# Association between socioeconomic status and diabetes in India



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**Title** Association between socioeconomic status and diabetes in India: a cross-sectional multilevel analysis

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## ABSTRACT

**Objectives** To quantify the association between socioeconomic status (SES) and type-2 diabetes in India

**Design** Nationally representative cross-sectional household survey

**Setting** Urban and rural areas across 29 states in India

**Participants** 168,135 survey respondents aged 18-49 y (women) and 18-54 y (men)

**Primary outcome measure** Self-reported diabetes status

**Results** Markers of SES were social caste, education, and household wealth. The overall prevalence of diabetes was 1.5%; this increased to 1.9% and 2.5% for those with the highest levels of education and household wealth, respectively. In adjusted multilevel logistic regression models, education (odds ratio 1.87 for higher education *vs* no education) and household wealth (odds ratio 4.04 for richest quintile *vs* poorest) were related to diabetes (P<0.0001). In a fully adjusted model including all socioeconomic variables and body mass index (BMI), the odds ratio for diabetes was 2.58 (95% credible interval [CI]: 1.99, 3.40) for the richest quintile of household wealth versus the poorest.

**Conclusions** We found that the highest socioeconomic status groups in India appear to be at greatest risk for type-2 diabetes. This raises important policy implications for addressing the disease burdens among the poor versus those among the non poor in the context of India, where nearly half of the population is living in poverty.

## ARTICLE SUMMARY

### Article Focus

- The relationship between socioeconomic factors and type-2 diabetes has not been previously studied for the whole of India
- Our objective was to investigate associations between measures of socioeconomic status (defined as social caste, education, household wealth) and self-reported diabetes status in India
- In addition we explored geographic variation in diabetes between states and local areas in India

### Key messages

- The highest socioeconomic groups appear to be at greatest risk for diabetes in India
- In addition, there is substantial geographic heterogeneity in the prevalence of diabetes
- These findings raise important policy implications for in addressing the disease burdens among the poor versus those among the non poor in the context of India, where nearly half of the population is living in poverty.

### Strengths and Limitations

- The key strength of this study is the use of a large, nationally-representative survey to assess the socioeconomic and geographic patterning of diabetes across all of India. Limitations include the relatively younger age of the sample and assessment of diabetes status on the basis of self-reports.

## INTROCUTION

The prevalence of type-2 diabetes in India has been investigated in numerous population based surveys conducted across a range of settings since the 1970s.[1-6] Despite multiple prevalence studies, few studies have considered the association between socioeconomic status (SES) and type-2 diabetes in India. Recently, it has been suggested that "poor people are disproportionately affected" by diabetes and other non-communicable diseases in low and middle income countries [7], although the empirical evidence in the Indian context remains limited. Studies among populations from a few geographic regions in India have provided some evidence of a positive SES-diabetes association [6 8-9]; however the strength and consistency of this association across the whole of India remains uncertain.

Type-2 diabetes is the most common form of diabetes globally, accounting for greater than 85% of cases.[10] The incidence of type-2 diabetes is related to genetic and non-genetic components, with the latter being greatly influenced by modifiable risk factors such as obesity, diets low in fibre and high in trans fat, and physical inactivity.[11-12] These lifestyle behaviours themselves are strongly patterned by SES [13], and may be mediators on the causal pathway between SES and the onset of type-2 diabetes.[14] In high income countries, the SES-diabetes relationship appears to be negative, with the poor at greatest risk. For example, strong associations have been observed between poverty, low education and type-2 diabetes among African American women [15-16], and among White women and men in the United States.[17] Similarly, a study from Canada described an inversely graded SES-diabetes association with an odds ratio of 1.9 for men (95% CI: 1.6-2.4) and 2.8 (95% CI: 2.2-3.4) for women for the lowest versus highest income groups.[18] A recent meta-analysis of 23 epidemiological studies and 43 measures of SES-diabetes association revealed an overall increased risk for type-2 diabetes for low SES groups based on education, occupation, and income.[19] The strength of the association, however, was less consistent in low and middle income countries (LMICs), and few studies have been conducted in these countries.

Concern has been raised over the anticipated rapid increase in type-2 diabetes prevalence in India.[20-21] Evidence on the secular increases in diabetes prevalence in India, however, have been limited to urban areas of Southern India[4 22-23], and have focused on the mean rates of diabetes rather than how it is distributed in the population. In this paper we investigate the SES-diabetes relation in India using a large-scale nationally representative survey. In addition, we investigate the geographical distribution of diabetes at the state and local area levels in India.

## METHODS

### Data source

We use data from the 3rd National Family Health Survey (NFHS), conducted in 29 states in India between November 2005 and August 2006.[24] NFHS-3 is a major national health survey in India which collected information on a range of indicators including reproductive health, nutritional status of adults and children, utilization of health care services, and blood testing for HIV prevalence. NFHS-3 covered all states in India, which comprise nearly 99% of the population, but excluded Union Territories. The survey was designed to provide estimates of key indicators (except HIV prevalence) for each state by urban and rural areas.

**Survey design**

A uniform multistage sampling strategy was adopted in all states, with separate sampling in urban and rural areas.[25-26] In rural areas, a two stage sample was carried out using a list of villages from the 2001 census as the sampling frame. In the first stage, a stratified sample of villages was drawn with probability proportional to the size of the village. In the second stage, a random selection of households was drawn in each village from a complete list of households complied during field visits carried out in each sampled village. In urban areas, a similar procedure was implemented beginning with a stratified random sample of municipal wards based on the 2001 census. Next, one census enumeration block (150-200 households) was selected from within wards using probability proportional to size. Finally, as in rural areas, field enumerators undertook a household listing operation in selected blocks and a random sample of households was made. In both rural and urban areas, 30 households were targeted for selection in each of the sampled units. The overall household response rate for NFHS-3 was 98%.[24]

All ever-married and never-married women aged 15-49 in selected households were invited to participate in the survey. In 22 states, men aged 15-54 in a subsample of households were eligible for the men's survey. In the remaining seven states (Andhra Pradesh, Karnataka, Maharashtra, Manipur, Tamil Nadu, Uttar Pradesh, and Nagaland) all men were invited to participate. The additional men recruited in these states was for the purpose of HIV testing to provide reliable state level estimates of HIV prevalence in certain states. Interviews were conducted in 1 of the 18 Indian languages in the respondent's home and the response rates were 95% for women and 87% for men.[24] During interviews, the weights and heights of survey respondents were measured by trained field technicians using standardized measuring equipment designed for survey settings.[27]

In total NFHS-3 collected information from 109,041 households, 124,385 women age 15-49, and 74,369 men age 15-54.[24] We restricted our analyses adults 18 years and older and non-pregnant women (n=171,207). Respondents who did not report or know their diabetes status (n= 2,385) or with incomplete information for any of the independent variables considered in the analysis (marital status, religion, caste, education, household wealth) were excluded (n=687). Analyses were conducted on a sample of 168,135 respondents, (65,255 men and 102,880 women). Additional analyses considering body mass index (BMI) were restricted to a sample of 158,936 due to missing and/or implausible values for height and/or weight.

**Outcome and independent variables**

The primary outcome was diabetes, assessed on the basis of self-reports by survey respondents. Socioeconomic status was measured by social caste, education, and household wealth. Social caste was reported by the household head. The categories were Other Caste, Scheduled caste, Scheduled tribe, Other Backward Class, and No Caste. Other Caste is a heterogeneous group that is traditionally viewed as having higher social status. Scheduled castes and scheduled tribes are considered lower, socially marginalized groups in India.[28] Education was specified as no education, primary, secondary, or higher education. Household wealth was defined by an index based on indicators of asset ownership and housing characteristics.[29] This index has been developed and validated in a number of countries to be a robust measure of wealth and has been found to be consistent with measures of income and expenditure.[30] Briefly, the measure was constructed as follows. Information on 33 indicators of housing characteristics (e.g., type of windows and flooring, water and sanitation facilities) and assets (e.g., ownership of home, car, computer, mobile phone) were weighted and combined with weights derived from a principal component analysis procedure.[24] The resulting variable was standardized to a mean of 0 and standard deviation of 1 and using this index the household population was divided into fifths from poorest to richest.

Control variables included age, gender, religion, place of residence, and BMI. Age was defined in 10 year categories and centred about its mean (32 years) in regression models. Gender was based on self-report. Religion was categorized as Hindu, Muslim, Sikh, Buddhist, or other religion. Marital status was defined as single, married, widowed, or separated. Place of residence (rural or urban) was defined according to the 2001 Census. BMI (in kg/$m^2$; weight in kilograms divided by the square of height in meters) was calculated for all survey respondents with valid measurements for weight and height. BMI was classified according to the following categories based on risk of type 2 diabetes and cardiovascular disease in Asian populations; less than 18.5 kg/$m^2$ (underweight); 18.5-23 kg/$m^2$ (acceptable risk); 23-27.5 kg/$m^2$ (increased risk); and 27.5 kg/$m^2$ or greater (high risk).[31]

**Analysis**

To account for the complex survey design, we employed multilevel logistic regression to model the probability of diabetes.[32] A three-level model was specified with a binary response ($y$, diabetes or not) for individual $i$ in local area (village or census block primary sampling units) $j$ in state $k$. The outcome diabetes, $\Pr(y_{ijk} = 1)$, was assumed to be binomially distributed $y_{ijk} \sim Binomial(1, \pi_{ijk})$ with probability $\pi_{ijk}$ related to the set of independent variables X and a random effect for each level by a logit link function:

$$Logit(\pi_{ijk}) = \beta_0 + \beta X + u_{0jk} + v_{0k}.$$

The right hand side of the equation consists of the fixed part linear predictor ($\beta_0 + \beta X$) and random intercepts attributable to local areas ($u_{0jk}$) and states ($v_{0k}$). The intercept, $\beta_0$ represents the log odds of diabetes in the reference group, and the $\beta$-coefficients represent the differential in the log odds of diabetes compared to the reference group defined for each independent variable. Coefficients were exponentiated and presented as odds ratios for interpretation. The random intercepts are assumed to be independently and identically distributed and have variances estimated for local areas ($\sigma_u^2$) and states ($\sigma_v^2$).[33] The variance parameters quantify heterogeneity in the log odds of diabetes at each level, after taking into account individual characteristics and place of residence in the fixed part. We expressed the variances at each level as a percentage of their contribution to the total variance from an initial model adjusting for age and gender only and from a final model accounting for all covariates. Models were estimated via Markov Chain Monte Carlo (MCMC) simulation using the statistical software *MLwiN*.[34-35]

## RESULTS

Characteristics of survey respondents by their self-reported diabetes status are given in **Table 1**. The overall prevalence of diabetes in this sample was 1.5% and this was higher in urban areas and among men (diabetes prevalence 2.0 % in urban *v* 1.0% in rural; 1.8% in men *v* 1.3% in women). Diabetes prevalence increased with age (7.5% in

50-54y *v* 0.3% in 18-29y), education (1.9% in higher *v* 1.0% in no education), household wealth (2.5% in richest *v* 0.4% in poorest), and BMI (4.8% in 27.5+ kg/m$^2$ *v* 0.6% in <18.5 kg/m$^2$). At the state level, the prevalence of diabetes varied between 0.3% in Rajasthan and 3.3% in Kerala and was generally higher in Southern and Eastern states (**Figure 1**).

In separate models that adjusted for age, marital status, religion, and place of residence, statistically significant associations were observed between SES and diabetes for each of the primary indicators of SES in this study: social caste, education, and household wealth. Compared to the other caste group, scheduled casts, scheduled tribes, and other backward classes had reduced odds of having diabetes with odds ratios of 0.81 (95% CI: 0.71, 0.94), 0.57 (95% CI: 0.46, 0.70), and 0.84 (95% CI: 0.75, 0.94), respectively (**Table 2**). Education showed a graded relation with diabetes and an odds ratio of 1.87 (95% CI: 1.61, 2.18) for those with higher education versus those with no education. Household wealth showed a graded association with diabetes with individuals from the richest households having an odds ratio for diabetes of 4.04 (95% CI: 3.08, 5.30) compared to those from the poorest households.

The effects of caste and education were attenuated in the mutually adjusted model. The reduced odds for diabetes remained consistent for scheduled tribes versus other caste groups (OR 0.72, 95% CI: 0.58, 0.90) as did an increased odds for those with secondary education versus no education (OR 1.18, 95% CI: 1.04, 1.35), however the graded relation with education was less consistent. The strong and graded relation between household wealth and diabetes remained consistent in this model with and odds ratio for diabetes of 3.65 (95% CI: 2.83, 4.78) for the richest versus the poorest groups.

Type-2 diabetes is strongly influenced by body weight.[36-38] Therefore, BMI was added to the final model to control for potential confounding of the SES-diabetes relationship in this sample. The odds ratios for caste and education remained consistent between the mutually adjusted model and final model which included BMI. The odds ratios for household wealth were further attenuated in the final model, however the positive graded association remained statistically significant with an adjusted odds ratio for those in the richest compared to the poorest households of 2.58 (95% CI: 1.99, 3.40).

Our analyses revealed dramatic variation in the prevalence of diabetes between states and local areas in India (**Table 3**). In an initial multilevel model adjusted for age and gender, states and local areas (defined as villages in rural areas and census blocks in urban areas) contributed 5.9% and 10.8%, respectively, to the total variation in diabetes. The addition of socioeconomic and demographic characteristics along with BMI to the model reduced the variance in diabetes attributed to local areas by 41% to 6.4% but the variation attributed to states was relatively unchanged at 5.4%.

Overall in India, the log odds for diabetes for the reference category (a 32 year old married women, with no education, BMI < 18.5 kg/m$^2$, belonging to the other caste group, in the poorest fifth of households, and living in a rural area) was -6.13 or a 0.22% probability of diabetes. Compared to this national reference point, being a resident of several Southern and Northeastern states was associated with a statistically significant increase in the odds of diabetes (**Figure 1**). The odds ratios for these sates were 2.29 (Tripura), 1.69 (Tamil Nadu), 1.69 (Kerala), 1.71 (Goa), 1.49 (Andhra Pradesh), and 1.56 (West Bengal). In contrast being resident of the states of Rajasthan, Jammu & Kashmir, Uttar Pradesh, Punjab, Madhya Pradesh, and Assam in Northern and Central India was associated with a statistically significant decrease (OR < 1) in the odds of reporting diabetes.

We conducted several sensitivity analyses to assess the consistency of our findings. First, we examined whether the observed associations were related to respondents' awareness and knowledge about diabetes. To do so, we considered responses to the question, "Do you have diabetes?" as a categorical variable, comparing "yes" and "don't know" versus "no" across the same set of independent variables using a multinomial logistic model. Associations between SES variables and positive reports of diabetes from this model, which included the possibility that respondents were unaware of their diabetes status, were nearly identical to findings from the logistic model which excluded those with unknown diabetes status (**Supplemental table 1**). The multinomial model also revealed that the richer and more highly educated respondents were less likely to report "do not know" as their diabetes status (compared to "no"). In addition, we examined BMI across the three categories of diabetes status (**Figure 3**). This revealed that those reporting "do not know" had the lowest BMI (mean 20.9, SD 3.7) which was largely consistent with the "no" group (mean 21.1, SD 3.9) and substantially lower than those reporting "yes" to diabetes (mean 24.4, SD 4.9). Finally, we examined interactions between socioeconomic variables (caste, education, wealth) and diabetes by residential location. Tests of these interactions were not statistically significant (P=0.20 for caste; P=0.72 for education; P=0.66 for wealth).

## DISCUSSION

In this study, we have two key findings. First, measures of SES were positively associated with self-reported diabetes in the NFHS-3. Although the observed effects of caste and education were largely attenuated in fully adjusted models, the effect of household wealth remained positive, graded and statistically significant even after controlling for BMI. Second, we observed a large variation in the prevalence of diabetes between local areas and States in India. A few Southern and northeastern states were associated with a higher risk for reporting diabetes while several northern and central states were at lower risk after adjusting for individual characteristics and place of residence.

