, x_{1j}, x_{2j}, x_{3j}) \\
& = \frac{P(h_{1j} = 1, h_{2j} = 1, h_{3j} = 1 | x_{1j}, x_{2j}, x_{3j})}{P(h_{2j} = 1, h_{3j} = 1 | x_{1j}, x_{2j}, x_{3j})} \\
& = \frac{\Phi_3({h_1}^*, {h_2}^*, {h_3}^*, \Omega_3)}{\Phi_2({h_2}^*, {h_3}^*, \Omega_{32})}
\end{aligned}
$$

The same using the alternative definition of awareness is given by

$$
\begin{aligned}
& P(\text{disease=No}|\text{consent=Yes,self-report=No}) \\
& = P(h_{3j} = 0 | h_{2j} = 1, h_{1j} = 0, x_{1j}, x_{2j}, x_{3j}) \\
& = \frac{P(h_{3j} = 0, h_{2j} = 1, h_{1j} = 0 | x_{1j}, x_{2j}, x_{3j})}{P(h_{2j} = 1, h_{1j} = 0 | x_{1j}, x_{2j}, x_{3j})} \\
& = \frac{\Phi_3(-{h_3}^*, {h_2}^*, -{h_1}^*, \Omega_3)}{\Phi_2({h_2}^*, -{h_1}^*, \Omega_{21})}
\end{aligned}
$$

These conditional probabilities are used for evaluating the caste disparities in awareness in terms of the marginal effect of caste on one being aware of his/her hypertension status. The average marginal effect of SC, for example, on being aware of their own status of hypertension is obtained by calculating the sample average of the quantity estimated by subtracting (i) the conditional probability of being aware after assigning all the sample members to SC and keeping all other characteristics unchanged from (ii) the conditional probability of being aware after assigning all the sample members to all other caste categories and keeping all other characteristics unchanged. The standard errors and the confidence intervals of the marginal effects are obtained using bootstrapping.

2.3.2 Caste Disparities in Uncontrolled BP

The caste disparities in uncontrolled BP even after being on medication are obtained using another trivariate probit model, with a similar setup but with different outcome variables. Let A be an event

denoting that a person who is on medication, gives consent to measure his/her BP, has uncontrolled BP. Let B_1 be an event denoting that a person who is on medication, gives consent to measure his/her BP, does not have uncontrolled BP. Let B_2 be an event denoting that a person who is not on medication, gives consent to measure his/her BP, does not have uncontrolled BP. Let C be an event denoting that a person who is not on medication, gives consent to measure his/her BP, has uncontrolled BP. Let D be an event denoting that a person who is on medication does not give consent to measure his/her BP. Let E be an event denoting that a person who is not on medication does not give consent to measure his/her BP. Let k_1 be a random variable denoting that a person is on medication for controlling BP. Let k_2 be a random variable denoting whether a person has given consent to measure his/her BP. Let k_3 be a random variable denoting that a person has uncontrolled BP. The variables $k_i; i = 1, 2, 3$ are all dichotomous, 0 indicating absence and 1 indicating presence. Let ${k_i}^*; i = 1, 2, 3$ be the latent variables such that

$$k_i = \begin{cases} 1, & \text{if } {k_i}^* \geq 0. \\ 0, & \text{otherwise.} \end{cases}$$

The objective is to obtain the following quantity

$$P(\text{uncontrolled BP given on medication}) = P(\text{uncontrolled BP} = \text{Yes}|\text{consent} = \text{Yes}, \text{medication} = \text{Yes}) \tag{9}$$

The distribution of the study sample according to the outcome variables is as follows.
The probability that a person has uncontrolled BP is given by

$$\begin{aligned} &P(\text{uncontrolled BP=Yes}|\text{consent=Yes,medication=Yes}) \\ &= P(k_{3j} = 1|k_{2j} = 1, k_{1j} = 1, x_{1j}, x_{2j}, x_{3j}) \\ &= \frac{P(k_{3j} = 1, k_{2j} = 1, k_{1j} = 1|x_{1j}, x_{2j}, x_{3j})}{P(k_{2j} = 1, k_{3j} = 1|x_{1j}, x_{2j}, x_{1j})} \\ &= \frac{\Phi_3({k_1}^*, {k_2}^*, {k_3}^*, \Omega_3)}{\Phi_2({k_1}^*, {k_2}^*, \Omega_{21})} \end{aligned}$$

The probabilities of occurrence of the above events in terms of the observed variables k_1, k_2 and k_3 are shown in equation (10).

$$\begin{aligned} P(A) &= P(k_1 = 1, k_2 = 1, k_3 = 1) \\ P(B_1) &= P(k_1 = 1, k_2 = 1, k_3 = 0) \\ P(B_2) &= P(k_1 = 0, k_2 = 1, k_3 = 0) \\ P(C) &= P(k_1 = 0, k_2 = 1, k_3 = 1) \\ P(D) &= P(k_1 = 1, k_2 = 0) \\ P(E) &= P(k_1 = 0, k_2 = 0) \end{aligned} \tag{10}$$

Consider the latent variables ${k_i}^*; i = 1, 2, 3$.

Thus from (10) we have

$$\begin{aligned} P(A) &= P({k_1}^* \geq 0, {k_2}^* \geq 0, {k_3}^* \geq 0) \\ P(B_1) &= P({k_1}^* \geq 0, {k_2}^* \geq 0, {k_3}^* < 0) \\ P(B_2) &= P({k_1}^* < 0, {k_2}^* \geq 0, {k_3}^* < 0) \\ P(C) &= P({k_1}^* < 0, {k_2}^* \geq 0, {k_3}^* \geq 0) \\ P(D) &= P({k_1}^* \geq 0, {k_2}^* < 0) \\ P(E) &= P({k_1}^* < 0, {k_2}^* < 0) \end{aligned} \tag{11}$$

The three equations corresponding to ${k_{ij}}^*$ for individual j and $i = 1, 2, 3$ can be written as follows.

$${k_{ij}}^* = {\beta_i}' x_{ij} + \varepsilon_{ij} \tag{12}$$

where ε_{ij} consists of the error terms associated with the equation of ${k_i}^*$ and the individual j, $\forall i$. It is assumed that the error terms $\sim$ trivariate normal distribution with mean $\mathbf{0}$ and correlation matrix $\Omega_3 = \begin{bmatrix} 1 & & \\ \rho_{21} & 1 & \\ \rho_{31} & \rho_{32} & 1 \end{bmatrix}$ In the presence of endogeneity, the off diagonal elements of the above matrix are non-zero.
Using equation (12), the probabilities in (11) can be written as follows.

$$\begin{aligned} P(A) &= P({k_1}^* \geq 0, {k_2}^* \geq 0, {k_3}^* \geq 0) = \Phi_3({k_1}^*, {k_2}^*, {k_3}^*, \Omega_3) = \Phi_3(\beta_1 x_{1j}, \beta_2 x_{2j}, \beta_3 x_{3j}, \Omega_3) \\ P(B_1) &= P({k_1}^* \geq 0, {k_2}^* \geq 0, {k_3}^* < 0) = \Phi_3({k_1}^*, {k_2}^*, -{k_3}^*, \Omega_3) = \Phi_3(\beta_1 x_{1j}, \beta_2 x_{2j}, -\beta_3 x_{3j}, \Omega_3) \\ P(B_2) &= P({k_1}^* < 0, {k_2}^* \geq 0, {k_3}^* < 0) = \Phi_3(-{k_1}^*, {k_2}^*, -{k_3}^*, \Omega_3) = \Phi_3(-\beta_1 x_{1j}, \beta_2 x_{2j}, -\beta_3 x_{3j}, \Omega_3) \\ P(C) &= P({k_1}^* < 0, {k_2}^* \geq 0, {k_3}^* > 0) = \Phi_3(-{h_1}^*, {h_2}^*, {h_3}^*, \Omega_3) = \Phi_3(-\beta_1 x_{1j}, \beta_2 x_{2j}, \beta_3 x_{3j}, \Omega_3) \\ P(D) &= P({k_1}^* < 0, {k_2}^* < 0) = \Phi_2({k_1}^*, -{k_2}^*, \Omega_{21}) = \Phi_2(\beta_1 x_{1j}, -\beta_2 x_{2j}, \Omega_{21}) \\ P(E) &= P({k_1}^* < 0, {k_2}^* < 0) = \Phi_2(-{k_1}^*, -{k_2}^*, \Omega_{21}) = \Phi_2(-\beta_1 x_{1j}, -\beta_2 x_{2j}, \Omega_{21}) \end{aligned} \tag{13}$$

where Ω_{21} is the 2×2 submatrix of Ω_3 involving ρ_{21}.