There are a few limitations to our study. First, the outcome was defined on the basis of self-reported diabetes, although interviews were conducted in person using a standardized instrument. Previous research has shown good agreement for self-reported diabetes when compared to medical records in a US population.[39] In addition, our sensitivity analyses considering respondents who reported "did not know" for their diabetes status were nearly identical to the main analyses. We find, however, evidence that higher SES groups were less likely to report "did not know" as compared to "no", which has been suggested previously on studies using self-reports of diabetes status in India.[6] However, the "did not know" group was more similar in terms of BMI, education, and wealth to the "no" rather than "yes" group. In addition, our sample was relatively young (<55 y for men and <50 y for women). The prevalence of diabetes increases with age and whether a similar SES-diabetes relationship exists among middle and older age groups in India is not clear.

Our findings of positive SES-diabetes associations are consistent with previous studies done in different parts of India. For example, an analysis of rural participants from the Indian Migration Study, which sampled primarily from four large states in the north, centre, and south of India [8], identified a positive SES-diabetes gradient among men (8.0% prevalence in high SES group *v* 1.8% in low SES group), and a weaker positive SES-diabetes association that was not statistically significant among women (5.1% *v* 3.9%). In addition, a study done in an urban setting in Madras (Chennai) found an odds ratio for diabetes of 2.2 (95% credible interval [CI]: 1.7-2.7) for high *v* low SES groups.[9] One larger study conducted in urban and rural surveillance locations in Northern, Southern, Eastern, and Western/Central India identified an odds ratio of 3.0 (95% CI: 2.5-3.7) for self-reported diabetes for those with graduate level education versus those without formal schooling.[6] Importantly, these studies were limited to selected geographical areas or cities in India. Our study has added to this literature using a national population health survey with good coverage in rural areas across India.

Previous research in India has identified a strong positive relation between SES and BMI among women and men in India. [40-42] These studies are important because they have used similar markers of SES in the Indian context along with an objectively defined outcome (height and weight were measured in NFHS and not self-reported). BMI (along with other measures of body weight) is an important risk factor for the development of type 2 diabetes. [36 38 43] Therefore, the consistency of our findings of a positive SES-diabetes association after controlling for BMI is encouraging. If BMI is part of the causal pathway between SES and diabetes, attenuation in the effect size for markers of SES would be expected. The graded and positive relation between household wealth and diabetes after accounting for BMI suggests that there are additional effects of household wealth on diabetes that are not mediated by BMI.

When compared to other studies in India, the overall prevalence of diabetes in the NFHS-3 was not high. This may have resulted from a combination of using self-reports of diabetes, the younger age of the NFHS-3 target population, and sampling from the general population which included a high proportion of respondents in rural areas. Among individuals over 30 years of age, the prevalence was 2.5% (3.0 % in men and 2.2% in women). Other studies using in rural India using similar age groups and blood measurements have reported diabetes prevalence of 4% and a study from rural Andhra Pradesh found a prevalence of 12% based on combination self-report and blood measurements.[8 44]

The current national estimate for diabetes prevalence in India is about 7% of the adult population aged 20-79. This estimate is based on 3 relatively recent and larger scale studies using a combination of oral glucose tolerance testing and self-reports of diabetes.[4-6] There continues to be considerable uncertainty in estimates of diabetes for the whole of India due to the limited study locations (with a focus on urban areas), wide variation in survey sampling methodology, differences in diabetes diagnostic criteria, and age groups studied. These differences in study design have hindered direct comparison of the prevalence between studies, across regions and over time. The NFHS-3 provides and important benchmark because it is the first nationally-representative survey of diabetes in India. Even if the prevalence estimates of diabetes have been underestimated in the NFHS-3, the observed SES-diabetes associations are plausible and important. Previous studies have largely overlooked the importance of socioeconomic status markers, which may be a key determinant of diabetes. Further large-scale population-based surveys can be strengthened by using simple finger-prick blood glucose measurements in addition to self-reports.

There has been considerable concern over the rising prevalence of diabetes in India, especially with studies on migrant Indian populations suggesting that South Asians may be more susceptible to the disease. In light of current findings, it appears that, at present, the more well-off segments of the Indian population are at greatest risk. This poses concerns on how to appropriately balance priorities to address the disease burden that afflicts the non poor versus the poor in the context of India where 40-50 percent[45] of the population are poor.

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SVS and DJC planned the study. DJC conducted statistical analyses and drafted the manuscript with supervision from SVS. Both authors participated in interpretation of the results and critical revisions of the manuscript.

The NFHS data are available through the Measure DHS project at www.measuredhs.com.

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**Table 1**: Characteristics of survey participants and frequency distribution of self-reported diabetes in India, males and females from the 3rd National Family Health Survey

| | **Diabetes** | | **Total** |
|---|---|---|---|
| | **n** | **%** | **n** |
| Participants | 2439 | 1.5 | 168135 |
| Residence | | | |
| Rural | 818 | 1.0 | 86013 |
| Urban | 1621 | 2.0 | 82122 |
| Age group | | | |
| 18-29 y | 266 | 0.3 | 76174 |
| 30-39 y | 602 | 1.2 | 51132 |
| 40-49 y | 1238 | 3.4 | 36402 |
| 50-54 y | 333 | 7.5 | 4427 |
| Gender | | | |
| Male | 1144 | 1.8 | 65255 |
| Female | 1295 | 1.3 | 102880 |
| Marital status | | | |
| Single | 132 | 0.3 | 38078 |
| Married | 2165 | 1.8 | 123457 |
| Widowed | 108 | 2.5 | 4320 |
| Divorced or separated | 34 | 1.5 | 2280 |
| Religion | | | |
| Hindu | 1775 | 1.4 | 123411 |
| Muslim | 340 | 1.6 | 21510 |
| Christian | 213 | 1.4 | 14779 |
| Sikh | 49 | 1.5 | 3236 |
| Buddhist | 34 | 1.4 | 2451 |
| Other | 28 | 1.0 | 2748 |
| Social Caste | | | |
| Other caste | 1026 | 1.8 | 56063 |
| Scheduled caste | 349 | 1.3 | 27677 |
| Scheduled tribe | 167 | 0.8 | 21372 |
| Other backward class | 781 | 1.4 | 55641 |
| No caste | 116 | 1.6 | 7382 |
| Education | | | |
| No education | 464 | 1.0 | 44856 |
| Primary | 358 | 1.4 | 24969 |
| Secondary | 1166 | 1.6 | 74715 |

| | | | |
|---|---|---|---|
| Higher | 451 | 1.9 | 23595 |
| Household wealth | | | |
| Poorest | 77 | 0.4 | 17252 |
| 2 | 175 | 0.8 | 22948 |
| 3 | 278 | 0.9 | 32070 |
| 4 | 573 | 1.4 | 42091 |
| Richest | 1336 | 2.5 | 53774 |
| Body mass index (kg/m$^2$) | | | |
| <18.5 | 243 | 0.6 | 42128 |
| 18.5-23 | 703 | 0.9 | 74089 |
| 23-27.5 | 833 | 2.7 | 31217 |
| 27.5+ | 547 | 4.8 | 11502 |

**Table 2**: Associations between socioeconomic status and self-reported diabetes in India; 3rd National family health survey

| | Model adjusted for age, gender, marital status, religion, residence | | | Mutually adjusted model | | | Mutually adjusted model with BMI | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Odds ratio | 95% CI | | Odds ratio | 95% CI | | Odds ratio | 95% CI | |
| Caste | | | | | | | | | |
| Other caste | 1.00 | | | 1.00 | | | 1.00 | | |
| Scheduled caste | 0.81 | 0.71 , | 0.94 | 1.05 | 0.91 , | 1.21 | 1.07 | 0.93 , | 1.24 |
| Scheduled tribe | 0.57 | 0.46 , | 0.70 | 0.72 | 0.58 , | 0.90 | 0.73 | 0.57 , | 0.92 |
| Other backward caste | 0.84 | 0.75 , | 0.94 | 0.95 | 0.85 , | 1.07 | 0.96 | 0.86 , | 1.08 |
| No caste | 0.89 | 0.71 , | 1.11 | 0.94 | 0.75 , | 1.17 | 0.95 | 0.76 , | 1.20 |
| Wealth | | | | | | | | | |
| Poorest | 1.00 | | | 1.00 | | | 1.00 | | |
| 2nd quintile | 1.59 | 1.20 , | 2.12 | 1.57 | 1.21 , | 2.07 | 1.49 | 1.14 , | 1.96 |
| 3rd quintile | 1.63 | 1.23 , | 2.16 | 1.55 | 1.21 , | 2.02 | 1.39 | 1.07 , | 1.81 |
| 4th quintile | 2.42 | 1.85 , | 3.17 | 2.25 | 1.76 , | 2.92 | 1.79 | 1.40 , | 2.34 |
| Richest | 4.04 | 3.08 , | 5.30 | 3.65 | 2.83 , | 4.78 | 2.58 | 1.99 , | 3.40 |
| Education | | | | | | | | | |
| No education | 1.00 | | | 1.00 | | | 1.00 | | |
| Primary | 1.23 | 1.06 , | 1.43 | 1.06 | 0.91 , | 1.22 | 1.00 | 0.86 , | 1.17 |
| Secondary | 1.68 | 1.49 , | 1.90 | 1.18 | 1.04 , | 1.35 | 1.12 | 0.98 , | 1.28 |
| Higher | 1.87 | 1.61 , | 2.18 | 1.12 | 0.95 , | 1.32 | 1.01 | 0.86 , | 1.20 |
| Body mass index | | | | | | | | | |
| <18.5 | | | | | | | 1.00 | | |
| 18.5-23 | | | | | | | 1.25 | 1.08 , | 1.46 |
| 23-27.5 | | | | | | | 2.08 | 1.79 , | 2.44 |
| 27.5+ | | | | | | | 2.98 | 2.51 , | 3.54 |

**Table 3:** Variance in self-reported diabetes status between local areas and states in India; expressed as percentage of the contribution to the total variance in diabetes

| | Age & gender adjusted* | | | Fully adjusted** | | |
|---|---|---|---|---|---|---|
| | Variance | SE | % | Variance | SE | % |
| States | 0.231 | 0.076 | 5.9 | 0.204 | 0.068 | 5.4 |
| Local areas | 0.425 | 0.043 | 10.8 | 0.240 | 0.041 | 6.4 |

*Multilevel model adjusted for age and gender only
**Multilevel model fully adjusted for age, gender, marital status, religion, social caste, household wealth, education, body mass index, and place of residence

## FIGURE LEGENDS

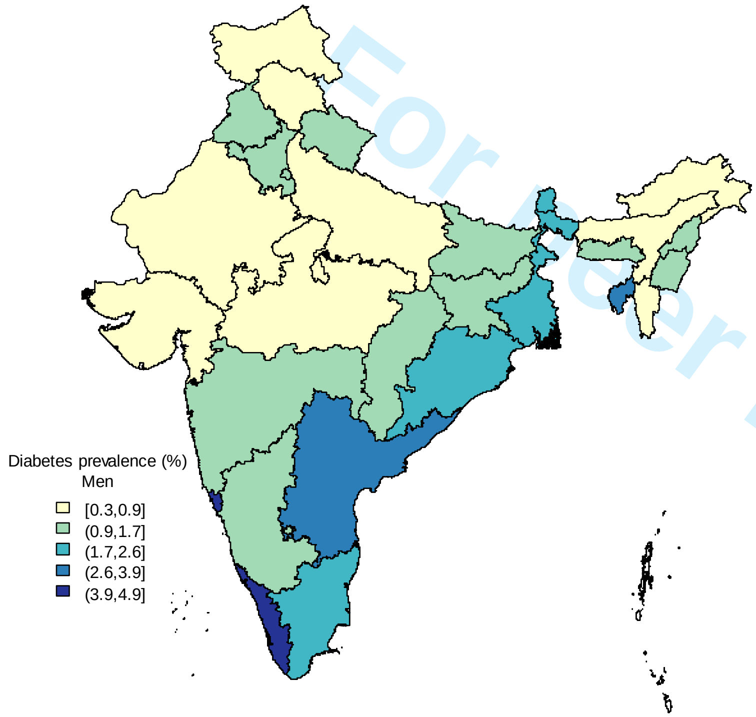
**Figure 1** State level prevalence of self-reported diabetes in India for men aged 18-54 (left) and women aged 18-49 (right). Darker colours indicate higher prevalence.

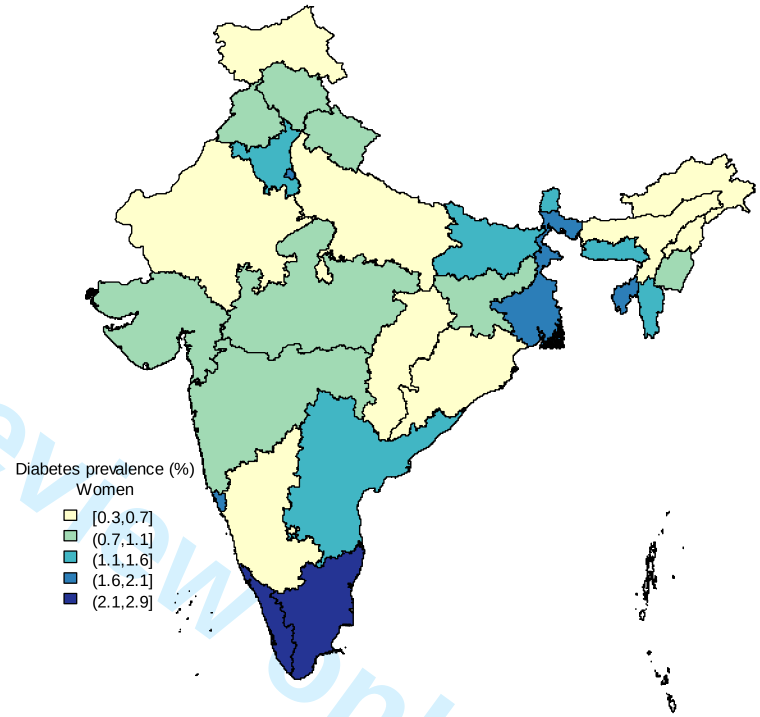
**Figure 2** Odds ratios for self-reported diabetes by state of residence in India; adjusted for age, gender, marital status, religion, social caste, household wealth, education, body mass index and place of residence.

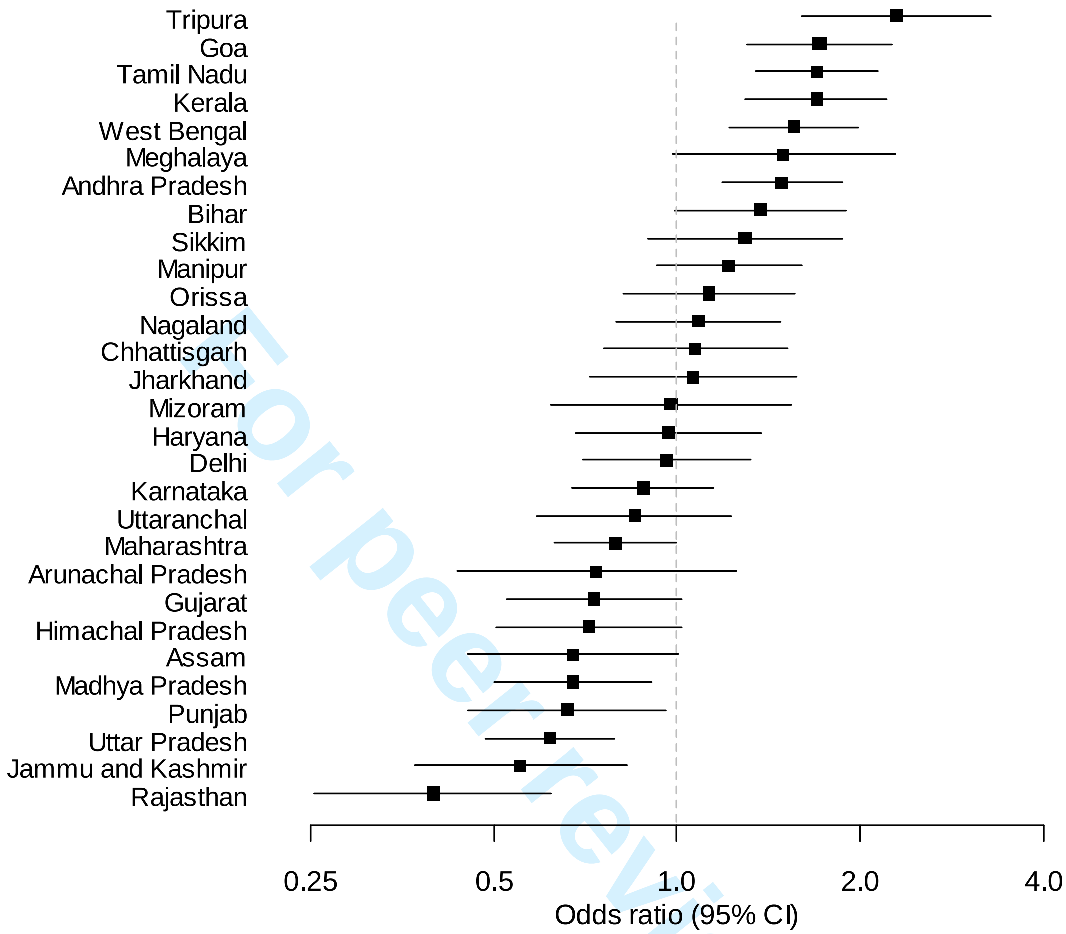
**Figure 3** Mean body mass index across three possible responses for self-reported diabetes (diabetes status not known, No- do not have diabetes, Yes- have diabetes). Vertical lines represent 95% confidence intervals. Body mass index (in $kg/m^2$) objectively defined based on measured height and weight values.

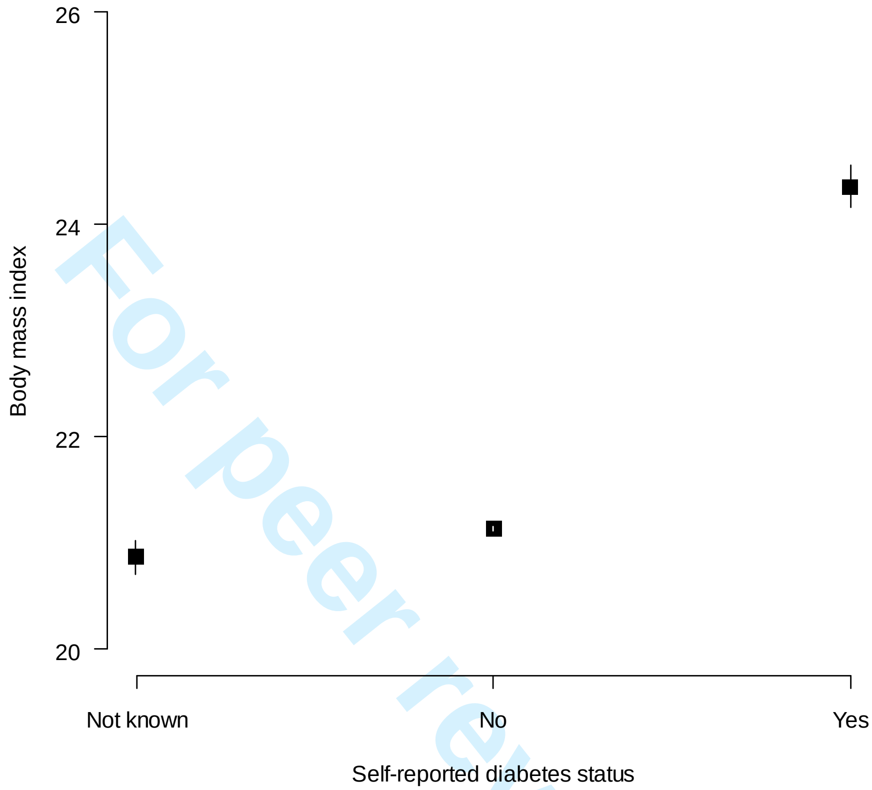
**Supplementary Table 1** Associations between socioeconomic status, self-reported diabetes, and unknown diabetes status using a multinomial regression model.

| | Diabetes | | Diabetes not known | |
|---|---|---|---|---|
| Variable | Odds ratio | 95% CI | Odds ratio | 95% CI |
| Caste | | | | |
| Other caste | 1.00 | | 1.00 | |
| Scheduled caste | 1.07 | 0.93 , 1.24 | 1.13 | 0.96 , 1.31 |
| Scheduled tribe | 0.73 | 0.58 , 0.91 | 1.52 | 1.25 , 1.84 |
| Other backward caste | 0.96 | 0.86 , 1.08 | 1.07 | 0.93 , 1.23 |
| No caste | 0.95 | 0.75 , 1.18 | 0.76 | 0.58 , 0.99 |
| Wealth | | | | |
| Poorest | 1.00 | | 1.00 | |
| 2nd quintile | 1.51 | 1.14 , 2.03 | 0.90 | 0.77 , 1.05 |
| 3rd quintile | 1.41 | 1.07 , 1.89 | 0.86 | 0.73 , 1.01 |
| 4th quintile | 1.82 | 1.38 , 2.44 | 0.82 | 0.68 , 0.98 |
| Richest | 2.63 | 1.97 , 3.56 | 0.64 | 0.51 , 0.79 |
| Education | | | | |
| No education | 1.00 | | 1.00 | |
| Primary | 1.00 | 0.87 , 1.17 | 0.86 | 0.76 , 0.99 |
| Secondary | 1.12 | 0.98 , 1.28 | 0.71 | 0.63 , 0.81 |
| Higher | 1.01 | 0.85 , 1.21 | 0.45 | 0.36 , 0.57 |
| Body mass index | | | | |
| <18.5 | 1.00 | | 1.00 | |
| 18.5-23 | 1.26 | 1.08 , 1.46 | 1.03 | 0.93 , 1.15 |
| 23-27.5 | 2.09 | 1.79 , 2.45 | 1.17 | 1.01 , 1.36 |
| 27.5+ | 2.99 | 2.52 , 3.55 | 1.33 | 1.06 , 1.66 |


Diabetes prevalence (%)
Men
[0.3,0.9]
(0.9,1.7]
(1.7,2.6]
(2.6,3.9]
(3.9,4.9]


Diabetes prevalence (%)
Women
[0.3,0.7]
(0.7,1.1]
(1.1,1.6]
(1.6,2.1]
(2.1,2.9]


Tripura
Goa
Tamil Nadu
Kerala
West Bengal
Meghalaya
Andhra Pradesh
Bihar
Sikkim
Manipur
Orissa
Nagaland
Chhattisgarh
Jharkhand
Mizoram
Haryana
Delhi
Karnataka
Uttaranchal
Maharashtra
Arunachal Pradesh
Gujarat
Himachal Pradesh
Assam
Madhya Pradesh
Punjab
Uttar Pradesh
Jammu and Kashmir
Rajasthan
0.25
0.5
1.0
2.0
4.0
Odds ratio (95% CI)


26
24
22
20
Body mass index
Not known
No
Yes
Self-reported diabetes status

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

**Article: Association between socioeconomic status and diabetes in India**

**Authors: Daniel J Corsi, SV Subramanian**

| | Item No | Recommendation |
|---|---|---|
| **Title and abstract** | 1 | (*a*) Design cross-sectional study, listed in abstract |
| | | (*b*) abstract and article summary (page 3) |
| **Introduction** | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported, (abstract, page 3, page 4-5) |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses (abstract, page 3, page 4-5) |
| **Methods** | | |
| Study design | 4 | Present key elements of study design early in the paper (abstract, page 6) |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection (abstract, page 5-7) |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants (page 6) |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable (page 7) |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group (page 7-8) |
| Bias | 9 | Describe any efforts to address potential sources of bias (page 8-9; page 12) |
| Study size | 10 | Explain how the study size was arrived at (page 7) |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why (page 8) |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding (page 8-9) |
| | | (*b*) Describe any methods used to examine subgroups and interactions (page 12) |
| | | (*c*) Explain how missing data were addressed (page 7) |
| | | (*d*) If applicable, describe analytical methods taking account of sampling strategy (page 8) |
| | | (*e*) Describe any sensitivity analyses (page 12) |
| **Results** | | |
| Participants | 13 | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (page 8) |
| | | (b) Give reasons for non-participation at each stage (n/a) |
| | | (c) Consider use of a flow diagram (n/a) |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (page 9-10, table 1) |
| | | (b) Indicate number of participants with missing data for each variable of interest (page 7; page 12) |
| Outcome data | 15* | Table 1 |
| Main results | 16DJC | (*a*) Tables 1 (unadjusted), 2 (age, gender, marital status, religion, place of residence adjusted; and fully adjusted model) |

| | | |
|---|---|---|
| | | (*b*) Report category boundaries when continuous variables were categorized (in methods, e.g. for BMI) |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period (n/a) |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses (Page 12) |
| **Discussion** | | |
| Key results | 18 | Summarise key results with reference to study objectives (page 13) |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias (page 13) |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence (page 16) |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results (pages 14-15) |
| **Other information** | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based (title page) |

*Give information separately for exposed and unexposed groups.

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

# Association between socioeconomic status and self-reported diabetes in India: a cross-sectional multilevel analysis

| | |
|---|---|
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| <b>Primary Subject Heading</b>: | Epidemiology |
| Secondary Subject Heading: | Diabetes and endocrinology |
| Keywords: | Socioeconomic factors, India, Noncommunicable disease, Diabetes, Geography, Multilevel |
| | |

**Title** Association between socioeconomic status and self-reported diabetes in India: a cross-sectional multilevel analysis

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**Running head** Socioeconomic status and diabetes in India

**Word count**: 3,340

**Funding Statement** This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors

**Conflict of Interest**: Authors declare no conflict of interest.

## ABSTRACT

**Objectives** To quantify the association between socioeconomic status (SES) and type-2 diabetes in India

**Design** Nationally representative cross-sectional household survey

**Setting** Urban and rural areas across 29 states in India

**Participants** 168,135 survey respondents aged 18-49 y (women) and 18-54 y (men)

**Primary outcome measure** Self-reported diabetes status

**Results** Markers of SES were social caste, household wealth, and education. The overall prevalence of self-reported diabetes was 1.5%; this increased to 1.9% and 2.5% for those with the highest levels of education and household wealth, respectively. In multilevel logistic regression models (adjusted for age, gender, religion, marital status, and place of residence) education (odds ratio 1.87 for higher education *vs* no education) and household wealth (odds ratio 4.04 for richest quintile *vs* poorest) were positively related to self-reported diabetes (P<0.0001). In a fully adjusted model including all socioeconomic variables and body mass index (BMI), household wealth emerged as positive and statistically significant with an odds ratio for self-reported diabetes of 2.58 (95% credible interval [CI]: 1.99-3.40) for the richest quintile of household wealth versus the poorest. Nationally in India a one-quintile increase in household wealth was associated with an odds ratio of 1.31 (95% CI: 1.20-1.42) for self-reported diabetes. This association was consistent across states with the relationship found to be positive in 97% (28 of 29 states) and statistically significant in 69% (20 of 29).

**Conclusions** We found that the highest socioeconomic status groups in India appear to be at greatest risk for type-2 diabetes. This raises important policy implications for

addressing the disease burdens among the poor versus those among the non poor in the context of India, where greater than 40 percent of the population is living in poverty.

## ARTICLE SUMMARY

### Article Focus

- The relationship between socioeconomic factors and type-2 diabetes has not been previously studied for the whole of India and across states
- Our objective was to investigate associations between measures of socioeconomic status (defined as social caste, education, household wealth) and self-reported diabetes status in India
- In addition we explored geographic variation in the prevalence of diabetes between states and local areas in India and between-state variability in the SES-diabetes relationship

### Key messages

- The highest socioeconomic groups appear to be at greatest risk for diabetes in India; with the strength of the association consistent in size and magnitude across states
- There is substantial geographic heterogeneity in the prevalence of diabetes
- These findings raise important policy implications for in addressing the disease burdens among the poor versus those among the non poor in the context of India, where nearly half of the population is living in poverty.

### Strengths and Limitations

- The key strength of this study is the use of a large, nationally-representative survey to assess the socioeconomic and geographic patterning of diabetes across all of India. Limitations include the relatively younger age of the sample and assessment of diabetes status on the basis of self-reports.

## INTROCUTION

The prevalence of type-2 diabetes in India has been investigated in numerous population based surveys conducted across a range of settings since the 1970s.[1-6] Despite multiple prevalence studies, no nationally representative studies exist which have considered the association between socioeconomic status (SES) and type-2 diabetes in India. In a review of 15 existing studies which have reported the prevalence of type-2 diabetes by SES and/or associations between SES and type-2 diabetes, all were found to have been based on local or regional samples and a majority were done in urban areas[4 6-19] (**Table 1**). It has been suggested that the prevalence of type-2 diabetes and other cardiovascular disease risk factors may increasingly become concentrated among low SES groups in India[20] and other low- and middle-income countries[21], although to date the empirical evidence from India in support of this hypothesis remains limited. The majority of studies reviewed in table 1 have provided evidence of a positive association between SES (defined as education, household wealth, social caste, or a composite of 2 or more markers) and diabetes among populations from selected geographic regions in India [6 11 17]; however the strength and consistency of this association across the whole of India has not previously been assessed.

Type-2 diabetes is the most common form of diabetes globally, accounting for greater than 85% of cases.[22] The incidence of type-2 diabetes is related to genetic and non-genetic components, with the latter being greatly influenced by modifiable risk factors such as obesity, diets low in fibre and high in trans fat, and physical inactivity.[23-24] Lifestyle behaviours are strongly patterned by SES [25], and may be mediators on the causal pathway between SES and the onset of type-2 diabetes.[26] In high income countries, the SES-diabetes relationship appears to be negative, with the poor at greatest risk. For example, strong associations have been observed between poverty, low education and type-2 diabetes among African American women [27-28], and among White women and men in the United States.[29] Similarly, a study from Canada described an inversely graded SES-diabetes association with an odds ratio of 1.9 for men (95% CI: 1.6-2.4) and 2.8 (95% CI: 2.2-3.4) for women for the lowest versus highest income groups.[30] A recent meta-analysis of 23 case-control and cohort studies and 43 measures of SES-diabetes association revealed an overall increased risk for type-2 diabetes for low SES groups based on education, occupation, and income.[31] The strength of the association, however, was less consistent in low and middle income countries (LMICs), and few studies have been conducted in these countries.

Concern has been raised over the anticipated rapid increase in type-2 diabetes prevalence in India.[32-33] Evidence on the secular increases in diabetes prevalence in India, however, have been limited to urban areas of Southern India[4 34-35], and have focused on the mean rates of diabetes rather than how it is distributed in the population. In this paper we address the need to comprehensively investigate the socioeconomic and geographic distribution of type-2 diabetes in the Indian population using a large-scale nationally representative survey. Specifically, we investigate the SES-diabetes association through the SES markers of social caste, household wealth, and education. In addition, we investigate the geographic distribution of the prevalence of diabetes across states and local areas along with variability in the SES-diabetes association across states.

## METHODS

**Data source**

We use data from the 3rd National Family Health Survey (NFHS), conducted in 29 states in India between November 2005 and August 2006.[36] NFHS-3 is a major national health survey in India which collected information on a range of indicators including reproductive health, nutritional status of adults and children, utilization of health care services, and blood testing for HIV prevalence. NFHS-3 covered all states in India, which comprise nearly 99% of the population, but excluded Union Territories. The survey was designed to provide estimates of key indicators (except HIV prevalence) for each state by urban and rural areas.