The log likelihood function, which is evaluated using the probabilities simulated by the GHK Monte Carlo simulator (Cappellari and Jenkins 2003), is given by

$$\begin{aligned} L = &\sum_{j \in A} \ln P({k_1}^* \geq 0, {k_2}^* \geq 0, {k_3}^* \geq 0) \\ &+ \sum_{j \in B_1} \ln P({k_1}^* \geq 0, {k_2}^* \geq 0, {k_3}^* < 0) \\ &+ \sum_{j \in B_2} \ln P({k_1}^* < 0, {k_2}^* \geq 0, {k_3}^* < 0) \\ &+ \sum_{j \in C} \ln P({k_1}^* < 0, {k_2}^* \geq 0, {k_3}^* \geq 0) \\ &+ \sum_{j \in D} \ln P({k_1}^* \geq 0, {k_2}^* < 0) \\ &+ \sum_{j \in E} \ln P({k_1}^* < 0, {k_2}^* < 0) \end{aligned} \tag{14}$$

From the estimates obtained from the trivariate probit model, the probability that a person has uncontrolled BP even after being on medication is given by

$$
\begin{aligned}
&P(\text{uncontrolled BP=Yes}|\text{consent=Yes,medication=Yes}) \\
&= P(k_{3j} = 1|k_{1j} = 1, k_{2j} = 1, x_{1j}, x_{2j}, x_{3j}) \\
&= \frac{P(k_{1j} = 1, k_{2j} = 1, k_{3j} = 1|x_{1j}, x_{2j}, x_{3j})}{P(k_{1j} = 1, k_{2j} = 1|x_{1j}, x_{2j}, x_{3j})} \\
&= \frac{\Phi_3({k_1}^*, {k_2}^*, {k_3}^*, \Omega_3)}{\Phi_2({k_1}^*, {k_2}^*, \Omega_{21})}
\end{aligned}
$$

The conditional probability defined above is used for evaluating the caste disparities in uncontrolled BP, being on medication, in terms of the marginal effect of caste on one having uncontrolled BP, given that he/she is on medication. The average marginal effect of SC, for example, is obtained by calculating the sample average of the quantity estimated by subtracting (i) the conditional probability of having uncontrolled BP after assigning all the sample members to SC and keeping all other characteristics unchanged from (ii) the conditional probability of having uncontrolled BP after assigning all the sample members to all other caste categories and keeping all other characteristics unchanged. The standard errors and the confidence intervals of the marginal effects are generated using bootstrapping.

2.4 Decomposition of Caste Disparities in Awareness of Hypertension

Along with the caste disparities, certain factors driving the caste disparities are identified using an extension of the Blinder Oaxaca decomposition (Bartus 2006).
Let Y denote a certain characteristic which is observed as a binary outcome. Let us consider two groups A and B. According to Fairlie's decomposition, the gap in the average, or the estimated value of expectation, of Y between A and B can be expressed as follows.

$$\bar{Y}_A - \bar{Y}_B = \frac{1}{N_A}\sum_{k=1}^{N_A} F(X_{Ak}b_A) - \frac{1}{N_B}\sum_{k=1}^{N_B} F(X_{Bk}b_A) + \frac{1}{N_B}\sum_{k=1}^{N_B} F(X_{Bk}b_A) - \frac{1}{N_B}\sum_{k=1}^{N_B} F(X_{Bk}b_B) \quad (15)$$

Now, for any (i, j), Taylor-series expansion of $F(X_i b_j)$ around $\bar{X}_i$ is as follows.

$$F(X_i b_j) = F(\bar{X}_i b_j) + R \quad (16)$$

where R consists of the higher order temrs.

Substituting (16) in (15) we get

$$\bar{Y}_A - \bar{Y}_B = [F(\bar{X}_A b_A) - F(\bar{X}_B b_A)] + [F(\bar{X}_B b_A) - F(\bar{X}_B b_B)] + R_1 \quad (17)$$

where R_1 consists of the higher order terms.

Using Taylor-series expansion around $\bar{X}_A b_A$ in the first term of (17) we get

$$F(\bar{X}_A b_A) - F(\bar{X}_B b_A) = f(\bar{X}_A b_A) b_A (\bar{X}_A - \bar{X}_B) + R_2 \quad (18)$$

where $f(.)$ is the probability density function and R_2 consists of the higher order terms.

The second term of (17) can be approximated by Taylor-series expansion around $\bar{x}_{Gen} b_{Gen}$ as follows.

$$F(\bar{X}_B b_A) - F(\bar{X}_B b_B) = f(\bar{X}_B b_B) \bar{X}_B (b_A - b_B) + R_3 \quad (19)$$

where R_3 consists of higher order terms.

Again, $f(\bar{X}_B b_B)\bar{X}_B$ can be approximated to $f(\bar{X}_A b_A)\bar{X}_A$ by Taylor-series expansion around $\bar{X}_A b_A$ as follows.

$$f(\bar{X}_B b_B)\bar{X}_B = f(\bar{X}_A b_A)\bar{X}_A + R_4 \tag{20}$$

Substituting (18), (19) and (20) in (17) and ignoring the higher order terms we get

$$\bar{Y}_A - \bar{Y}_B = f(\bar{X}_A b_A)\bar{X}_A b_A(\bar{X}_A - \bar{X}_B) + \bar{X}_B[f(\bar{X}_A b_A)b_A - f(\bar{X}_B b_B)b_B] \tag{21}$$

Since, for binary response variables, the marginal effect of a variable X_k is given as $b_k f(X_k)$ where $f(.)$ is the probability density function and b_k is the regression coefficient corresponding to X_k, therefore (21) can be written as follows.

$$\bar{Y}_A - \bar{Y}_B = m_A(\bar{X}_A - \bar{X}_B) + \bar{X}_B(m_A - m_B) \tag{22}$$

where m_i denotes the vector of the marginal effects within the group i.

The first term of the equation (22) is referred to as the endowment effect. It explains the change in the outcome due to the change in the characteristics across the groups, the marginal effect being constant. A positive endowment indicates the expected reduction in the gap of the outcome across the groups if both the groups had the same distribution with respect to certain characteristics. The second term represents the change in the outcome due to the difference in the marginal effects across the group, the characteristics being constant. Certain driving factors of the caste disparities in awareness about hypertension status are identified by the extension of the Blinder Oaxaca decomposition, defined in equation (22).

3 Results

Table 1 shows the percentage distribution of respondents by the background characteristics. The first column shows the distribution for all castes. The next four columns show the same for each caste separately. The characteristics of SC, ST and OBC are compared with that of general. There are significantly higher proportions of people without any formal education among ST, followed by SC and OBC compared to the general caste. Employment shows a different picture. There are higher proportions of the minority castes with employment for at least 3 months compared to the general caste. The minority castes lag behind in terms of certain household characteristics such as having a separate kitchen, having improved sanitation, using clean fuel for cooking and having pucca house. The practice of Yoga is lower among SC, ST and OBC compared to the general caste. However, ST and OBC have higher proportion of physical activity compared to the general caste. The proportion of smokers is significantly higher among SC and ST than general. Also, all the minority castes have significantly higher proportion of alcohol drinkers compared to the general caste. The occurrence of other chronic disease apart from hypertension is significantly lower among ST compared to general.

Figure 3 shows the mortality and fertility indicators for each caste in India. The SC category has significantly higher mortality compared to the general caste with crude death rate (CDR) significantly higher than that of general caste. The age specific death rates (ASDRs) of age 80-94 years of SC are significantly higher than that of general caste. The total fertility rate (TFR) is significantly higher among the minority castes compared to the general caste. Also, the age specific fertility rates (ASFRs) of age 20-29 years are significantly higher than that of general caste.