**Survey design**

A uniform multistage sampling strategy was adopted in all states, with separate sampling in urban and rural areas.[37-38] In rural areas, a two stage sample was carried out using a list of villages from the 2001 census as the sampling frame. In the first stage, a stratified sample of villages was drawn with probability proportional to the size of the village. In the second stage, a random selection of households was drawn in each village from a complete list of households complied during field visits carried out in each sampled village. In urban areas, a similar procedure was implemented beginning with a stratified random sample of municipal wards based on the 2001 census. Next, one census enumeration block (150-200 households) was selected from within wards using probability proportional to size. Finally, as in rural areas, field enumerators undertook a household listing operation in selected blocks and a random sample of households was made. In both rural and urban areas, 30 households were targeted for selection in each of the sampled units. The overall household response rate for NFHS-3 was 98%.[36]

All women aged 15-49 in selected households were invited to participate in the survey. In 22 states, men aged 15-54 in a random subsample of households drawn from each PSU (about 6 households per PSU) were eligible for the men's survey. In the remaining seven states (Andhra Pradesh, Karnataka, Maharashtra, Manipur, Tamil Nadu, Uttar Pradesh, and Nagaland) eligible men all in selected households were invited to participate. The additional men recruited in these states was for the purpose of HIV testing to provide reliable state level estimates of HIV prevalence in certain states. Interviews were conducted in 1 of the 18 Indian languages in the respondent's home and the response rates were 95% for women and 87% for men.[36] During interviews, the weights and heights of survey respondents were measured by trained field technicians using standardized measuring equipment designed for survey settings.[39]

In total NFHS-3 collected information from 109,041 households, 124,385 women from 15 to 49 years of age, and 74,369 men from 15 to 54 years of age. We restricted our analyses to adults aged 18 years and older and non-pregnant women (n=171,207). Respondents who did not report or know their diabetes status (n= 2,373) or with incomplete information for any of the independent variables considered in the analysis (marital status, religion, caste, education, household wealth) were excluded (n=699). Main analyses were conducted on a sample of 168,135 respondents, (65,255 men and 102,880 women). Additional analyses considering body mass index (BMI) were restricted to a sample of 158,936 due to missing and/or implausible values for height and/or weight. **Figure 1** provides a flow diagram detailing the NFHS sample, exclusions, and final analytic sample sizes.

**Outcome and independent variables**

The primary outcome was diabetes, assessed on the basis of self-reports by survey respondents. Markers of socioeconomic status were social caste, household wealth, and education Social caste was reported by the household head. The categories were Other Caste, Scheduled caste, Scheduled tribe, Other Backward Class, and No Caste. Other Caste is a heterogeneous group that is traditionally viewed as having higher social status. Scheduled castes and scheduled tribes are considered lower, socially marginalized groups in India.[40] Household wealth was defined by an index based on indicators of asset ownership and housing characteristics.[41] This index has been developed and validated in a number of countries to be a robust measure of wealth and has been found to be consistent with measures of income and expenditure.[42] Briefly, the measure was constructed as follows. Information on 33 indicators of housing characteristics (e.g., type of windows and flooring, water and sanitation facilities) and assets (e.g., ownership of home, car, computer, mobile phone) were weighted and combined with weights derived from a principal component analysis procedure.[36] The resulting variable was standardized to a mean of 0 and standard deviation of 1 and using this index the household population was divided into fifths from poorest to richest. Education was categorized in four levels as no education, primary, secondary, or higher education.

Background characteristics included age, gender, religion, marital status, place of residence, and BMI. Age was defined in 10 year categories and centred about its mean (32 years) in regression models. Gender was based on self-report. Religion was categorized as Hindu, Muslim, Sikh, Buddhist, or other religion. Marital status was defined as single, married, widowed, or separated. Place of residence (rural or urban) was defined according to the 2001 Census. BMI (in kg/$m^2$; weight in kilograms divided by the square of height in meters) was calculated for all survey respondents with valid measurements for weight and height. BMI was classified according to the following categories based on risk of type 2 diabetes and cardiovascular disease in Asian populations; less than 18.5 kg/$m^2$ (underweight); 18.5-22.9 kg/$m^2$ (acceptable risk); 23-27.4 kg/$m^2$ (increased risk); and 27.5 kg/$m^2$ or greater (high risk).[43]

**Analysis**

To account for the complex survey design, we employed multilevel logistic regression to model the probability of diabetes.[44] A three-level model was specified with a binary response (*y*, diabetes or not) for individual *i* in local area (village or census block primary sampling units) *j* in state *k*. The outcome diabetes, $\Pr(y_{ijk} = 1)$, was assumed to be binomially distributed $y_{ijk} \sim Binomial(1, \pi_{ijk})$ with probability $\pi_{ijk}$ related to the set of independent variables X and a random effect for each level by a logit link function:

$$Logit(\pi_{ijk}) = \beta_0 + \beta X_{ijk} + v_{0k} + u_{0jk}\,. \quad \text{(Equation 1)}$$

The right hand side of the equation consists of the fixed part linear predictor ($\beta_0 + \beta X_{ijk}$) and random intercepts attributable to states ($v_{0k}$) and local areas ($u_{0jk}$). The intercept, $\beta_0$ represents the log odds of diabetes in the reference group, and the $\beta$-coefficients represent the differential in the log odds of diabetes compared to the reference group defined for each independent variable. Coefficients were exponentiated and presented as odds ratios for interpretation. The random intercepts are assumed to be independently and identically distributed and have variances estimated for states ($\sigma_v^2$) and local areas ($\sigma_u^2$).[45] The variance parameters quantify heterogeneity in the log odds of diabetes at each level, after taking into account individual characteristics and place of residence in the fixed part. We expressed the variances at each level as a percentage of their contribution to the total variance from an initial model adjusting for age and gender only and from a final model accounting for all covariates. We specified a sequence of six models during analyses. In the first three models, one SES marker (social caste, household wealth, education) was added to a model which adjusted for background characteristics (age, gender, religion, and place of residence). In the fourth mutually adjusted model, all SES markers were included along with background characteristics from the previous models. In the fifth model, BMI was included with markers of SES and background characteristics from model 4. In the sixth model, we also tested whether the association between household wealth varied across states in terms of strength or direction, given that different states vary tremendously by levels of economic development and could be considered at different levels of epidemiological transition. In order to test this between state variability we expanded Equation 1 to allow the slope of household wealth to vary across states:

$$Logit(\pi_{ijk}) = \beta_0 + \beta_{1k} wealth_{ijk} + \beta X_{ijk} + v_{0k} + v_{1k} + u_{0jk}$$ . (Equation 2)

The key feature of Equation 2 is that the effect of wealth on self-reported diabetes in state $k$ consists of the overall average effect across all states ($\beta_1$), plus a state-specific ($v_{1k}$) differential in this effect. We summarized and presented the results of this model as the odds ratio for self-reported diabetes overall in India and for each state given a 1-quintile increase in household wealth and conditional on all covariates from model 5. Additional analyses were carried out separately for male and female samples using an identical sequence of models (with the exclusion of gender as a background characteristic).

Estimation of models was done using Markov Chain Monte Carlo (MCMC) simulation and the statistical software *MLwiN*.[46-47]

## RESULTS

Characteristics of survey respondents by their self-reported diabetes status are given in **Table 2**. The overall prevalence of diabetes in this sample was 1.5% and this was higher in urban areas and among men (diabetes prevalence 2.0 % in urban *v* 1.0% in rural; 1.8% in men *v* 1.3% in women). Diabetes prevalence increased with age (7.5% in 50-54y *v* 0.3% in 18-29y), education (1.9% in higher *v* 1.0% in no education), household wealth (2.5% in richest *v* 0.4% in poorest), and BMI (4.8% in 27.5+ $kg/m^2$ *v* 0.6% in <18.5 $kg/m^2$). At the state level, the prevalence of diabetes varied between 0.3% in Rajasthan and 3.3% in Kerala and was generally higher in Southern and Eastern states (**Figure 2**).

In separate models that adjusted for age, marital status, religion, and place of residence, statistically significant associations were observed between SES and self-reported diabetes for each of the primary markers of SES in this study: social caste, household wealth, and education. Compared to the other caste group, scheduled casts, scheduled tribes, and other backward classes had reduced odds of having diabetes with odds ratios of 0.81 (95% CI: 0.71-0.94), 0.57 (95% CI: 0.46-0.70), and 0.84 (95% CI: 0.75-0.94), respectively (**Table 3**, Models 1-3). Education showed a graded relation with diabetes and an odds ratio of 1.87 (95% CI: 1.61-2.18) for those with higher education versus those with no education. Household wealth showed a graded association with diabetes with individuals from the richest households having an odds ratio for diabetes of 4.04 (95% CI: 3.08-5.30) compared to those from the poorest households.

The effects of social caste and education were attenuated in the mutually adjusted model (model 4), suggesting that their independent effects on self-reported diabetes were at least partially mediated by the inclusion of household in this model. The reduced odds for diabetes remained consistent for scheduled tribes versus other caste groups (OR 0.72, 95% CI: 0.58-0.90) as did an increased odds for those with secondary education versus no education (OR 1.18, 95% CI: 1.04-1.35), however the graded relation with education was less consistent. In separate mutually adjusted models that were stratified by gender, education showed a graded association in men although it was not statistically significant with the odds ratio for diabetes men found to be 1.27 (95% CI: 0.98-1.70) for men with higher versus no education (**Supplemental Table 1**). Among women, those with secondary education continued to show an increased odds of self-reported diabetes compared to those with no education (OR 1.28, 95% CI: 1.08-1.50). Overall, the strong and graded relation between household wealth and diabetes remained consistent in model 4 with an odds ratio for diabetes of 3.65 (95% CI: 2.83, 4.78) for the richest versus the poorest groups; similar associations were found in the gender-specific models (Supplemental Table 1). Type-2 diabetes is strongly influenced by body weight.[48-50] Therefore, BMI was added to model 5 to control for potential confounding of the SES-diabetes relationship in this sample. In addition, BMI was added separately in this model because its inclusion resulted in the reduction of sample size by ~5% due to missing values for BMI. The odds ratios for caste and education remained consistent between the mutually adjusted model and final model which included BMI. The odds ratios for household wealth were further attenuated in the final model, however the positive graded association remained statistically significant with an adjusted odds ratio for those in the richest compared to the poorest households of 2.58 (95% CI: 1.99-3.40).

Our analyses revealed dramatic variation in the prevalence of diabetes between states and local areas in India (**Table 4**). In an initial multilevel model adjusted for age and gender, states and local areas (defined as villages in rural areas and census blocks in urban areas) contributed 5.9% and 10.8%, respectively, to the total variation in diabetes. The addition of socioeconomic and demographic characteristics along with BMI to the model reduced the variance in diabetes attributed to local areas by 41% to 6.4% but the variation attributed to states was relatively unchanged at 5.4%.

Overall in India, the log odds for diabetes for the reference category (a 32 year old married women, with no education, BMI <18.5 kg/m$^2$, belonging to the other caste group, in the poorest fifth of households, and living in a rural area) was -6.13 or a 0.22% probability of diabetes. Compared to this national reference point, being a resident of several Southern and Northeastern states was associated with a statistically significant increase in the odds of diabetes (**Figure 3**). The odds ratios for self-reported diabetes these sates were: 2.29 (Tripura), 1.69 (Tamil Nadu), 1.69 (Kerala), 1.71 (Goa), 1.49 (Andhra Pradesh), and 1.56 (West Bengal). In contrast being resident of the states of Rajasthan, Jammu & Kashmir, Uttar Pradesh, Punjab, Madhya Pradesh, and Assam in Northern and Central India was associated with a statistically significant decrease (OR < 1.0) in the odds of self-reported diabetes.

In order to assess the variability in the SES-diabetes association across states in India, a final model (model 6) was specified to allow the odds ratio for diabetes for a one-quintile increase in household wealth to vary across states. In this model, the overall odds ratio for diabetes in India for a one-quintile increase in household wealth was 1.31 (95% CI: 1.20-1.42) (**Figure 4**). In 15 states, the association was stronger than the national average; varying between an odds ratio of 1.33 in Rajasthan and 1.55 in Jammu & Kashmir. Although the association was less than the national average in 14 states, it was found to be positive in 28/29 (97%) states and statistically significant in 20/29 (69%). Only in West Bengal was an inverse association observed, but it was not statistically significant (OR 0.95 95% CI: 0.83-1.09). Odds ratios and 95% CI for the overall association and across all states are presented in **Supplemental Table 2**. In summary, the association between household wealth and self-reported diabetes was consistent across the states both in direction and magnitude.

We conducted several sensitivity analyses to assess the consistency of our findings. First, we examined whether the observed associations were related to respondents' awareness and knowledge about diabetes. To do so, we considered responses to the question, "Do you have diabetes?" as a categorical variable, comparing "yes" (diabetic) and "don't know" (unknown) versus "no" (non-diabetic) across the same set of independent variables using a multinomial logistic model. Associations between SES variables and positive reports of diabetes from this model, which included the possibility that respondents were unaware of their diabetes status, were nearly identical to findings from the logistic model which excluded those with unknown diabetes status (**Supplemental Table 3**). The multinomial model also revealed that the richer and more highly educated respondents were less likely to report unknown status compared to non-diabetic. In addition, we examined BMI across the three categories of diabetes status

(**Figure 5**). This revealed that those with unknown diabetes had the lowest BMI (mean 20.9, SD 3.7) which was largely consistent with the non-diabetic group (mean 21.1, SD 3.9) and substantially lower than those with self-reported diabetes (mean 24.4, SD 4.9). Finally, we examined interactions between socioeconomic variables (caste, education, wealth) and diabetes by residential location. Tests of these interactions were not statistically significant (P=0.20 for caste; P=0.72 for education; P=0.66 for wealth).

## DISCUSSION

In this study, we have three key findings. First, measures of SES were positively associated with self-reported diabetes in the NFHS-3. Although the observed effects of caste and education were largely attenuated in fully adjusted models, the effect of household wealth remained positive, graded and statistically significant even after controlling for BMI. Second, we observed a large variation in the prevalence of diabetes between local areas and States in India. A few Southern and northeastern states were associated with a higher risk for reporting diabetes while several northern and central states were at lower risk after adjusting for individual characteristics and place of residence. Lastly, the observed association between household wealth and self-reported diabetes was consistent, positive, and statistically significant across a majority of states in India.

There are a few limitations to our study. First, the outcome was defined on the basis of self-reported diabetes, although interviews were conducted in person using a standardized instrument. Previous research has shown good agreement for self-reported diabetes when compared to medical records in a US population [51], and that that self-reported health conditions demonstrate the expected relationship with SES in India.[52] In addition, our sensitivity analyses considering respondents who reported "unknown" for diabetes status were nearly identical to the main analyses. We did find, however, evidence that higher SES groups were less likely to report "did not know" as compared to "no", which has been suggested previously on studies using self-reports of diabetes status in India.[6] However, the unknown group was more similar in terms of BMI, education, and wealth to the non-diabetic rather than diabetic group. In addition, our findings of positive SES-diabetes associations were consistent with several studies identified in our literature review which used blood glucose measurements for the assessment of diabetes status (summarized in Table 1). Lastly, although our sample was relatively young (<55 y for men and <50 y for women) it is representative of the young population of profile of India; 84% of the Indian adult population (18-69 y) and 47% of the total Indian population at all ages fall within the ages covered by this study.[53] Our study does exclude approximately 12% of the Indian population (women over the age of 50 and men over the age of 55) due to the sample design of the NFHS. The prevalence of diabetes increases with age and whether a similar SES-diabetes relationship exists among middle and older age groups in all parts India is not clear, although our findings are consistent with previous studies which have included older ages.

Our findings of positive SES-diabetes associations are consistent with previous studies done in different parts of India. For example, an analysis of rural participants from the Indian Migration Study, which sampled primarily from four large states in the north, centre, and south of India [17], identified a positive SES-diabetes gradient among men (8.0% prevalence in high SES group *v* 1.8% in low SES group), and a weaker positive SES-diabetes association that was not statistically significant among women (5.1% *v* 3.9%). In addition, a study done in an urban setting in Madras (Chennai) found an odds ratio for diabetes of 2.2 (95% confidence interval [CI]: 1.7-2.7) for high *v* low SES groups.[11] One larger study conducted in urban and rural surveillance locations in Northern, Southern, Eastern, and Western/Central India identified an odds ratio of 3.0 (95% CI: 2.5-3.7) for self-reported diabetes for those with graduate level education versus those without formal schooling.[6] Importantly, these studies were limited to selected geographical areas or cities in India. Our study has added to this literature using a national population health survey with good coverage in rural areas across India.

Previous research in India has identified a strong positive relation between SES and BMI among women and men in India. [54-56] These studies are important because they have used similar markers of SES in the Indian context along with an objectively defined outcome (height and weight were measured in NFHS and not self-reported). BMI (along with other measures of body weight) is an important risk factor for the development of type 2 diabetes. [48 50 57] Therefore, the consistency of our findings of a positive SES-diabetes association after controlling for BMI is encouraging. If BMI is part of the causal pathway between SES and diabetes, attenuation in the effect size for markers of SES would be expected. The graded and positive relation between household wealth and diabetes after accounting for BMI suggests that there are additional effects of household wealth on diabetes that are not mediated by BMI. The effects of social caste and education were largely attenuated after the inclusion of household wealth and prior to the inclusion of BMI. Household wealth was the strongest socioeconomic factor associated with self-reported diabetes, suggesting that social and behavioural changes associated with diabetes in India may be more closely related to increasing wealth and/or standard of living than educational attainment.

When compared to other studies in India, the overall prevalence of diabetes in the NFHS-3 was not high. This may have resulted from a combination of using self-reports of diabetes, the younger age of the NFHS-3 target population, and sampling from the general population which included a high proportion of respondents in rural areas. Among individuals over 30 years of age, the prevalence was 2.5% (3.0 % in men and 2.2% in women). Other studies using in rural India using similar age groups and blood measurements have reported diabetes prevalence of 4% and a study from rural Andhra Pradesh found a prevalence of 12% based on combination self-report and blood measurements.[17 58]

The current national estimate for diabetes prevalence in India is about 7% of the adult population aged 20-79. This estimate is based on 3 relatively recent and larger scale studies using a combination of oral glucose tolerance testing and self-reports of diabetes.[4-6] There continues to be considerable uncertainty in estimates of diabetes for the whole of India due to the limited study locations (with a focus on urban areas), wide variation in survey sampling methodology, differences in diabetes diagnostic criteria, and age groups studied. These differences in study design have hindered direct comparison of the prevalence between studies, across regions and over time. The NFHS-3 provides and important benchmark because it is the first nationally-representative survey of diabetes in India. Even if the prevalence estimates of diabetes have been underestimated in the NFHS-3, the observed SES-diabetes associations are plausible and important. Previous studies have largely overlooked the importance of socioeconomic status markers, which may be a key determinant of diabetes. Further large-scale population-based surveys can be strengthened by using simple finger-prick blood glucose measurements in addition to self-reports.

There has been considerable concern over the rising prevalence of diabetes in India, especially with studies on migrant Indian populations suggesting that South Asians may be more susceptible to the disease. In light of current findings, it appears that, at present, the more well-off segments of the Indian population are at greatest risk. This poses concerns on how to appropriately balance priorities to address the disease burden that afflicts the non poor versus the poor in the context of India where greater than 40% of the population continue to live in extreme poverty on less than $1.25 per day.[59]

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SVS and DJC planned the study. DJC conducted statistical analyses and drafted the manuscript with supervision from SVS. Both authors participated in interpretation of the results and critical revisions of the manuscript.

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**Table 1** Overview of studies reporting prevalence of type-2 diabetes by markers of socioeconomic status (SES) and the association between increasing SES and diabetes in India

| **Author** | **Study period** | **Coverage** | **Setting** | **Age** | **Sample size** | **Diabetes assessment** | **SES marker** | **Gender** | **Diabetes prevalence: low SES (l); high SES (h)** | **SES-diabetes associatio Odds ratio (95% confidence interval) for high SES vs low SES** |
|---|---|---|---|---|---|---|---|---|---|---|
| Singh[7] | 1994 | Local | Rural | 25-64 | 1769 | blood glucose | Composite | Male | 0.9% (l); 6.1% (h)* | - |
| | | | | | | | | Female | 0.9% (l); 6.9% (h)* | - |
| Singh[8] | 1994 | Local | Rural | 25-64 | 1806 | blood glucose | Composite | Male | 2.5% (l); 8.6% (h)* | 2.03 (1.86-2.51)* |
| | | | | | | | | Female | 1.2% (l); 6.9% (h)* | 1.97 (1.67-2.36)* |
| Singh[9] | 1994 | Local | Combined | 25-64 | 3575 | blood glucose | Composite | Male | - | 4.07 (1.89-10.01)* (Urba |
| | | | | | | | | | - | 3.75 (1.37-12.78)* (Rura |
| | | | | | | | | Female | - | 1.48 (0.64-4.00) (Urban) |
| | | | | | | | | | - | 2.55 (0.91-8.83) (Rural) |
| Singh[10] | 1998 | Regional | Urban | 25-64 | 3257 | blood glucose | Composite | Female | 0.5% (l); 4.8% (h)* | - |
| Ramachandran[4] | 2000 | Regional | Urban | 20+ | 11216 | blood glucose | Income | Combined | 12.5% (l); 21.6% (h)* | 1.43 (1.30-1.57)*; 1.16 (1.05-1.30)* |
| Ramachandran[11] | 1999-2000 | Local | Urban | 40+ | 2383 | blood glucose, drug treatment | Income | Combined | 12.6% (l); 25.5% (h)* | 2.15 (1.70-2.72) |
| Gupta[12] | 1999-2001 | Local | Urban | 20+ | 1123 | self-report | Education | Male | 6.8% (l); 7.9% (h) | - |
| | | | | | | | | Female | 6.6% (l); 8.3% (h) | - |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Reddy[13] | 2002-2003 | Regional | Urban | 20-69 | 19973 | blood glucose, drug treatment | Education | Male | 7.6% (l); 8.4% (h) | 1.11 (0.71-1.67) |
| | | | | | | | | Female | 11.2% (l); 4.2% (h)* | 0.36 (0.23-0.56)* |
| Mohan[6] | 2003-2005 | Regional | Combined | 15-64 | 44523 | self-report | Education | Combined | 3.4% (l); 5.6% (h)* | 3.02 (2.45-3.71)* |
| Ajay[14] | 2002-2003 | Regional | Urban | 20-69 | 10930 | blood glucose, drug treatment | Education | Combined | 11.6% (l); 6.9% (h)* | 0.69 (0.54-0.89)* |
| Vijayakumar[15] | 2007 | Local | Rural | 18+ | 1990 | blood glucose, self-report | Social caste | Combined | 5.9% (l); 17.4% (h) | - |
| | | | | | | | Wealth | Combined | | 1.43 (1.04-1.95)* |
| Gupta[16] | 1999-2003 | Local | Urban | 20-59 | 1289 | blood glucose, self-report | Education | Male | 8.0% (l); 18.8% (h)* | - |
| | | | | | | | | Female | 6.0% (l); 34.7% (h)* | - |
| | | | | | | | | Combined | 6.9% (l); 26.4% (h)* | - |
| Kinra[17] | 2005-2007 | Regional | Rural | 20-69 | 1983 | blood glucose, self-report | Wealth | Male | 1.8% (l); 8.0% (h)* | - |
| | | | | | | | | Female | 3.9% (l); 5.1% (h) | - |
| Samuel[18] | 1969-2002 | Regional | Urban | 26-32 | 2218 | blood glucose†, drug treatment | Wealth | Male | 26.2% (l); 31.9% (h)* (Urban) | - |
| | | | | | | | | | 10.9% (l); 31.8% (h) (Rural) | - |
| | | | Rural | | | | | Female | 12.1% (l); 30.3% (h)* (Urban) | - |
| | | | | | | | | | 16.1% (l); 32.1% (h)* (Rural) | - |
| | | | Combined | | | | | Combined | - | 2.8 (1.9-4.1)* |
| | | | Urban | | | | Education | Male | 15.0% (l); 34.7% (h) (Urban) | - |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 25.7% (l); 19.7% (h) | - |
| | | | Rural | | | | | Female | 31.5% (l); 32.2% (h)* (Urban) | - |
| | | | | | | | | | 19.1% (l); 50.0% (h) | - |
| | | | Combined | | | | | Combined | - | 1.0 (0.6-1.6) |
| Zaman[19] | 2005 | Regional | Rural | 30+ | 4535 | blood glucose, self-report | Income | Male | 16.2% (l); 21.2% (h)* | - |
| | | | | | | | | Female | 12.1% (l); 15.0% (h)* | - |
| | | | | | | | Education | Male | 12.4% (l); 20.1% (h)* | - |
| | | | | | | | | Female | 12.8% (l); 13.1% (h) | - |

Notes: Socioeconomic status (SES) markers defined as education, household wealth, social caste, or a composite of 2 or more measures; *P<0.05; - indicates not reported; †includes impaired glucose tolerance and impaired fasting glucose

**Table 2** Characteristics of survey participants and frequency distribution of self-reported diabetes in India, males and females from the 3rd National Family Health Survey

| | Self-reported diabetes | | Total |
|---|---|---|---|
| | ***n*** | **%** | ***n*** |
| Participants | 2439 | 1.5 | 168135 |
| Residence | | | |
| Rural | 818 | 1.0 | 86013 |
| Urban | 1621 | 2.0 | 82122 |
| Age group | | | |
| 18-29 y | 266 | 0.3 | 76174 |
| 30-39 y | 602 | 1.2 | 51132 |
| 40-49 y | 1238 | 3.4 | 36402 |
| 50-54 y | 333 | 7.5 | 4427 |
| Gender | | | |
| Male | 1144 | 1.8 | 65255 |
| Female | 1295 | 1.3 | 102880 |
| Marital status | | | |
| Single | 132 | 0.3 | 38078 |
| Married | 2165 | 1.8 | 123457 |
| Widowed | 108 | 2.5 | 4320 |
| Divorced or separated | 34 | 1.5 | 2280 |
| Religion | | | |
| Hindu | 1775 | 1.4 | 123411 |
| Muslim | 340 | 1.6 | 21510 |
| Christian | 213 | 1.4 | 14779 |
| Sikh | 49 | 1.5 | 3236 |
| Buddhist | 34 | 1.4 | 2451 |
| Other | 28 | 1.0 | 2748 |
| Social Caste | | | |
| Other caste | 1026 | 1.8 | 56063 |
| Scheduled caste | 349 | 1.3 | 27677 |
| Scheduled tribe | 167 | 0.8 | 21372 |
| Other backward class | 781 | 1.4 | 55641 |
| No caste | 116 | 1.6 | 7382 |
| Education | | | |
| No education | 464 | 1.0 | 44856 |
| Primary | 358 | 1.4 | 24969 |

| | | | |
|---|---|---|---|
| Secondary | 1166 | 1.6 | 74715 |
| Higher | 451 | 1.9 | 23595 |
| | | | |
| Household wealth | | | |
| Poorest | 77 | 0.4 | 17252 |
| 2nd quintile | 175 | 0.8 | 22948 |
| 3rd quintile | 278 | 0.9 | 32070 |
| 4th quintile | 573 | 1.4 | 42091 |
| Richest | 1336 | 2.5 | 53774 |
| | | | |
| Body mass index ($kg/m^2$) | | | |
| <18.5 | 243 | 0.6 | 42128 |
| 18.5-22.9 | 703 | 0.9 | 74089 |
| 23-27.4 | 833 | 2.7 | 31217 |
| 27.5+ | 547 | 4.8 | 11502 |

**Table 3** Associations between socioeconomic status and self-reported diabetes in India; 3rd National family health survey, 2005-6

| | Models 1-3 | | Model 4 | | Model 5 | |
|---|---|---|---|---|---|---|
| Variable | Odds ratio | 95% CI | Odds ratio | 95% CI | Odds ratio | 95% CI |
| Social Caste | | | | | | |
| Other caste | 1.00 | | 1.00 | | 1.00 | |
| Scheduled caste | 0.81 | (0.71 - 0.94) | 1.05 | (0.91 - 1.21) | 1.07 | (0.93 - 1.24) |
| Scheduled tribe | 0.57 | (0.46 - 0.70) | 0.72 | (0.58 - 0.90) | 0.73 | (0.57 - 0.92) |
| Other backward caste | 0.84 | (0.75 - 0.94) | 0.95 | (0.85 - 1.07) | 0.96 | (0.86 - 1.08) |
| No caste | 0.89 | (0.71 - 1.11) | 0.94 | (0.75 - 1.17) | 0.95 | (0.76 - 1.20) |
| Wealth | | | | | | |
| Poorest | 1.00 | | 1.00 | | 1.00 | |
| 2nd quintile | 1.59 | (1.20 - 2.12) | 1.57 | (1.21 - 2.07) | 1.49 | (1.14 - 1.96) |
| 3rd quintile | 1.63 | (1.23 - 2.16) | 1.55 | (1.21 - 2.02) | 1.39 | (1.07 - 1.81) |
| 4th quintile | 2.42 | (1.85 - 3.17) | 2.25 | (1.76 - 2.92) | 1.79 | (1.40 - 2.34) |
| Richest | 4.04 | (3.08 - 5.30) | 3.65 | (2.83 - 4.78) | 2.58 | (1.99 - 3.40) |
| Education | | | | | | |
| No education | 1.00 | | 1.00 | | 1.00 | |
| Primary | 1.23 | (1.06 - 1.43) | 1.06 | (0.91 - 1.22) | 1.00 | (0.86 - 1.17) |
| Secondary | 1.68 | (1.49 - 1.90) | 1.18 | (1.04 - 1.35) | 1.12 | (0.98 - 1.28) |
| Higher | 1.87 | (1.61 - 2.18) | 1.12 | (0.95 - 1.32) | 1.01 | (0.86 - 1.20) |
| Body mass index ($kg/m^2$) | | | | | | |
| <18.5 | | | | | 1.00 | |
| 18.5-22.9 | | | | | 1.25 | (1.08 - 1.46) |
| 23-27.4 | | | | | 2.08 | (1.79 - 2.44) |
| 27.5+ | | | | | 2.98 | (2.51 - 3.54) |

Notes: In models 1-3 one SES marker (social caste, household wealth, education) was modelled at a time while adjusting for age, gender, religion, and place of residence. In model 4, all SES markers were included along with covariates form models 1-3. In model 5, BMI was included with markers of SES and covariates from model 4.

**Table 4** Variance in self-reported diabetes status between local areas and states in India; expressed as percentage of the contribution to the total variance in diabetes

| | Age & gender adjusted* | | | Fully adjusted** | | |
|---|---|---|---|---|---|---|
| | Variance | SE | % | Variance | SE | % |
| States | 0.231 | 0.076 | 5.9 | 0.204 | 0.068 | 5.4 |
| Local areas | 0.425 | 0.043 | 10.8 | 0.240 | 0.041 | 6.4 |

Notes:
*Multilevel model adjusted for age and gender only
**Multilevel model fully adjusted for age, gender, marital status, religion, social caste, household wealth, education, body mass index, and place of residence

## FIGURE LEGENDS

**Figure 1** Flow diagram showing exclusions and final sample sizes, 2005-6 National Family Health Survey (NFHS)

Notes for figure 1: *2,333 individuals reported unknown diabetes status; in 40 individuals diabetes status was not reported/missing. Of the 2,333 individuals who reported unknown diabetes status, 2,210 (94.7%) had complete data for BMI and were included in sensitivity analyses.
**Analyses involving body mass index (BMI) as an independent variable were restricted to 158,936 individuals

**Figure 2** State level prevalence of self-reported diabetes in India for men aged 18-54 (left) and women aged 18-49 (right). Darker colours indicate higher prevalence.

Notes for figure 2: State name abbreviations: AP Andhra Pradesh; AR Arunachal Pradesh; AS Assam; BR Bihir; CT Chhattisgarh; DL Delhi; GA Goa; GJ Gujarat; HR Haryana; HP Himachal Pradesh; JK Jammu & Kashmir; JH Jharkhand; KA Karnataka; KL Kerala; MP Madhya Pradesh; MH Maharashtra; MN Manipur; ML Meghalaya; MZ Mizoram; NL Nagaland; OR Orissa; PB Punjab; RJ Rajasthan; SK Sikkim; TN Tamil Nadu; TR Tripura; UP Uttar Pradesh; UK Uttarakhand (Uttaranchal); WB West Bengal

**Figure 3** Odds ratios for self-reported diabetes by state of residence in India

Notes for figure 3: horizontal lines are 95% credible intervals; adjusted for age, gender, marital status, religion, social caste, household wealth, education, body mass index and place of residence.