Figure 4a shows the percentage of individuals in each caste category who self-reported as having hypertension. The highest percentage is observed among the general caste, followed by OBC, SC and ST. The error bars show the 95% confidence intervals. The non-overlapping confidence intervals suggest that the percentages withing the caste groups are significantly different from each other. Also, figure 4b shows the percentage of individuals in each caste category who actually have the disease based on biomarker or on medication. Within each caste, self-report of hypertension is significantly lower than the actual disease status. The actual disease status among SC, ST and OBC is significantly lower than that among general. In contrast to self-report, there is no significant difference in the actual disease status between SC and ST.

Figure 5 shows the state-wise percentage of individuals within each caste category who self-reported as having hypertension. It also shows the state-wise percentage of the actual disease status. The prevalence of hypertension based on self-report is lower among SC, ST and OBC compared to general. The prevalence of self-reported hypertension among SC, ST, OBC and general is 24%, 15%, 26% and 32% respectively (figure 4a). Based on self-reports, a prevalence more than the national average among SC is observed in Punjab, Haryana, Uttarakhand, Assam, Kerala and Andhra Pradesh. The same among ST is observed in Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana, Uttarakhand, Maharashtra, Goa, Telengana, Andhra Pradesh, Kerala, Tamil Nadu and all the north eastern states except Nagaland and Tripura. Among OBC, a prevalence more than the national average is seen in Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana, Goa, Kerala, Andhra Pradesh, Telengana and Tripura. Punjab, Jammu & Kashmir, Goa, Telengana and Kerala have the prevalence of self-reported hypertension higher than the national average among general.

The self-reported prevalence of hypertension among SC population in Meghalaya and Arunachal Pradesh, ST population in Odisha and Chhattisgarh is less than 10%. However, the actual prevalence of hypertension among the same is above 40%.

Table 2 shows the comparison in the the distribution of the sample by background characteristics among the persons who agreed/disagreed to participate in the medical examination. Within most of the characteristics, the proportion of a certain level among participants is significantly different from the proportion of the same among non-participants. For example, the proportion of SC and OBC among participants is significantly higher than that among non-participants. In contrast, the proportion of general caste among participants is significantly lower than that among non-participants. Thus the distribution of persons who agree and who do not agree to participate in the medical examination are associated with different background characteristics. This shows that willingness to participate in the medical examination is not random and there is a need for including sample selection in the analysis.

3.1 Caste Disparities in Awareness and Uncontrolled BP

The trivariate probit model involving self report of hypertension, consent for participation and actual presence of hypertension (appendix table A1) shows shows that, adjusted for the certain background characteristics, SC, ST and OBC are less likely to self report hypertension compared to general caste. However, SC and OBC are more likely to participate in the medical examination. SC, ST are less likely to be diagnosed with hypertension compared to general caste. Significant correlation is found between the unexplained factors of the three equations associated with the trivariate probit model. This suggests the presence of endogeneity in the model.

The trivariate probit model involving medication for controlling BP, consent for participation and uncontrolled BP (appendix table A2) shows that, adjusted for the certain background characterisitcs, ST and OBC are less likely to take medication for controlling BP and OBC are less likely to have

uncontrolled BP compared to general caste. Significant correlation is seen between the unexplained factors of the three equations associated with the model.

Table 3 shows the marginal effects of caste groups SC, ST and OBC on the awareness of hypertension and uncontrolled BP even after being on medication.

According to the standard definition of awareness, SC, ST and OBC are less likely to be aware of their hypertension status compared to the general caste people. Among them, ST are least aware, followed by OBC, SC and general. According to the alternative definition, SC group is likely to be more aware of their disease status compared to the general caste people. ST and OBC are less likely to be aware about their state of hypertension compared to the general caste. ST are least aware, followed by OBC, general and SC. The ST group, being least aware, is more likely to have elevated BP even after being on medication for controlling BP compared to the general caste.

3.2 Driving Factors of Caste Disparities in Awareness of Hypertension

Figures 6-8 show the percentage contribution of each variable among SC, ST and OBC respectively in comparison to general.

Figure 6 shows that education up to secondary level, higher secondary, higher education and behaviours of current smoking and alcohol drinking have a higher contribution in the explained component. Presence of diabetes, heart disease and high cholesterol also show the same. The composition of these factors mainly drives the caste gap in awareness between SC and general.

Figure 7 shows that higher education, behaviour of drinking alcohol and presence of heart disease have higher contribution in the explained component; determining the caste disparities in awareness with their compositions between ST and general.

Figure 8 suggests that the composition of persons with secondary education, having diabetes, heart disease and high cholesterol explains the caste gap in awareness among OBC and general.

Table 1 shows that the minority castes have lower level of education than the general caste. Consumption of alcohol within SC, ST and OBC is significantly higher than that among general caste. According to the decomposition model, improving these in the minority castes will lead to reduce the caste disparities in awareness of hypertension.

4 Discussion

To the best of our knowledge, this is the first study to address the disparities in awareness of hypertension status in India by caste. This was addressed earlier in the United States using the Health and Retirement Study, according to which the African Americans and Latinos were found to be more likely to be unaware of having hypertension and diabetes compared to non-Latino whites (Chatterji et al. 2012). Also, there are very few studies which focused on the awareness of hypertension, although it is very crutial for early detection of hypertension and prevension of its consequences such as CVD and stroke. Several studies in the United States focused on the disparities by hypertension or related things by ethnicity. A study in the United States, from the National Health and Nutrition Examination Survey (NHNES), on national trends in racial and ethnic disparities in anti hypertensive medication use and blood pressure control among adults with hypertension from 2011 to 2018 revealed that the Black individuals were more aware of their hypertension status and more likely to be on treatment compared to the others. This study essentially reveals the importance of understanding disparities in hypertension management to address cardiovascular outcomes effectively (Lu et al. 2022). In context to the ethnic disparities in the use of anti-hypertensive and blood

pressure control, a study from the United States shows that lower awareness and treatment were significantly associated with lower blood pressure control among Asian and Hispanic individual but not among the Black individuals (Lu et al. 2021). The American College of Cardiology's analysis of racial disparities in hypertension prevalence and management highlighted significant differences in blood pressure control rates based on race and ethnicity, with disparities in care leading to poor control rates among certain racial groups. This study emphasises the need to address disparities in hypertension management to improve health outcomes across diverse populations (Saeed et al. 2020). A number of studies from different parts of the world report the disparities in blood pressure level by ethnic groups. A study from Amsterdam, the Netherlands assessed the change in the blood pressure levels over time in a multi ethnic population based cohort. It reports that there was an increase in the gap in the systolic blood pressure of the Ghanaian, Moroccan and the Turkish population compared to the Dutch population over time (Vriend et al. 2023). A cohort study from the UK focused on the ethnic differences in hypertension management and their contribution to blood pressure control. The cohort consisted individuals of European, South Asian, and African/African Caribbean ethnicity who never took any anti-hypertensive. The cohort was followed from 2006 to 2019. The study reports that the initiation of any-hypertensive did not vary by ethnicity, but the control of blood pressure was lower among the people from African/African Caribbean ethnicity, compared to the other groups (Eastwood et al. 2022). Most of the studies related to hypertension and caste disparities in India focused on disparities in the presence or absence of the disease along with the disparities in management of hypertension across different groups such as caste. A study based on the fourth round of the National Family Health Survey (NFHS) in India shows that women in lower caste groups in India were more likely to have hypertension as compared to the upper caste women (Uddin et al. 2020). Another study based on the same data reports the socioeconomic and geographical inequalities of the disease burden and treatment seeking behaviour of hypertension among women aged 15-45 years in India. This study points out rural-urban inequality in prevalence, awareness and care seeking of hypertension. It also points out some possible causes of this inequality as lack of knowledge, poor health seeking behaviour and difficulties in getting health care services in the rural areas. The study also reports that women belonging to backward castes, i.e. SC or ST, had higher rate of inequality in prevalence, awareness and care seeking compared to the general caste (Vijayakumar et al. 2024). A study based on a nationally representative survey of persons aged 45 years or higher and their spouses reported the prevalence of hypertension in India to be 42 percent. Among the hypertensive persons, 54 percent were aware, 51 percent were treated and 29 percent had controlled blood pressure. The prevalence of hypertension was lowest among ST (37 percent), followed by SC (39 percent), OBC (42 percent) and general (46 percent). Among hypertensive persons, the awareness was found to be highest among general (61 percent), followed by OBC (54 percent), SC (52 percent) and ST (36 percent). Among the same, highest care seeking was observed among general (57 percent), followed by OBC (51 percent), SC (48 percent) and ST (32 percent). The highest proportion of hypertensives who had controlled blood pressure was observed among general (32 percent), followed by OBC (30 percent), SC (26 percent) and ST (17 percent) (Mohanty et al. 2021). A study from Andhra Pradesh, India reports that the prevalence of hypertension is generally low among traditional population groups, which are essentially the tribal population (Kusuma et al. 2004).

The current study relates the caste disparities in the uncontrolled BP with that in the awareness of hypertension. It also finds out certain factors which drive the caste gap in the awareness of hypertension. These make it a unique study along with the other studies in this field in India.

5 Conclusion

In India, the minority caste groups are still lagging behind the general caste with respect to education, socio-economic and health status. The SC, ST and OBC are in a worse position compared to general in terms of the mortality and fertility indicators and household wealth index. SC people have significantly higher mortality rate compared to the general caste. The fertility rate is higher among SC, ST and OBC compared to the general caste. Most of the SC and ST households are shifted towards the two lowest wealth quintiles, poorest and poorer. The awareness of one's hypertension status in India is less among SC, ST and OBC than the other castes. ST are the least aware. The estimates of caste disparities in awareness of hypertension status in India are affected by accounting for selection. In India, one's decision to participate in the medical examination for determining the disease status is associated with certain characteristics of the individual. Therefore one must account for selection while modelling awareness.

This study explores awareness according to both the standard and alternative definitions. According to the standard definition, SC, ST and OBC are less likely to be aware compared to the other castes. However, according to the alternative definition, the SC are more likely to be aware compared to general. OBC are less likely to be aware but also are close to the general in terms of awareness. The ST are least likely to be aware about hypertension status compared to the general. The extent to which SC, ST and OBC are less likely to be aware about their disease status according to the standard definition is higher than corresponding to the alternative definition. Thus the extent of unawareness is higher in terms of self-reporting the disease and actually being negative, rather than non self-reporting the disease and actually being positive. Apart from awareness, caste disparities exist in uncontrolled BP even after being in medication for controlling BP. There is significant correlation between the unobserved factors associated with medication for controlling BP and diagnosed with hypertension given medication. Further, the conditional probability of having hypertension given medication is lower among SC, ST and OBC compared to the general caste category. The probability of being diagnosed with hypertension given medication for controlling BP is least among the ST population. Level of education, current use of tobacco, consumption of alcohol, and having diabetes, heart disease and high cholesterol are some of the identified driving factors; the composition of these factors among caste groups determine the caste gap in awareness.

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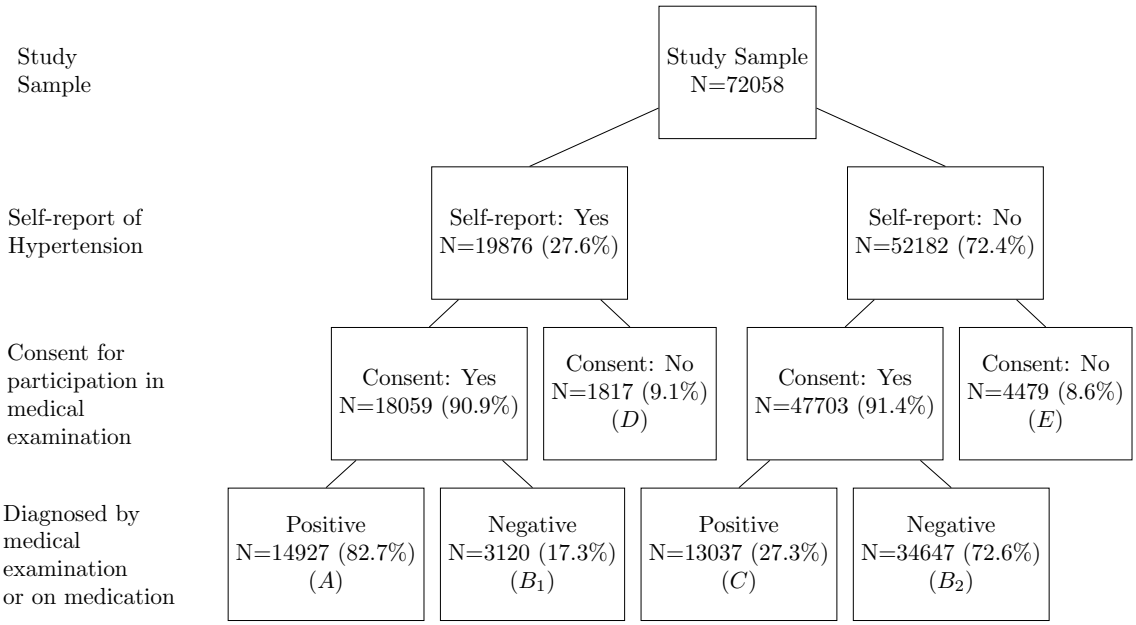


Figure 1: Self-Report, Consent and Disease in the Sampling Structure of LASI Wave 1

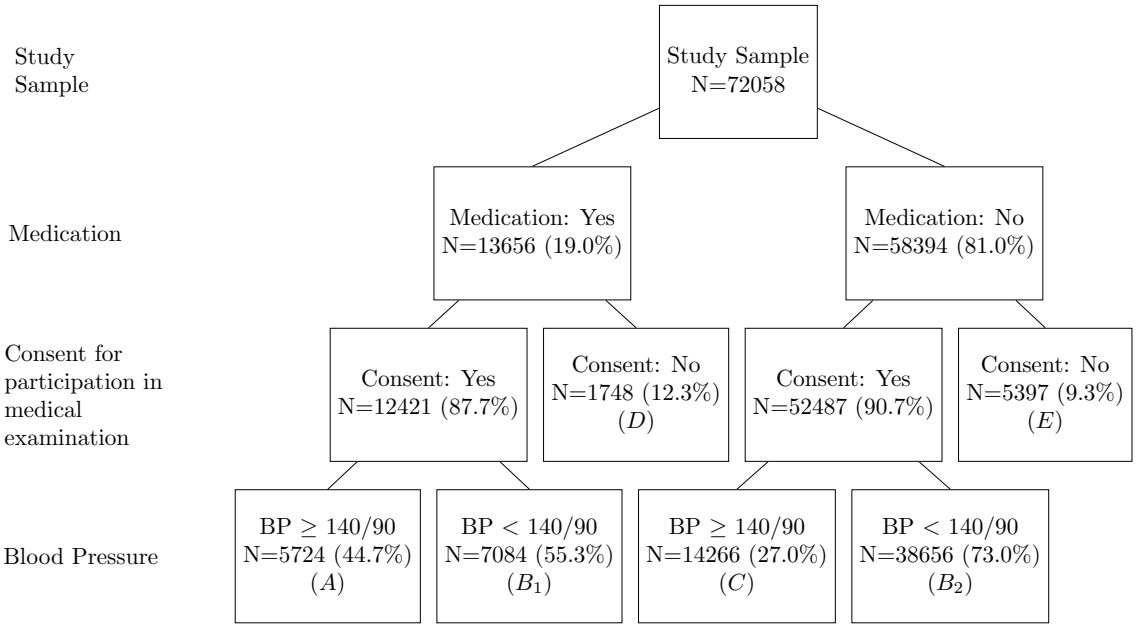


Figure 2: Medication, Consent and Uncontrolled BP in the Sampling Structure of LASI Wave 1