**Figure 4** Odds ratio (OR) for self-reported diabetes for a one-quintile increase in household wealth for men (aged 18-54) and women (aged 18-49) in India and 29 states

Notes for figure 4: Adjusted for age, gender, marital status, religion, social caste, education, body mass index and place of residence.

**Figure 5** Mean body mass index across three possible responses for self-reported diabetes.

Notes for figure 5: Vertical lines represent 95% confidence intervals. Body mass index (in $kg/m^2$) calculated from measured height and weight values. Horizontal line represents overall mean body mass index (21.2 $kg/m^2$, SD 3.9).

# SUPPLEMENTAL MATERIAL

**Supplemental Table 1** Associations between socioeconomic status and self-reported diabetes in India from models restricted to male and female samples; 3rd National family health survey 2005-6

| | Men aged 18-54 | | | | | | Women aged 18-49 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Models 1-3 | | Model 4 | | Model 5 | | Models 1-3 | | Model 4 | | Model 5 | |
| **Variable** | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** |
| Social Caste | | | | | | | | | | | | |
| Other caste | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| Scheduled caste | 0.84 | (0.68 - 1.03) | 1.14 | (0.92 - 1.39) | 1.20 | (0.96 - 1.48) | 0.77 | (0.64 - 0.93) | 0.95 | (0.78 - 1.14) | 0.97 | (0.79 - 1.16) |
| Scheduled tribe | 0.55 | (0.40 - 0.75) | 0.73 | (0.52 - 1.00) | 0.78 | (0.56 - 1.07) | 0.54 | (0.39 - 0.71) | 0.65 | (0.48 - 0.87) | 0.64 | (0.48 - 0.87) |
| Other backward caste | 0.86 | (0.74 - 1.00) | 1.01 | (0.86 - 1.19) | 1.04 | (0.88 - 1.23) | 0.78 | (0.67 - 0.91) | 0.86 | (0.74 - 1.01) | 0.87 | (0.75 - 1.02) |
| No caste | 0.92 | (0.62 - 1.37) | 0.96 | (0.65 - 1.40) | 1.04 | (0.71 - 1.52) | 0.87 | (0.66 - 1.16) | 0.90 | (0.68 - 1.21) | 0.91 | (0.67 - 1.22) |
| Wealth | | | | | | | | | | | | |
| Poorest | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| 2nd quntile | 1.40 | (0.97 - 2.11) | 1.35 | (0.94 - 1.97) | 1.32 | (0.89 - 1.88) | 1.72 | (1.17 - 2.46) | 1.66 | (1.15 - 2.44) | 1.69 | (1.18 - 2.52) |
| 3rd quntile | 1.46 | (1.03 - 2.15) | 1.36 | (0.95 - 1.96) | 1.29 | (0.88 - 1.80) | 1.73 | (1.17 - 2.52) | 1.60 | (1.10 - 2.26) | 1.48 | (1.07 - 2.25) |
| 4th quntile | 2.10 | (1.51 - 3.10) | 1.87 | (1.34 - 2.62) | 1.65 | (1.14 - 2.28) | 2.66 | (1.79 - 3.87) | 2.34 | (1.64 - 3.32) | 1.89 | (1.38 - 2.83) |
| Richest | 4.55 | (3.22 - 6.81) | 3.82 | (2.73 - 5.37) | 3.04 | (2.05 - 4.27) | 3.67 | (2.42 - 5.41) | 3.16 | (2.19 - 4.47) | 2.24 | (1.62 - 3.32) |
| Education | | | | | | | | | | | | |
| No education | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| Primary | 1.1 | (0.86 1.3 | 0.9 | (0.75 1.2 | 0.9 | (0.70 1.2 | 1.3 | (1.16 1.6 | 1.1 | (0.98 1.4 | 1.1 | (0.92 1.3 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | - | 8) | 6 | - | 1) | 2 | - | 0) | 9 | - | 7) | 7 | - | 0) | 1 | - | 3) |
| Secondary | 1.66 | (1.37- | 2.01) | 1.13 | (0.90- | 1.44) | 1.07 | (0.85- | 1.36) | 1.76 | (1.52- | 2.02) | 1.28 | (1.08- | 1.50) | 1.21 | (1.02- | 1.43) |
| Higher | 2.36 | (1.87- | 2.92) | 1.27 | (0.98- | 1.70) | 1.13 | (0.86- | 1.48) | 1.40 | (1.12- | 1.73) | 0.91 | (0.72- | 1.15) | 0.85 | (0.66- | 1.08) |
| Body mass index (kg/m$^2$) | | | | | | | | | | | | | | | | | | |
| <18 | | | | | | | 1.00 | | | | | | | | | 1.00 | | |
| 18.5-22.9 | | | | | | | 1.25 | (0.99- | 1.55) | | | | | | | 1.24 | (1.01- | 1.53) |
| 23-27.4 | | | | | | | 2.00 | (1.59- | 2.50) | | | | | | | 2.12 | (1.75- | 2.68) |
| 27.5+ | | | | | | | 2.15 | (1.65- | 2.86) | | | | | | | 3.58 | (2.89- | 4.56) |

Notes: OR odds ratio; In models 1-3 one SES marker (social caste, household wealth, education) was modelled at a time while adjusting for age, gender, religion, and place of residence. In model 4, all SES markers were included along with covariates form models 1-3. In model 5, BMI was included with markers of SES and covariates from model 4.

**Supplemental Table 2** Odds ratio (OR) for self-reported diabetes for a one-quintile increase in household wealth for men (aged 18-54) and women (aged 18-49) in India and 29 states

| | | Self-reported diabetes | |
|---|---|---|---|
| **State** | ***n*** | **Wealth OR** | **95% CI*** |
| India | 158,936 | 1.31 | (1.20 - 1.42) |
| Jammu and Kashmir | 3,383 | 1.55 | (1.21 - 1.98) |
| Maharashtra | 14,053 | 1.51 | (1.27 - 1.78) |
| Orissa | 4,838 | 1.50 | (1.24 - 1.81) |
| Arunachal Pradesh | 1,798 | 1.49 | (1.14 - 1.94) |
| Uttar Pradesh | 17,555 | 1.47 | (1.28 - 1.70) |
| Sikkim | 2,406 | 1.46 | (1.11 - 1.92) |
| Madhya Pradesh | 7,756 | 1.43 | (1.19 - 1.71) |
| Assam | 3,904 | 1.43 | (1.15 - 1.77) |
| Uttaranchal | 3,120 | 1.42 | (1.12 - 1.81) |
| Punjab | 4,134 | 1.41 | (1.10 - 1.81) |
| Mizoram | 2,089 | 1.40 | (1.07 - 1.85) |
| Karnataka | 9,049 | 1.40 | (1.19 - 1.64) |
| Chhattisgarh | 4,246 | 1.36 | (1.14 - 1.64) |
| Delhi | 3,026 | 1.35 | (1.05 - 1.73) |
| Rajasthan | 4,433 | 1.33 | (1.03 - 1.71) |
| Meghalaya | 2,135 | 1.29 | (1.03 - 1.63) |
| Jharkhand | 3,044 | 1.29 | (1.06 - 1.57) |
| Tamil Nadu | 10,106 | 1.28 | (1.11 - 1.48) |
| Andhra Pradesh | 11,824 | 1.25 | (1.09 - 1.45) |
| Himachal Pradesh | 3,563 | 1.25 | (0.97 - 1.61) |
| Gujarat | 4,322 | 1.25 | (1.00 - 1.56) |
| Goa | 3,883 | 1.20 | (0.98 - 1.48) |
| Nagaland | 6,350 | 1.19 | (0.99 - 1.44) |
| Tripura | 2,089 | 1.18 | (0.96 - 1.45) |
| Manipur | 6,941 | 1.14 | (0.95 - 1.37) |
| Haryana | 3,173 | 1.11 | (0.90 - 1.38) |
| Bihar | 3,882 | 1.10 | (0.93 - 1.30) |
| Kerala | 4,018 | 1.10 | (0.89 - 1.35) |
| West Bengal | 7,816 | 0.95 | (0.83 - 1.09) |

Notes: Odds ratios (OR) and 95% credible intervals (CI) adjusted for age, gender, marital status, religion, social caste, education, body mass index and place of residence.

**Supplemental Table 3** Associations between socioeconomic status and body mass index for self-reported diabetics and those with unknown diabetes status compared to self-reported non-diabetics using a multilevel multinomial regression model.

| | Self-reported diabetes | | Unknown diabetes status | |
|---|---|---|---|---|
| Variable | Odds ratio | 95% CI* | Odds ratio | 95% CI |
| Social Caste | | | | |
| Other caste | 1.00 | | 1.00 | |
| Scheduled caste | 1.07 | (0.93 - 1.24) | 1.13 | (0.96 - 1.31) |
| Scheduled tribe | 0.73 | (0.58 - 0.91) | 1.52 | (1.25 - 1.84) |
| Other backward caste | 0.96 | (0.86 - 1.08) | 1.07 | (0.93 - 1.23) |
| No caste | 0.95 | (0.75 - 1.18) | 0.76 | (0.58 - 0.99) |
| Wealth | | | | |
| Poorest | 1.00 | | 1.00 | |
| 2nd quintile | 1.51 | (1.14 - 2.03) | 0.90 | (0.77 - 1.05) |
| 3rd quintile | 1.41 | (1.07 - 1.89) | 0.86 | (0.73 - 1.01) |
| 4th quintile | 1.82 | (1.38 - 2.44) | 0.82 | (0.68 - 0.98) |
| Richest | 2.63 | (1.97 - 3.56) | 0.64 | (0.51 - 0.79) |
| Education | | | | |
| No education | 1.00 | | 1.00 | |
| Primary | 1.00 | (0.87 - 1.17) | 0.86 | (0.76 - 0.99) |
| Secondary | 1.12 | (0.98 - 1.28) | 0.71 | (0.63 - 0.81) |
| Higher | 1.01 | (0.85 - 1.21) | 0.45 | (0.36 - 0.57) |
| Body mass index | | | | |
| <18.5 | 1.00 | | 1.00 | |
| 18.5-22.9 | 1.26 | (1.08 - 1.46) | 1.03 | (0.93 - 1.15) |
| 23-27.4 | 2.09 | (1.79 - 2.45) | 1.17 | (1.01 - 1.36) |
| 27.5+ | 2.99 | (2.52 - 3.55) | 1.33 | (1.06 - 1.66) |

Notes: model adjusted for age, gender, religion, marital status, place of residence
*95% credible interval

**Title** Association between socioeconomic status and self-reported diabetes in India: a cross-sectional multilevel analysis

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**ABSTRACT**

**Objectives** To quantify the association between socioeconomic status (SES) and type-2 diabetes in India

**Design** Nationally representative cross-sectional household survey

**Setting** Urban and rural areas across 29 states in India

**Participants** 168,135 survey respondents aged 18-49 y (women) and 18-54 y (men)

**Primary outcome measure** Self-reported diabetes status

**Results** Markers of SES were social caste, ~~education, and~~ household wealth, and education. The overall prevalence of self-reported diabetes was 1.5%; this increased to 1.9% and 2.5% for those with the highest levels of education and household wealth, respectively. In ~~adjusted~~ multilevel logistic regression models~~-~~ (adjusted for age, gender, religion, marital status, and place of residence~~regression models~~), ~~-~~education (odds ratio 1.87 for higher education *vs* no education) and household wealth (odds ratio 4.04 for richest quintile *vs* poorest) were positively related to self-reported diabetes (P<0.0001). In a fully adjusted model including all socioeconomic variables and body mass index (BMI), household wealth emerged as positive and statistically significant with an ~~the~~ odds ratio for self-reported diabetes ~~was~~ of 2.58 (95% credible interval [CI]: 1.99-~~,~~ 3.40) for the richest quintile of household wealth versus the poorest. Nationally in India a one-quintile increase in household wealth was associated with an odds ratio of 1.31 (95% CI: 1.20-1.42) for self-reported diabetes~~-~~. This association was consistent across states with the relationship found to be positive in 97% (28 of 29 states) and statistically significant in 69% (20 of 29).

**Conclusions** We found that the highest socioeconomic status groups in India appear to be at greatest risk for type-2 diabetes. This raises important policy implications for addressing the disease burdens among the poor versus those among the non poor in the context of India, where ~~nearly~~ greater than ~~half of the~~ 40 percent of the population is living in poverty.

## ARTICLE SUMMARY

### Article Focus

- The relationship between socioeconomic factors and type-2 diabetes has not been previously studied for the whole of India and across states
- Our objective was to investigate associations between measures of socioeconomic status (defined as social caste, education, household wealth) and self-reported diabetes status in India
- In addition we explored geographic variation in ~~diabetes~~ the prevalence of diabetes between states and local areas in India and between-state variability in the SES-diabetes relationship

### Key messages

- The highest socioeconomic groups appear to be at greatest risk for diabetes in India; with the strength of the association consistent in size and magnitude across states
- ~~In addition, t~~There is substantial geographic heterogeneity in the prevalence of diabetes
- These findings raise important policy implications for in addressing the disease burdens among the poor versus those among the non poor in the context of India, where nearly half of the population is living in poverty.

### Strengths and Limitations

- The key strength of this study is the use of a large, nationally-representative survey to assess the socioeconomic and geographic patterning of diabetes across all of India. Limitations include the relatively younger age of the sample and assessment of diabetes status on the basis of self-reports.

**INTROCUTION**

The prevalence of type-2 diabetes in India has been investigated in numerous population based surveys conducted across a range of settings since the 1970s.[1-6] Despite multiple prevalence studies, few no nationally representative studies exist which have considered the association between socioeconomic status (SES) and type-2 diabetes in India. In a review of 15 existing studies which have reported the prevalence of type-2 diabetes by SES and/or associations between SES and type-2 diabetes, all were found to have been based on local or regional samples and a majority were done in urban areas[4 6-19] (**Table 1**). Recently, iIt has been suggested that that the prevalence of type-2 diabetes and other cardiovascular disease risk factors may increasingly become concentrated among low SES groups in India[20] and other"poor people are disproportionately affected" by diabetes and other non-communicable diseases in low-and middle--income countries-[21], , although to date the the empirical evidence in thefrom Indian context in support of this hypothesis remains limited. The majority of Sstudies reviewed in table 1 among populations from a few geographic regions in India have provided some evidence of a positive SES-diabetes association between SES (defined as education, household wealth, social caste, or a composite of 2 or more markers) -and diabetes among populations from selected geographic regions in India [6 11 17]; however the strength and consistency of this association across the whole of India remains uncertainhas not previously been assessed.

Type-2 diabetes is the most common form of diabetes globally, accounting for greater than 85% of cases.[22] The incidence of type-2 diabetes is related to genetic and non-genetic components, with the latter being greatly influenced by modifiable risk

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factors such as obesity, diets low in fibre and high in trans fat, and physical inactivity.[23-24] ~~These l~~Lifestyle behaviours ~~themselves~~ are strongly patterned by SES [25], and may be mediators on the causal pathway between SES and the onset of type-2 diabetes.[26] In high income countries, the SES-diabetes relationship appears to be negative, with the poor at greatest risk. For example, strong associations have been observed between poverty, low education and type-2 diabetes among African American women [27-28], and among White women and men in the United States.[29] Similarly, a study from Canada described an inversely graded SES-diabetes association with an odds ratio of 1.9 for men (95% CI: 1.6-2.4) and 2.8 (95% CI: 2.2-3.4) for women for the lowest versus highest income groups.[30] A recent meta-analysis of 23 ~~epidemiological~~ case-control and cohort studies and 43 measures of SES-diabetes association revealed an overall increased risk for type-2 diabetes for low SES groups based on education, occupation, and income.[31] The strength of the association, however, was less consistent in low and middle income countries (LMICs), and few studies have been conducted in these countries.

Concern has been raised over the anticipated rapid increase in type-2 diabetes prevalence in India.[32-33] Evidence on the secular increases in diabetes prevalence in India, however, have been limited to urban areas of Southern India[4 34-35], and have focused on the mean rates of diabetes rather than how it is distributed in the population. In this paper we address the need to comprehensively investigate the socioeconomic and geographic distribution of type-2 diabetes in the Indian population using a large-scale nationally representative survey. Specifically, we investigate the SES-diabetes ~~relation~~ association through the SES markers of social caste, household wealth, and education. ~~in~~

India using a large-scale nationally representative survey. In addition, we investigate the geographical geographic distribution of the prevalence of diabetes at the state and local area levels in Indiaacross states and local areas along with variability in the SES-diabetes association across states..