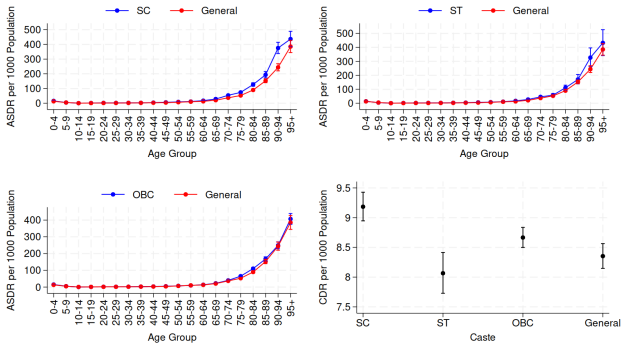
Table 1: Background Characteristics of the Respondents, LASI Wave 1, India 2017-18

	Overall (N=72262)	SC (N=13832)	ST (N=6165)	OBC (N=32869)	General (N=19395)
Age					
<45	8.7	8.6	8.0*	8.8	8.8
45-59	45.4	46.1***	48.4***	45.6***	43.7
60-74	35.5	35.7	35.4	35.0**	36.0
75 and above	10.4	9.6***	8.3***	10.6***	11.5
Sex					
Male	42.0	41.5	41.9	42.2	42.1
Female	58.0	58.5	58.1	57.8	57.9
Education					
Never attended	49.5	64.4***	66.1***	48.5***	35.3
Upto Primary (1-4)	10.8	10.2	12***	11.0	10.7
Primary completed (5-7)	12.4	9.4***	8.1***	13.9*	13.3
Middle completed (8-9)	8.8	6.8***	5.7***	8.2***	12.0
Secondary completed (10)	7.5	4.4***	3.5***	7.6***	10.8
Higher secondary (11-12)	4.8	2.8***	2.4***	4.5***	7.4
Higher	6.3	2.0***	2.3***	6.3***	10.6
Employed for at least 3 months	72.4	77.6***	84.6***	73.5***	63.2
Marital Status					
Currently Married	75.6	73.6***	74.7***	76.0	76.6
Widowed	21.7	24.1***	22.6***	20.9	21.0
Divorced/Separated/De	1.1	1.2*	1.5***	1.1	1.0
Never married/live-in	1.6	1.2	1.2	2.0***	1.3
Religion					
Hindu	81.9	87.7***	80.4***	83.7***	75.3
Muslim	11.7	1.2***	1.9***	13.3***	19.5
Other	6.4	11.1***	17.8***	3.1***	5.2
Household Characteristics					
Separate Kitchen	64.8	54.0***	53.8***	66.2***	73.7
Improved Sanitation	65.3	54.9***	56.4***	65.7***	74.8
Improved Source of Drinking Water	95.1	96.0*	96.8***	94.1***	95.6
Clean Cooking Fuel	52.3	40.7***	26.2***	56.4***	62.5
Concrete House	54.8	45.5***	27.7***	55.9***	68.7
Self Reported Health Status					
Excellent	4.6	4.0***	4.2***	4.2***	5.6
Very good	18.5	15.6***	22.7***	19.2***	18.1
Good	37.4	36.9***	39.6***	38.6***	34.9
Fair	29.0	31.0	25.5***	28.2***	30.2
Poor	10.6	12.5***	7.9***	9.9***	11.2
Health Practices and Behaviours					
Yoga	12.1	10.5***	6.7***	10.9***	16.8
Physical Activity More than Once a Week	70.1	68.7	73.4***	71.3***	68.1
Ever Smoking	15.7	19.9***	17.7***	14.3	14.5
Current Smoking	12.2	16.2***	14.3***	10.7*	11.2
Consuming Alcohol	13.9	17.0***	30.4***	12.3***	9.3

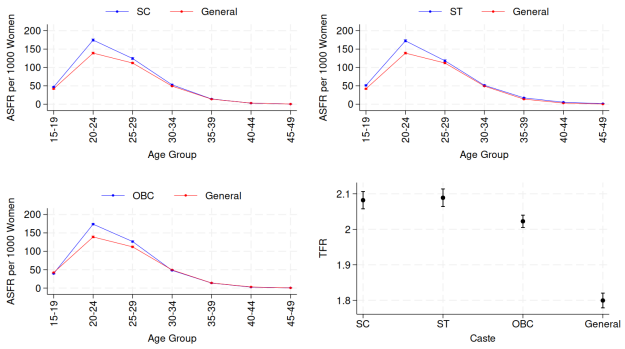
Table 1 continued from previous page

	Overall (N=72262)	SC (N=13832)	ST (N=6165)	OBC (N=32869)	General (N=19395)
Covered with Health Insurance	20.7	19.4***	32.1***	22.1***	15.7
Chronic Diseases Except Hypertension					
Diabetes	11.6	8.3***	4.7***	13.1	13.5
Cancer	0.6	0.6***	0.4***	0.5***	1.0
Lung Disease	6.3	6.6**	4.5***	6.8***	6.0
Heart Disease	3.6	3.1***	1.1***	3.6***	4.7
Stroke	1.8	2.0	1.1***	1.6***	2.2
Bone/Joint Disease	15.7	15.3***	9.8***	16.4	16.7
Neurological Disease	2.4	2.6	1.5***	2.4	2.5
High Cholesterol	2.2	1.4***	0.7***	2.1***	3.4
Any of above	33.4	30.9***	19.3***	34.9***	37.1

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

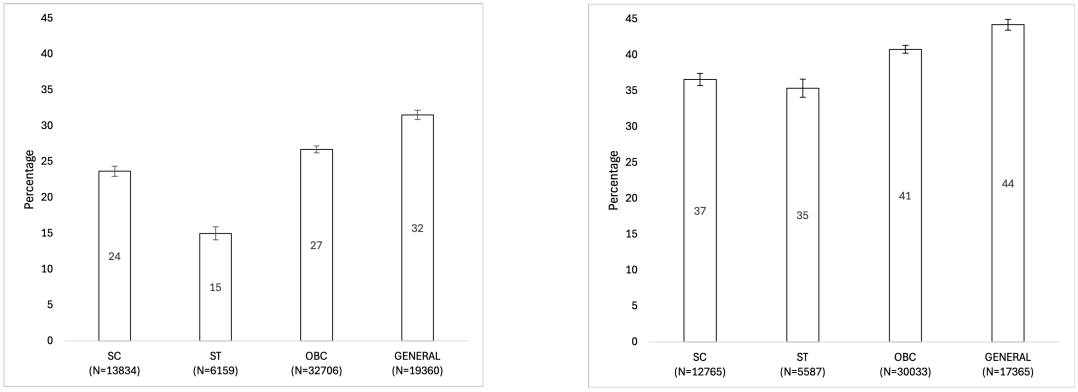


(a) Mortality



(b) Fertility

Figure 3: Caste-wise Mortality and Fertility Indicators, NFHS 5, India 2019-21



(a) Self-Report (b) Uncontrolled BP or On Medication

Figure 4: Percentage of Individuals with Hypertension within Each Caste, LASI Wave 1, India 2017-18

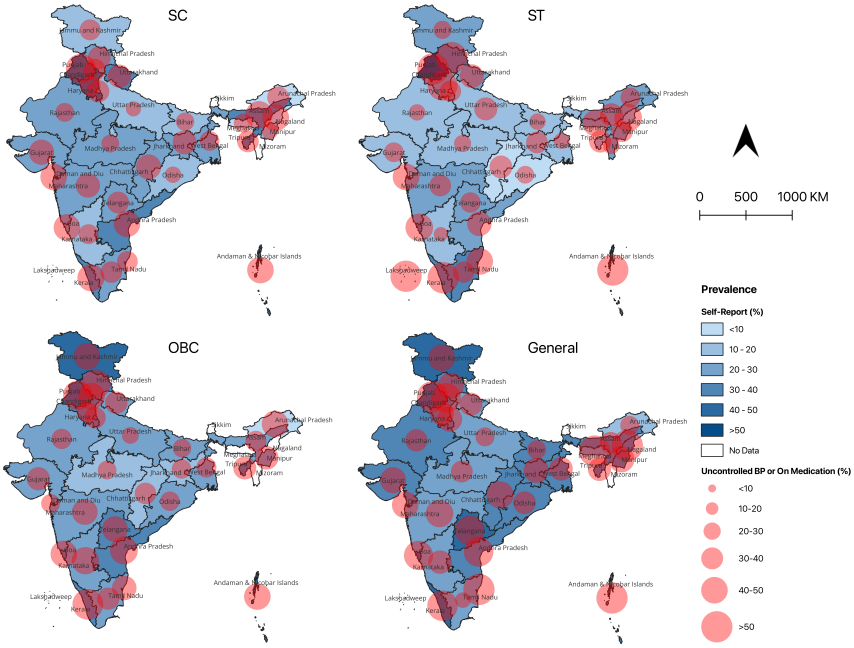


Figure 5: State-wise Percentage of Individuals with Hypertension within Each Caste, LASI Wave 1, India 2017-18

Table 2: Distribution of the respondents who gave and did not give consent for BP measurement, LASI Wave 1, India 2017-18

	Did not give consent: n(%)	Gave consent: n(%)	P value
Caste			

Table 2 continued

	Did not give consent: n(%)	Gave consent: n(%)	P value
SC	1247 (16.8)	12586 (19.4)	<0.001
ST	654 (8.8)	5512 (8.5)	0.351
OBC	3259 (44.0)	29612 (45.7)	0.005
General	2254 (30.4)	17126 (26.4)	<0.001
Age			
<45	568 (7.7)	5707 (8.8)	0.001
45-59	3394 (45.8)	29440 (45.4)	0.544
60-74	2309 (31.1)	23293 (35.9)	<0.001
≥75	1143 (15.4)	6394 (9.9)	<0.001
Gender			
Male	3204 (43.2)	27139 (41.9)	0.025
Female	4210 (56.8)	37696 (58.1)	0.025
Education			
Non-literate	3527 (47.6)	32237 (49.7)	0.001
Upto Primary (1-4)	647 (8.7)	7167 (11.1)	<0.001
Primary completed (5-7)	838 (11.3)	8119 (12.5)	0.003
Middle completed (8-9)	586 (7.9)	5735 (8.8)	0.007
Secondary completed (10)	715 (9.7)	4697 (7.2)	<0.001
Higher secondary (11-12)	392 (5.3)	3035 (4.7)	0.019
Higher	702 (9.5)	3848 (5.9)	<0.001
Marital Status			
Currently Married	5404 (72.9)	49217 (75.9)	<0.001
Widowed	1748 (23.6)	13902 (21.4)	<0.001
Separated	120 (1.6)	694 (1.1)	<0.001
Never married/live-in	141 (1.9)	1019 (1.6)	0.032
Place of residence			
Rural	4204 (56.7)	45056 (69.5)	<0.001
Urban	3210 (43.3)	19779 (30.5)	<0.001
Religion			
Hindu	5734 (77.3)	53454 (82.4)	<0.001
Muslim	1151 (15.5)	7278 (11.2)	<0.001
Other	530 (7.1)	4103 (6.3)	0.006
Physical activity			
Up to once a week	2399 (35.6)	18998 (29.3)	<0.001
More than once a week	4336 (64.4)	45901 (70.7)	<0.001
Self Reported Health Status			
Excellent	359 (5.6)	2887 (4.4)	<0.001
Very good	1438 (22.6)	11750 (18.1)	<0.001
Good	2205 (34.6)	24463 (37.6)	<0.001
Fair	1681 (26.4)	19046 (29.3)	<0.001
Poor	686 (10.8)	6878 (10.6)	0.632
Ever Smoker			
Non smoker	5855 (87.0)	54505 (84.0)	<0.001
Smoker	877 (13.0)	10376 (16.0)	<0.001
Current Smoker			
Non smoker	6073 (90.2)	56814 (87.6)	<0.001

Table 2 continued

	Did not give consent: n(%)	Gave consent: n(%)	P value
Smoker	659 (9.8)	8067 (12.4)	<0.001
Alcohol Drinker			
Non-drinker	5820 (86.4)	55826 (86.0)	0.956
Drinker	913 (13.6)	9072 (14.0)	0.956
Health Insurance			
Not covered	5439 (81.2)	51261 (79.1)	<0.001
Covered	1259 (18.8)	13563 (20.9)	<0.001
Any other chronic disease			
Not diagnosed	4565 (64.0)	43447 (66.9)	<0.001
Diagnosed	2565 (36.0)	21489 (33.1)	<0.001
Diabetes			
Not diagnosed	6086 (85.4)	57638 (88.8)	<0.001
Diagnosed	1043 (14.6)	7287 (11.2)	<0.001
Cancer			
Not diagnosed	7074 (99.2)	64539 (99.4)	0.069
Diagnosed	56 (0.8)	394 (0.6)	0.069
Chronic lung disease			
Not diagnosed	6662 (93.4)	60847 (93.7)	0.377
Diagnosed	468 (6.6)	4088 (6.3)	0.377
Chronic heart disease			
Not diagnosed	6895 (96.7)	62581 (96.4)	0.174
Diagnosed	236 (3.3)	2354 (3.6)	0.174
Stroke			
Not diagnosed	6931 (97.2)	63828 (98.3)	<0.001
Diagnosed	199 (2.8)	1106 (1.7)	<0.001
Chronic bone/joint diseases			
Not diagnosed	6084 (85.3)	54665 (84.2)	0.012
Diagnosed	1046 (14.7)	10271 (15.8)	0.012
Neurological problems			
Not diagnosed	6882 (96.5)	63452 (97.7)	<0.001
Diagnosed	247 (3.5)	1475 (2.3)	<0.001
High cholesterol			
Not diagnosed	6996 (98.1)	63487 (97.8)	0.057
Diagnosed	134 (1.9)	1446 (2.2)	0.057

Table 3: Marginal Effects of Caste Groups on Awareness of Hypertension and Uncontrolled BP after Medication

	Awareness: Standard Definition	Awareness: Alternative Definition	Uncontrolled BP after Medication
General	(reference)	(reference)	(reference)
SC	-0.0046*** (0.00001)	0.0041*** (0.00001)	-0.0084*** (0.00001)
ST	-0.0746*** (0.00009)	-0.0213*** (0.00013)	0.0061*** (0.00001)
OBC	-0.0258*** (0.00003)	-0.0023*** (0.00002)	-0.0107*** (0.00002)

Table 3 continued from previous page

	Awareness:	Awareness:	Uncontrolled BP

$^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.1$

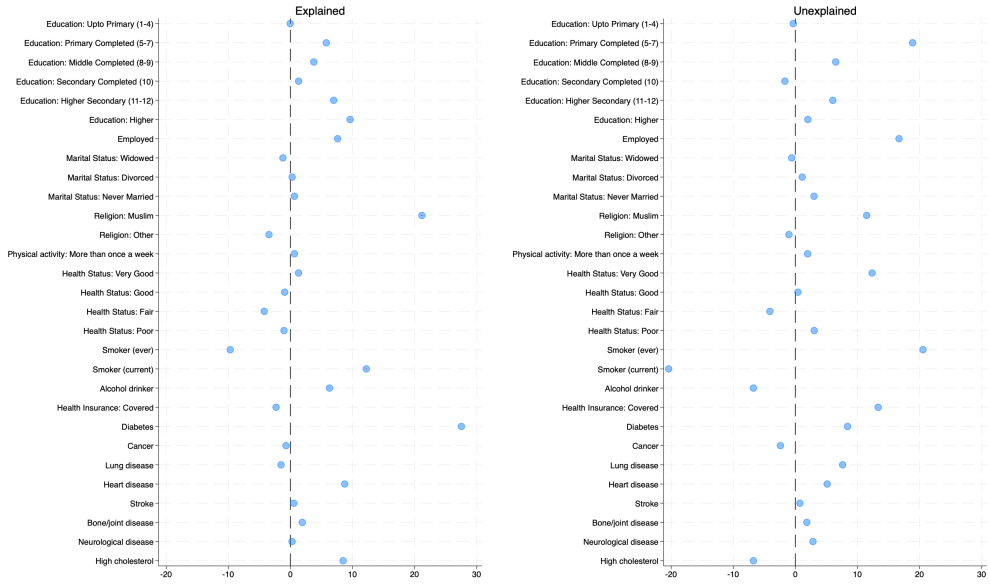


Figure 6: Percentage Contribution of the Explained and Unexplained Component of Each Predictor in Decomposition Model for SC and general