## METHODS

### Data source

We use data from the 3rd National Family Health Survey (NFHS), conducted in 29 states in India between November 2005 and August 2006.[36] NFHS-3 is a major national health survey in India which collected information on a range of indicators including reproductive health, nutritional status of adults and children, utilization of health care services, and blood testing for HIV prevalence. NFHS-3 covered all states in India, which comprise nearly 99% of the population, but excluded Union Territories. The survey was designed to provide estimates of key indicators (except HIV prevalence) for each state by urban and rural areas.

### Survey design

A uniform multistage sampling strategy was adopted in all states, with separate sampling in urban and rural areas.[37-38] In rural areas, a two stage sample was carried out using a list of villages from the 2001 census as the sampling frame. In the first stage, a stratified sample of villages was drawn with probability proportional to the size of the village. In the second stage, a random selection of households was drawn in each village from a complete list of households complied during field visits carried out in each sampled village. In urban areas, a similar procedure was implemented beginning with a stratified random sample of municipal wards based on the 2001 census. Next, one census enumeration block (150-200 households) was selected from within wards using probability proportional to size. Finally, as in rural areas, field enumerators undertook a household listing operation in selected blocks and a random sample of households was made. In both rural and urban areas, 30 households were targeted for selection in each of the sampled units. The overall household response rate for NFHS-3 was 98%.[36]

All ~~ever-married and never-married~~ women aged 15-49 in selected households were invited to participate in the survey. In 22 states, men aged 15-54 in a random subsample of households drawn from each PSU (about 6 households per PSU)~~subsample of households~~ were eligible for the men's survey. In the remaining seven states (Andhra Pradesh, Karnataka, Maharashtra, Manipur, Tamil Nadu, Uttar Pradesh, and Nagaland) ~~all~~ eligible men all in selected households were invited to participate. The additional men recruited in these states was for the purpose of HIV testing to provide reliable state level estimates of HIV prevalence in certain states. Interviews were conducted in 1 of the 18 Indian languages in the respondent's home and the response rates were 95% for women and 87% for men.[36] During interviews, the weights and heights of survey respondents were measured by trained field technicians using standardized measuring equipment designed for survey settings.[39]

In total NFHS-3 collected information from 109,041 households, 124,385 women from~~age~~ 15 to ~~-~~49 years of age, and 74,369 men ~~ag~~from ~~e-~~15 to~~5-~~ 54 years of age.~~[24]~~ We restricted our analyses to adults aged 18 years and older and non-pregnant women (n=171,207). Respondents who did not report or know their diabetes status (n= 2,373~~85~~) or with incomplete information for any of the independent variables considered in the analysis (marital status, religion, caste, education, household wealth) were excluded (n=699~~87~~). Main ~~-A~~analyses were conducted on a sample of 168,135 respondents, (65,255 men and 102,880 women). Additional analyses considering body mass index (BMI) were restricted to a sample of 158,936 due to missing and/or implausible values for height and/or weight. **Figure 1** provides a flow diagram detailing the NFHS sample, exclusions, and final analytic sample sizes.

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**Outcome and independent variables**

The primary outcome was diabetes, assessed on the basis of self-reports by survey respondents. Markers of ~~S~~socioeconomic status ~~was measured by~~were social caste, ~~education, and~~ household wealth, and education~~.~~ Social caste was reported by the household head. The categories were Other Caste, Scheduled caste, Scheduled tribe, Other Backward Class, and No Caste. Other Caste is a heterogeneous group that is traditionally viewed as having higher social status. ~~-~~Scheduled castes and scheduled tribes are considered lower, socially marginalized groups in India.[40] ~~Education was specified as no education, primary, secondary, or higher education.~~ Household wealth was defined by an index based on indicators of asset ownership and housing characteristics.[41] This index has been developed and validated in a number of countries to be a robust measure of wealth and has been found to be consistent with measures of income and expenditure.[42] Briefly, the measure was constructed as follows. Information on 33 indicators of housing characteristics (e.g., type of windows and flooring, water and sanitation facilities) and assets (e.g., ownership of home, car, computer, mobile phone) were weighted and combined with weights derived from a principal component analysis procedure.[36] The resulting variable was standardized to a mean of 0 and standard deviation of 1 and using this index the household population was divided into fifths from poorest to richest. Education was categorized in four levels as no education, primary, secondary, or higher education.

~~Control variables~~Background characteristics included age, gender, religion, marital status, place of residence, and BMI. Age was defined in 10 year categories and centred about its mean (32 years) in regression models. Gender was based on self-report. Religion was categorized as Hindu, Muslim, Sikh, Buddhist, or other religion. Marital status was defined as single, married, widowed, or separated. Place of residence (rural or urban) was defined according to the 2001 Census. BMI (in $kg/m^2$; weight in kilograms divided by the square of height in meters) was calculated for all survey respondents with valid measurements for weight and height. BMI was classified according to the following categories based on risk of type 2 diabetes and cardiovascular disease in Asian populations; less than 18.5 $kg/m^2$ (underweight); 18.5-22.9~~3~~ $kg/m^2$ (acceptable risk); 23-27.4~~5~~ $kg/m^2$ (increased risk); and 27.5 $kg/m^2$ or greater (high risk).[43]

**Analysis**

To account for the complex survey design, we employed multilevel logistic regression to model the probability of diabetes.[44] A three-level model was specified with a binary response (*y*, diabetes or not) for individual *i* in local area (village or census block primary sampling units) *j* in state *k*. The outcome diabetes, $\Pr(y_{ijk} = 1)$, was assumed to be binomially distributed $y_{ijk} \sim Binomial(1, \pi_{ijk})$ with probability $\pi_{ijk}$ related to the set of independent variables X and a random effect for each level by a logit link function:

$$Logit(\pi_{ijk}) = \beta_0 + \beta X_{ijk} + v_{0k} + u_{0jk} .$$ (Equation 1)

The right hand side of the equation consists of the fixed part linear predictor ( $\beta_0 + \beta X_{ijk}$ ) and random intercepts attributable to ~~local areas ( $u_{0jk}$ ) and~~ states ( $v_{0k}$ ) and local areas ( $u_{0jk}$ ). The intercept, $\beta_0$ represents the log odds of diabetes in the reference group, and the $\beta$-coefficients represent the differential in the log odds of diabetes compared to the reference group defined for each independent variable. Coefficients were exponentiated and presented as odds ratios for interpretation. The random intercepts are assumed to be independently and identically distributed and have variances estimated for ~~local areas ( $\sigma_u^2$ ) and~~ states ( $\sigma_v^2$ ) and local areas ( $\sigma_u^2$ ).[45] The variance parameters quantify heterogeneity in the log odds of diabetes at each level, after taking into account individual characteristics and place of residence in the fixed part. We expressed the variances at each level as a percentage of their contribution to the total variance from an initial model adjusting for age and gender only and from a final model accounting for all covariates. We specified a sequence of six models during analyses. In the first three models, one SES marker (social caste, household wealth, education) was added to a model which adjusted for background characteristics (age, gender, religion, and place of residence). In the fourth mutually adjusted model, all SES markers were included along with background characteristics from the previous models. In the fifth model, BMI was included with markers of SES and background characteristics from model 4. In the sixth model, we also tested whether the association between household wealth varied across states in terms of strength or direction, given that different states vary tremendously by levels of economic development and could be considered at different levels of epidemiological transition. In order to test this between state variability we expanded Equation 1 to allow the slope of household wealth to vary across states:

$$Logit(\pi_{ijk}) = \beta_0 + \beta_{1k} wealth_{ijk} + \beta X_{ijk} + v_{0k} + v_{1k} + u_{0jk}$$ . (Equation 2)

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The key feature of Equation 2 is that the effect of wealth on self-reported diabetes in state *k* consists of the overall average effect across all states ( $\beta_1$ ), plus a state-specific ( $v_{1k}$ ) differential in this effect. We summarized and presented the results of this model as the odds ratio for self-reported diabetes overall in India and for each state given a 1-quintile increase in household wealth and conditional on all covariates from model 5. Additional analyses were carried out separately for male and female samples using an identical sequence of models (with the exclusion of gender as a background characteristic). Estimation of ~~Models~~models was done ~~were estimated via~~using Markov Chain Monte Carlo (MCMC) simulation ~~using~~ and the statistical software *MLwiN*.[46-47]

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**RESULTS**

Characteristics of survey respondents by their self-reported diabetes status are given in **Table 2~~1~~**. The overall prevalence of diabetes in this sample was 1.5% and this was higher in urban areas and among men (diabetes prevalence 2.0 % in urban *v* 1.0% in rural; 1.8% in men *v* 1.3% in women). Diabetes prevalence increased with age (7.5% in 50-54y *v* 0.3% in 18-29y), education (1.9% in higher *v* 1.0% in no education), household wealth (2.5% in richest *v* 0.4% in poorest), and BMI (4.8% in 27.5+ kg/m$^2$ *v* 0.6% in <18.5 kg/m$^2$). At the state level, the prevalence of diabetes varied between 0.3% in Rajasthan and 3.3% in Kerala and was generally higher in Southern and Eastern states (**Figure 2~~1~~**).

In separate models that adjusted for age, marital status, religion, and place of residence, statistically significant associations were observed between SES and self-reported diabetes for each of the primary ~~indicators~~ markers of SES in this study: social caste, ~~education, and~~ household wealth, and education. Compared to the other caste group, scheduled casts, scheduled tribes, and other backward classes had reduced odds of having diabetes with odds ratios of 0.81 (95% CI: 0.71-~~,~~0.94), 0.57 (95% CI: 0.46-~~,~~0.70), and 0.84 (95% CI: 0.75-~~,~~0.94), respectively (**Table 3~~2~~**, Models 1-3). Education showed a graded relation with diabetes and an odds ratio of 1.87 (95% CI: 1.61-~~,~~2.18) for those with higher education versus those with no education. Household wealth showed a graded association with diabetes with individuals from the richest households having an odds ratio for diabetes of 4.04 (95% CI: 3.08-~~,~~5.30) compared to those from the poorest households.

The effects of social caste and education were attenuated in the mutually adjusted model (model 4), suggesting that their independent effects on self-reported diabetes were at least partially mediated by the inclusion of household in this model. T~~. T~~he reduced odds for diabetes remained consistent for scheduled tribes versus other caste groups (OR 0.72, 95% CI: 0.58-~~,~~0.90) as did an increased odds for those with secondary education versus no education (OR 1.18, 95% CI: 1.04-~~,~~1.35), however the graded relation with education was less consistent. In separate mutually adjusted models that were stratified by gender, education showed a graded association in men although it was not statistically significant with the odds ratio for diabetes men found to be 1.27 (95% CI: 0.98-1.70) for men with higher versus no education (**Supplemental Table 1**). Among women, those with secondary education continued to show an increased odds of self-reported diabetes

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compared to those with no education (OR 1.28, 95% CI: 1.08-1.50). Overall, Tthe strong and graded relation between household wealth and diabetes remained consistent in this modelmodel 4 with and odds ratio for diabetes of 3.65 (95% CI: 2.83, 4.78) for the richest versus the poorest groups; similar associations were found in the gender-specific models (Supplemental Table 1). Type-2 diabetes is strongly influenced by body weight.[48-50] Therefore, BMI was added to the final model model 5 to control for potential confounding of the SES-diabetes relationship in this sample. In addition, BMI was added separately in this model because its inclusion resulted in the reduction of sample size by ~5% due to missing values for BMI. The odds ratios for caste and education remained consistent between the mutually adjusted model and final model which included BMI. The odds ratios for household wealth were further attenuated in the final model, however the positive graded association remained statistically significant with an adjusted odds ratio for those in the richest compared to the poorest households of 2.58 (95% CI: 1.99-, 3.40).

Our analyses revealed dramatic variation in the prevalence of diabetes between states and local areas in India (**Table 43**). In an initial multilevel model adjusted for age and gender, states and local areas (defined as villages in rural areas and census blocks in urban areas) contributed 5.9% and 10.8%, respectively, to the total variation in diabetes. The addition of socioeconomic and demographic characteristics along with BMI to the model reduced the variance in diabetes attributed to local areas by 41% to 6.4% but the variation attributed to states was relatively unchanged at 5.4%.

Overall in India, the log odds for diabetes for the reference category (a 32 year old married women, with no education, BMI <18.5 kg/m$^2$, belonging to the other caste group, in the poorest fifth of households, and living in a rural area) was -6.13 or a 0.22% probability of diabetes. Compared to this national reference point, being a resident of several Southern and Northeastern states was associated with a statistically significant increase in the odds of diabetes (**Figure 3~~1~~**). The odds ratios for self-reported diabetes these sates were: 2.29 (Tripura), 1.69 (Tamil Nadu), 1.69 (Kerala), 1.71 (Goa), 1.49 (Andhra Pradesh), and 1.56 (West Bengal). In contrast being resident of the states of Rajasthan, Jammu & Kashmir, Uttar Pradesh, Punjab, Madhya Pradesh, and Assam in Northern and Central India was associated with a statistically significant decrease (OR < 1.0) in the odds of ~~reporting diabetes~~self-reported diabetes.

In order to assess the variability in the SES-diabetes association across states in India, a final model (model 6) was specified to allow the odds ratio for diabetes for a one-quintile increase in household wealth to vary across states. In this model, the overall odds ratio for diabetes in India for a one-quintile increase in household wealth was 1.31 (95% CI: 1.20-1.42) (**Figure 4**). In 15 states, the association was stronger than the national average; varying between an odds ratio of 1.33 in Rajasthan and 1.55 in Jammu & Kashmir. Although the association was less than the national average in 14 states, it was found to be positive in 28/29 (97%) states and statistically significant in 20/29 (69%). Only in West Bengal was an inverse association observed, but it was not statistically significant (OR 0.95 95% CI: 0.83-1.09). Odds ratios and 95% CI for the overall association and across all states are presented in **Supplemental Table 2**. In summary, the association between household wealth and self-reported diabetes was consistent across the states both in direction and magnitude.

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We conducted several sensitivity analyses to assess the consistency of our findings. First, we examined whether the observed associations were related to respondents' awareness and knowledge about diabetes. To do so, we considered responses to the question, "Do you have diabetes?" as a categorical variable, comparing "yes" (diabetic) and "don't know" (unknown) versus "no" (non-diabetic) across the same set of independent variables using a multinomial logistic model. Associations between SES variables and positive reports of diabetes from this model, which included the possibility that respondents were unaware of their diabetes status, were nearly identical to findings from the logistic model which excluded those with unknown diabetes status (**Supplemental Table 3~~1~~**). The multinomial model also revealed that the richer and more highly educated respondents were less likely to report unknown ~~"do not know" as their diabetes~~ status ~~(~~compared to non-diabetic~~"no")~~. In addition, we examined BMI across the three categories of diabetes status (**Figure 5~~3~~**). This revealed that those ~~reporting "do not know"~~ with unknown diabetes had the lowest BMI (mean 20.9, SD 3.7) which was largely consistent with the non-diabetic~~"no"~~ group (mean 21.1, SD 3.9) and substantially lower than ~~those reporting "yes" to diabetes~~those with self-reported diabetes (mean 24.4, SD 4.9). Finally, we examined interactions between socioeconomic variables (caste, education, wealth) and diabetes by residential location. Tests of these interactions were not statistically significant (P=0.20 for caste; P=0.72 for education; P=0.66 for wealth).

## DISCUSSION

In this study, we have three key findings. First, measures of SES were positively associated with self-reported diabetes in the NFHS-3. Although the observed effects of caste and education were largely attenuated in fully adjusted models, the effect of household wealth remained positive, graded and statistically significant even after controlling for BMI. Second, we observed a large variation in the prevalence of diabetes between local areas and States in India. A few Southern and northeastern states were associated with a higher risk for reporting diabetes while several northern and central states were at lower risk after adjusting for individual characteristics and place of residence. Lastly, the observed association between household wealth and self-reported diabetes was consistent, positive, and statistically significant across a majority of states in India.