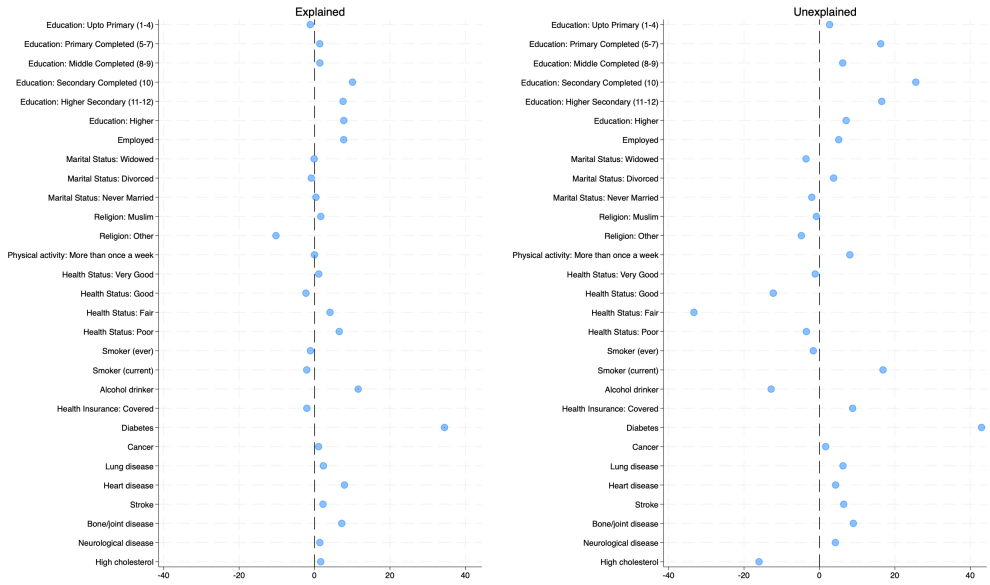


Figure 7: Percentage Contribution of the Explained and Unexplained Component of Each Predictor in Decomposition Model for ST and general

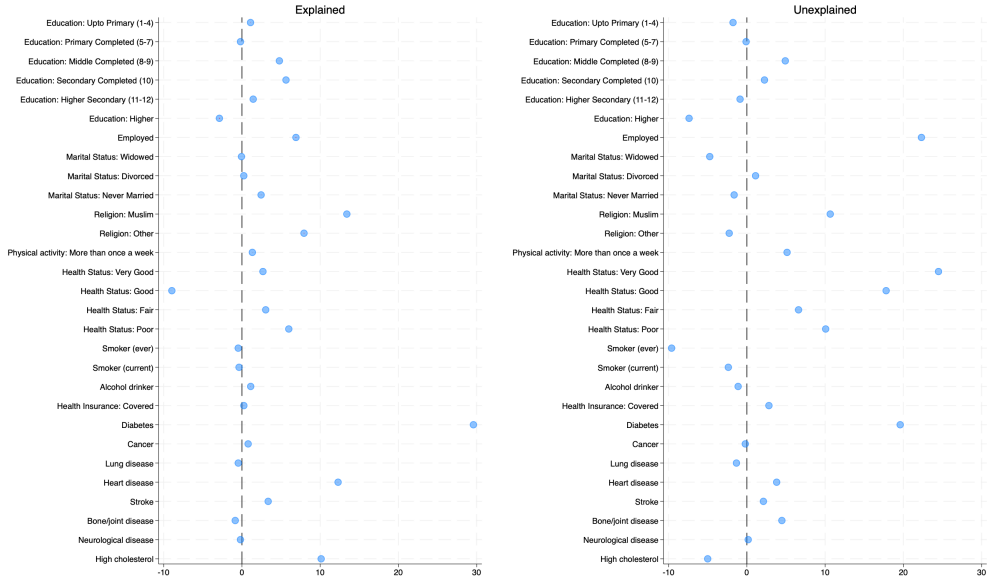


Figure 8: Percentage Contribution of the Explained and Unexplained Component of Each Predictor in Decomposition Model for OBC and general

A Appendix

Table A1: Factors Associated with Self Report, Consent and Diagnosis of Hypertension, Trivariate Probit Model with Selection

	Panel I Self Report	Panel II Consent	Panel III Diagnosis
Caste			
General	(reference)	(reference)	(reference)
SC	-0.0172 (0.0173)	0.0031 (0.0223)	-0.0162 (0.0161)
ST	-0.1835*** (0.0244)	-0.0848*** (0.0289)	-0.0221 (0.0213)
OBC	-0.0527*** (0.0135)	0.0424** (0.0171)	-0.0079 (0.0126)
Age			
<45	(reference)	(reference)	(reference)
45-59	0.2773*** (0.0226)	-0.0501* (0.0272)	0.3472*** (0.0209)
60-74	0.4667*** (0.0240)	0.0248 (0.0296)	0.6567*** (0.0223)
75 and above	0.5043*** (0.0293)	-0.0550 (0.0370)	0.7177*** (0.0274)
Gender			
Male	(reference)	(reference)	(reference)
Female	0.2252*** (0.0161)	-0.0294 (0.0201)	0.0880*** (0.0147)
Education			
No formal education	(reference)	(reference)	(reference)
Upto Primary (1-4)	0.0264 (0.0189)	0.0986*** (0.0252)	0.0714*** (0.0172)
Primary completed (5-7)	0.0868*** (0.0181)	0.0595** (0.0236)	0.0638*** (0.0168)
Middle completed (8-9)	0.0573*** (0.0217)	0.0218 (0.0275)	0.0638*** (0.0199)
Secondary completed (10)	0.0843*** (0.0235)	-0.0140 (0.0288)	0.0810*** (0.0218)
Higher secondary (11-12)	0.0527* (0.0282)	-0.0220 (0.0346)	0.0026 (0.0263)
Higher	0.0934*** (0.0261)	-0.1672*** (0.0303)	0.1293*** (0.0248)
Employed	-0.0592*** (0.0142)	-0.0887*** (0.0184)	0.0047 (0.0133)
Marital Status			
Currently married	(reference)	(reference)	(reference)
Widowed	0.0989*** (0.0148)	-0.0496** (0.0194)	0.1650*** (0.0138)
Divorced	-0.0596 (0.0524)	-0.1933*** (0.0598)	0.0483 (0.0468)
Never married	-0.1381*** (0.0458)	0.1345** (0.0602)	-0.1816*** (0.0413)
Religion			
Hindu	(reference)	(reference)	(reference)
Muslim	0.1824*** (0.0175)	-0.1118*** (0.0222)	0.1325*** (0.0166)
Other	0.0689*** (0.0228)	-0.0419 (0.0286)	0.1150*** (0.0210)
Place of residence: Urban	0.1236*** (0.0140)	-0.1609*** (0.0178)	0.1176*** (0.0131)
Household Characteristics			
Has separate kitchen	0.0928*** (0.0126)	-0.0035 (0.0161)	0.0723*** (0.0115)
Improved sanitation	0.1050*** (0.0133)	-0.0857*** (0.0173)	0.0761*** (0.0120)
Improved source of drinking water	-0.0431* (0.0248)	0.0236 (0.0310)	-0.0828*** (0.0233)
Clean cooking fuel	0.1546*** (0.0137)	-0.0410** (0.0180)	0.1570*** (0.0126)
Concrete house	0.0291** (0.0129)	-0.1421*** (0.0167)	-0.0128 (0.0118)
Self reported health status			
Excellent	(reference)	(reference)	(reference)

Table A1 continued from previous page

	Panel I Self Report	Panel II Consent	Panel III Diagnosis
Very good	0.1466*** (0.0308)	-0.0231 (0.0344)	0.0131 (0.0267)
Good	0.1997*** (0.0293)	0.0693** (0.0329)	0.0469* (0.0254)
Fair	0.4134*** (0.0298)	0.0400 (0.0339)	0.1317*** (0.0260)
Poor	0.5491*** (0.0329)	-0.0351 (0.0388)	0.1411*** (0.0294)
Health Practices and behaviours			
Yoga	0.1764*** (0.0165)	0.0613*** (0.0220)	0.0345** (0.0158)
Physical activity	-0.0688*** (0.0125)	0.0183 (0.0160)	-0.0427*** (0.0116)
Ever smoker	0.0618** (0.0308)	0.1793*** (0.0444)	-0.0475* (0.0287)
Current smoker	-0.1510*** (0.0333)	-0.0849* (0.0476)	-0.0714** (0.0307)
Alcohol driker	0.0247 (0.0186)	-0.0346 (0.0230)	0.1743*** (0.0163)
Has health insurance	0.0249* (0.0137)	0.0419** (0.0176)	0.0512*** (0.0126)
Other chronic diseases			
Diabetes	0.8663*** (0.0167)	-0.1046*** (0.0217)	0.5360*** (0.0168)
Cancer	0.0522 (0.0694)	-0.0498 (0.0879)	-0.0646 (0.0666)
Lung disease	0.1257*** (0.0223)	0.0316 (0.0304)	-0.0366* (0.0214)
Heart disease	0.6565*** (0.0292)	0.0997** (0.0405)	0.4411*** (0.0287)
Stroke	0.5765*** (0.0412)	0.0376 (0.0569)	0.3699*** (0.0408)
Bone/joint disease	0.2017*** (0.0148)	0.0447** (0.0203)	0.0659*** (0.0142)
Neurological disease	0.1273*** (0.0353)	0.1111** (0.0508)	0.0454 (0.0340)
High cholesterol	0.5734*** (0.0371)	0.1949*** (0.0515)	0.2717*** (0.0361)
Constant	-1.9568*** (0.0532)	1.7998*** (0.0640)	-1.3558*** (0.0484)
Error Correlation			
c_{21}	-0.0198** (0.0098)		
c_{31}	0.6431*** (0.0052)		
c_{32}	0.7321*** (0.0138)		

***p<0.01, **p<0.05, *p<0.1

Table A2: Factors Associated with Medication, Consent and Uncontrolled BP, Trivariate Probit Model with Selection

	Panel I Medication	Panel II Consent	Panel III Uncontrolled BP
Caste			
General	(reference)	(reference)	(reference)
SC	-0.0245 (0.0195)	0.0184 (0.0225)	-0.0232 (0.0170)
ST	-0.2053*** (0.0287)	-0.0831*** (0.0294)	0.0278 (0.0228)
OBC	-0.0400*** (0.0147)	0.0576*** (0.0174)	-0.0280** (0.0136)
Age			
<45	(reference)	(reference)	(reference)
45-59	0.4268*** (0.0283)	-0.0528* (0.0275)	0.2776*** (0.0225)
60-74	0.7127*** (0.0295)	0.0308 (0.0299)	0.4957*** (0.0245)
75 and above	0.7816*** (0.0345)	-0.0445 (0.0374)	0.5723*** (0.0291)
Gender			
Male	(reference)	(reference)	(reference)

Table A2 continued from previous page

	Panel I Medication	Panel II Consent	Panel III Uncontrolled BP
Female	0.2259*** (0.0180)	-0.0326 (0.0206)	0.0021 (0.0156)
Education			
No formal education	(reference)	(reference)	(reference)
Upto Primary (1-4)	0.0811*** (0.0209)	0.1085*** (0.0255)	0.0147 (0.0188)
Primary completed (5-7)	0.0902*** (0.0204)	0.0652*** (0.0239)	0.0117 (0.0181)
Middle completed (8-9)	0.1232*** (0.0240)	0.0446 (0.0278)	0.0247 (0.0210)
Secondary completed (10)	0.1418*** (0.0255)	-0.0053 (0.0292)	-0.0135 (0.0230)
Higher secondary (11-12)	0.0950*** (0.0309)	-0.0056 (0.0350)	-0.0539* (0.0279)
Higher	0.1734*** (0.0281)	-0.1710*** (0.0307)	0.0897*** (0.0282)
Employed	-0.0501*** (0.0157)	-0.0975*** (0.0186)	0.0636*** (0.0148)
Marital Status			
Currently married	(reference)	(reference)	(reference)
Widowed	0.1132*** (0.0161)	-0.0579*** (0.0197)	0.1694*** (0.0145)
Divorced	-0.0356 (0.0594)	-0.2096*** (0.0606)	0.1409*** (0.0512)
Never married	-0.3058*** (0.0555)	0.1361** (0.0603)	-0.1034** (0.0444)
Religion			
Hindu	(reference)	(reference)	(reference)
Muslim	0.2250*** (0.0189)	-0.1049*** (0.0225)	0.1146*** (0.0181)
Other	0.1209*** (0.0248)	-0.0372 (0.0290)	0.1143*** (0.0221)
Place of residence: Urban	0.1810*** (0.0152)	-0.1619*** (0.0180)	0.0724*** (0.0161)
Household Characteristics			
Has separate kitchen	0.1215*** (0.0144)	0.0049 (0.0163)	0.0396*** (0.0122)
Improved sanitation	0.1458*** (0.0153)	-0.0847*** (0.0174)	0.0506*** (0.0132)
Improved source of drinking water	-0.0886*** (0.0266)	0.0220 (0.0315)	-0.0800*** (0.0245)
Clean cooking fuel	0.2353*** (0.0155)	-0.0356** (0.0181)	0.1226*** (0.0133)
Concrete house	0.0249* (0.0145)	-0.1466*** (0.0169)	0.0069 (0.0144)
Self reported health status			
Excellent	(reference)	(reference)	(reference)
Very good	0.2150*** (0.0360)	-0.0106 (0.0348)	-0.0756*** (0.0281)
Good	0.2239*** (0.0345)	0.0696** (0.0333)	-0.0432 (0.0269)
Fair	0.4260*** (0.0349)	0.0488 (0.0344)	0.0148 (0.0274)
Poor	0.5272*** (0.0378)	-0.0236 (0.0393)	-0.0389 (0.0308)
Health Practices and behaviours			
Yoga	0.1007*** (0.0181)	0.0498** (0.0222)	0.0081 (0.0168)
Physical aftivity	-0.1055*** (0.0137)	0.0187 (0.0162)	-0.0217* (0.0122)
Ever smoker	0.0245 (0.0340)	0.1953*** (0.0448)	-0.0963*** (0.0308)
Current smoker	-0.1548*** (0.0374)	-0.0989** (0.0480)	-0.0410 (0.0322)
Alcohol driker	-0.0436** (0.0216)	-0.0558** (0.0233)	0.2274*** (0.0171)
Has health insurance	0.0780*** (0.0152)	0.0416** (0.0178)	0.0300** (0.0135)
Other chronic diseases			
Diabetes	0.8855*** (0.0167)	-0.0927*** (0.0221)	0.2000*** (0.0173)
Cancer	-0.0625 (0.0767)	-0.0649 (0.0892)	0.0351 (0.0705)
Lung disease	0.1380*** (0.0236)	0.0489 (0.0306)	-0.1891*** (0.0226)
Heart disease	0.6649*** (0.0284)	0.1428*** (0.0413)	-0.0120 (0.0291)
Stroke	0.6052*** (0.0411)	0.0410 (0.0577)	0.1016** (0.0405)

Table A2 continued from previous page

	Panel I Medication	Panel II Consent	Panel III Uncontrolled BP
Bone/joint disease	0.1935*** (0.0159)	0.0566*** (0.0205)	-0.0294* (0.0151)
Neurological disease	0.1066*** (0.0374)	0.1111** (0.0513)	-0.0757** (0.0361)
High cholesterol	0.4953*** (0.0361)	0.2057*** (0.0522)	-0.0355 (0.0374)
Constant	-2.6228*** (0.0613)	1.7813*** (0.0652)	-1.0939*** (0.0552)
Error Correlation			
c_{21}	-0.0652*** (0.0110)		
c_{31}	0.2181*** (0.0081)		
c_{32}	-0.1518 (0.1915)		

***p<0.01, **p<0.05, *p<0.1