There are a few limitations to our study. First, the outcome was defined on the basis of self-reported diabetes, although interviews were conducted in person using a standardized instrument. Previous research has shown good agreement for self-reported diabetes when compared to medical records in a US population .[51], and that that self-reported health conditions demonstrate the expected relationship with SES in India.[52] In addition, our sensitivity analyses considering respondents who reported "did not knowunknown" for their diabetes status were nearly identical to the main analyses. We did find, however, evidence that higher SES groups were less likely to report "did not know" as compared to "no", which has been suggested previously on studies using self-reports of diabetes status in India.[6] However, the "did not knowunknown" group was more similar in terms of BMI, education, and wealth to the "nonon-diabetic" rather than diabetic"yes" group. In addition, our findings of positive SES-diabetes associations were consistent with several studies identified in our literature review which used blood glucose measurements for the assessment of diabetes status (summarized in Table 1).

Lastly, although our sample was relatively young (<55 y for men and <50 y for women) it is representative of the young population of profile of India; 84% of the Indian adult population (18-69 y) and 47% of the total Indian population at all ages fall within the ages covered by this study.[53] Our study does exclude approximately 12% of the Indian population (women over the age of 50 and men over the age of 55) due to the sample design of the NFHS. . The prevalence of diabetes increases with age and whether a similar SES-diabetes relationship exists among middle and older age groups in all parts India is not clear, although our findings are consistent with previous studies which have included older ages.

Our findings of positive SES-diabetes associations are consistent with previous studies done in different parts of India. For example, an analysis of rural participants from the Indian Migration Study, which sampled primarily from four large states in the north, centre, and south of India [17], identified a positive SES-diabetes gradient among men (8.0% prevalence in high SES group *v* 1.8% in low SES group), and a weaker positive SES-diabetes association that was not statistically significant among women (5.1% *v* 3.9%). In addition, a study done in an urban setting in Madras (Chennai) found an odds ratio for diabetes of 2.2 (95% ~~credible~~ confidence interval [CI]: 1.7-2.7) for high *v* low SES groups.[11] One larger study conducted in urban and rural surveillance locations in Northern, Southern, Eastern, and Western/Central India identified an odds ratio of 3.0 (95% CI: 2.5-3.7) for self-reported diabetes for those with graduate level education versus those without formal schooling.[6] Importantly, these studies were limited to selected geographical areas or cities in India. Our study has added to this literature using a national population health survey with good coverage in rural areas across India.

Previous research in India has identified a strong positive relation between SES and BMI among women and men in India. [54-56] These studies are important because they have used similar markers of SES in the Indian context along with an objectively defined outcome (height and weight were measured in NFHS and not self-reported). BMI (along with other measures of body weight) is an important risk factor for the development of type 2 diabetes. [48 50 57] Therefore, the consistency of our findings of a positive SES-diabetes association after controlling for BMI is encouraging. If BMI is part of the causal pathway between SES and diabetes, attenuation in the effect size for markers of SES would be expected. The graded and positive relation between household wealth and diabetes after accounting for BMI suggests that there are additional effects of household wealth on diabetes that are not mediated by BMI. The effects of social caste and education were largely attenuated after the inclusion of household wealth and prior to the inclusion of BMI. Household wealth was the strongest socioeconomic factor associated with self-reported diabetes, suggesting that social and behavioural changes associated with diabetes in India may be more closely related to increasing wealth and/or standard of living than educational attainment.

When compared to other studies in India, the overall prevalence of diabetes in the NFHS-3 was not high. This may have resulted from a combination of using self-reports of diabetes, the younger age of the NFHS-3 target population, and sampling from the general population which included a high proportion of respondents in rural areas. Among individuals over 30 years of age, the prevalence was 2.5% (3.0 % in men and

2.2% in women). Other studies using in rural India using similar age groups and blood measurements have reported diabetes prevalence of 4% and a study from rural Andhra Pradesh found a prevalence of 12% based on combination self-report and blood measurements.[17 58]

The current national estimate for diabetes prevalence in India is about 7% of the adult population aged 20-79. This estimate is based on 3 relatively recent and larger scale studies using a combination of oral glucose tolerance testing and self-reports of diabetes.[4-6] There continues to be considerable uncertainty in estimates of diabetes for the whole of India due to the limited study locations (with a focus on urban areas), wide variation in survey sampling methodology, differences in diabetes diagnostic criteria, and age groups studied. These differences in study design have hindered direct comparison of the prevalence between studies, across regions and over time. The NFHS-3 provides and important benchmark because it is the first nationally-representative survey of diabetes in India. Even if the prevalence estimates of diabetes have been underestimated in the NFHS-3, the observed SES-diabetes associations are plausible and important. Previous studies have largely overlooked the importance of socioeconomic status markers, which may be a key determinant of diabetes. Further large-scale population-based surveys can be strengthened by using simple finger-prick blood glucose measurements in addition to self-reports.

There has been considerable concern over the rising prevalence of diabetes in India, especially with studies on migrant Indian populations suggesting that South Asians may be more susceptible to the disease. In light of current findings, it appears that, at present, the more well-off segments of the Indian population are at greatest risk. This poses concerns on how to appropriately balance priorities to address the disease burden that afflicts the non poor versus the poor in the context of India where greater than 40% of the population continue to live in extreme poverty -50 percenton less than $1.25 per day[48] of the population are poor.[59]

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SVS and DJC planned the study. DJC conducted statistical analyses and drafted the manuscript with supervision from SVS. Both authors participated in interpretation of the results and critical revisions of the manuscript.

The NFHS data are available through the Measure DHS project at www.measuredhs.com.

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**Table 1**: Overview of studies reporting prevalence of type-2 diabetes by markers of socioeconomic status (SES) and the association between increasing SES and diabetes in India

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| Author | Study period | Coverage | Setting | Age | Sample size | Diabetes assessment | SES marker | Gender | Diabetes prevalence: low SES (l); high SES (h) | SES-diabetes association: Odds ratio (95% confidence interval) for, high SES vs low SES |
|---|---|---|---|---|---|---|---|---|---|---|
| Singh[7] | 1994 | Local | Rural | 25-64 | 1769 | blood glucose | Composite | Male | 0.9% (l); 6.1% (h)* | - |
| | | | | | | | | Female | 0.9% (l); 6.9% (h)* | - |
| Singh[8] | 1994 | Local | Rural | 25-64 | 1806 | blood glucose | Composite | Male | 2.5% (l); 8.6% (h)* | 2.03 (1.86-2.51)* |
| | | | | | | | | Female | 1.2% (l); 6.9% (h)* | 1.97 (1.67-2.36)* |
| Singh[9] | 1994 | Local | Combined | 25-64 | 3575 | blood glucose | Composite | Male | - | 4.07 (1.89-10.01)* (Urban) |
| | | | | | | | | | - | 3.75 (1.37-12.78)* (Rural) |
| | | | | | | | | Female | - | 1.48 (0.64-4.00) (Urban) |
| | | | | | | | | | - | 2.55 (0.91-8.83) (Rural) |
| Singh[10] | 1998 | Regional | Urban | 25-64 | 3257 | blood glucose | Composite | Female | 0.5% (l); 4.8% (h)* | - |
| Ramachandran[4] | 2000 | Regional | Urban | 20+ | 11216 | blood glucose | Income | Combined | 12.5% (l); 21.6% (h)* | 1.43 (1.30-1.57)*; 1.16 (1.05-1.30)* |
| Ramachandran[11] | 1999-2000 | Local | Urban | 40+ | 2383 | blood glucose, drug treatment | Income | Combined | 12.6% (l); 25.5% (h)* | 2.15 (1.70-2.72) |
| Gupta[12] | 1999-2001 | Local | Urban | 20+ | 1123 | self-report | Education | Male | 6.8% (l); 7.9% (h) | - |
| | | | | | | | | Female | 6.6% (l); 8.3% (h) | - |

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|---|---|---|---|---|---|---|---|---|---|---|
| Reddy[13] | 2002-2003 | Regional | Urban | 20-69 | 19973 | blood glucose, drug treatment | Education | Male | 7.6% (l); 8.4% (h) | 1.11 (0.71-1.67) |
| | | | | | | | | Female | 11.2% (l); 4.2% (h)* | 0.36 (0.23-0.56)* |
| Mohan[6] | 2003-2005 | Regional | Combined | 15-64 | 44523 | self-report | Education | Combined | 3.4% (l); 5.6% (h)* | 3.02 (2.45-3.71)* |
| Ajay[14] | 2002-2003 | Regional | Urban | 20-69 | 10930 | blood glucose, drug treatment | Education | Combined | 11.6% (l); 6.9% (h)* | 0.69 (0.54-0.89)* |
| Vijayakumar[15] | 2007 | Local | Rural | 18+ | 1990 | blood glucose, self-report | Social caste | Combined | 5.9% (l); 17.4% (h) | - |
| | | | | | | | Wealth | Combined | | 1.43 (1.04-1.95)* |
| Gupta[16] | 1999-2003 | Local | Urban | 20-59 | 1289 | blood glucose, self-report | Education | Male | 8.0% (l); 18.8% (h)* | - |
| | | | | | | | | Female | 6.0% (l); 34.7% (h)* | - |
| | | | | | | | | Combined | 6.9% (l); 26.4% (h)* | - |
| Kinra[17] | 2005-2007 | Regional | Rural | 20-69 | 1983 | blood glucose, self-report | Wealth | Male | 1.8% (l); 8.0% (h)* | - |
| | | | | | | | | Female | 3.9% (l); 5.1% (h) | - |
| Samuel[18] | 1969-2002 | Regional | Urban | 26-32 | 2218 | blood glucose†, drug treatment | Wealth | Male | 26.2% (l); 31.9% (h)* (Urban) | - |
| | | | | | | | | | 10.9% (l); 31.8% (h) (Rural) | - |
| | | | Rural | | | | | Female | 12.1% (l); 30.3% (h)* (Urban) | - |
| | | | | | | | | | 16.1% (l); 32.1% (h)* (Rural) | - |
| | | | Combined | | | | | Combined | - | 2.8 (1.9-4.1)* |
| | | | Urban | | | | Education | Male | 15.0% (l); 34.7% (h) (Urban) | - |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 25.7% (l); 19.7% (h) | - |
| | | | Rural | | | | | Female | 31.5% (l); 32.2% (h)* (Urban) | - |
| | | | | | | | | | 19.1% (l); 50.0% (h) | - |
| | | | Combined | | | | | Combined | - | 1.0 (0.6-1.6) |
| Zaman[19] | 2005 | Regional | Rural | 30+ | 4535 | blood glucose, self-report | Income | Male | 16.2% (l); 21.2% (h)* | - |
| | | | | | | | | Female | 12.1% (l); 15.0% (h)* | - |
| | | | | | | | Education | Male | 12.4% (l); 20.1% (h)* | - |
| | | | | | | | | Female | 12.8% (l); 13.1% (h) | - |

Notes ~~for Table 1~~: Socioeconomic status (SES) markers defined as education, household wealth, social caste, or a composite of 2 or more measures; *P<0.05; - indicates not reported; †includes impaired glucose tolerance and impaired fasting glucose

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**Table ~~1~~2~~:~~** Characteristics of survey participants and frequency distribution of self-reported diabetes in India, males and females from the 3rd National Family Health Survey

| | Self-reported ~~D~~diabetes | | Total |
|---|---|---|---|
| | *n* | *%* | *n* |
| Participants | 2439 | 1.5 | 168135 |
| Residence | | | |
| Rural | 818 | 1.0 | 86013 |
| Urban | 1621 | 2.0 | 82122 |
| Age group | | | |
| 18-29 y | 266 | 0.3 | 76174 |
| 30-39 y | 602 | 1.2 | 51132 |
| 40-49 y | 1238 | 3.4 | 36402 |
| 50-54 y | 333 | 7.5 | 4427 |
| Gender | | | |
| Male | 1144 | 1.8 | 65255 |
| Female | 1295 | 1.3 | 102880 |
| Marital status | | | |
| Single | 132 | 0.3 | 38078 |
| Married | 2165 | 1.8 | 123457 |
| Widowed | 108 | 2.5 | 4320 |
| Divorced or separated | 34 | 1.5 | 2280 |
| Religion | | | |
| Hindu | 1775 | 1.4 | 123411 |
| Muslim | 340 | 1.6 | 21510 |
| Christian | 213 | 1.4 | 14779 |
| Sikh | 49 | 1.5 | 3236 |
| Buddhist | 34 | 1.4 | 2451 |
| Other | 28 | 1.0 | 2748 |
| Social Caste | | | |
| Other caste | 1026 | 1.8 | 56063 |
| Scheduled caste | 349 | 1.3 | 27677 |
| Scheduled tribe | 167 | 0.8 | 21372 |
| Other backward class | 781 | 1.4 | 55641 |
| No caste | 116 | 1.6 | 7382 |
| Education | | | |
| No education | 464 | 1.0 | 44856 |
| Primary | 358 | 1.4 | 24969 |

| | | | |
|---|---|---|---|
| Secondary | 1166 | 1.6 | 74715 |
| Higher | 451 | 1.9 | 23595 |
| Household wealth | | | |
| Poorest | 77 | 0.4 | 17252 |
| 2nd quintile | 175 | 0.8 | 22948 |
| 3rd quintile | 278 | 0.9 | 32070 |
| 4th quintile | 573 | 1.4 | 42091 |
| Richest | 1336 | 2.5 | 53774 |
| Body mass index (kg/m$^2$) | | | |
| <18.5 | 243 | 0.6 | 42128 |
| 18.5-22.9 | 703 | 0.9 | 74089 |
| 23-27.4 | 833 | 2.7 | 31217 |
| 27.5+ | 547 | 4.8 | 11502 |

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**Table** 3~~2:~~ Associations between socioeconomic status and self-reported diabetes in India; 3rd National family health survey, 2005-6

| | ~~Model adjusted for age, gender, marital status, religion, residence~~Models 1-3 | | ~~Mutually adjusted model~~Model 4 | | ~~Mutually adjusted model with BMI~~Mo[del 5] | |
|---|---|---|---|---|---|---|
| Variable | Odds ratio | 95% CI | Odds ratio | 95% CI | Odds ratio | 95% CI |
| Social Caste | | | | | | |
| Other caste | 1.00 | | 1.00 | | 1.00 | |
| Scheduled caste | 0.81 | (0.71 - 0.94) | 1.05 | (0.91 - 1.21) | 1.07 | (0.93 - 1.24) |
| Scheduled tribe | 0.57 | (0.46 - 0.70) | 0.72 | (0.58 - 0.90) | 0.73 | (0.57 - 0.92) |
| Other backward caste | 0.84 | (0.75 - 0.94) | 0.95 | (0.85 - 1.07) | 0.96 | (0.86 - 1.08) |
| No caste | 0.89 | (0.71 - 1.11) | 0.94 | (0.75 - 1.17) | 0.95 | (0.76 - 1.20) |
| Wealth | | | | | | |
| Poorest | 1.00 | | 1.00 | | 1.00 | |
| 2nd quintile | 1.59 | (1.20 - 2.12) | 1.57 | (1.21 - 2.07) | 1.49 | (1.14 - 1.96) |
| 3rd quintile | 1.63 | (1.23 - 2.16) | 1.55 | (1.21 - 2.02) | 1.39 | (1.07 - 1.81) |
| 4th quintile | 2.42 | (1.85 - 3.17) | 2.25 | (1.76 - 2.92) | 1.79 | (1.40 - 2.34) |
| Richest | 4.04 | (3.08 - 5.30) | 3.65 | (2.83 - 4.78) | 2.58 | (1.99 - 3.40) |
| Education | | | | | | |
| No education | 1.00 | | 1.00 | | 1.00 | |
| Primary | 1.23 | (1.06 - 1.43) | 1.06 | (0.91 - 1.22) | 1.00 | (0.86 - 1.17) |
| Secondary | 1.68 | (1.49 - 1.90) | 1.18 | (1.04 - 1.35) | 1.12 | (0.98 - 1.28) |
| Higher | 1.87 | (1.61 - 2.18) | 1.12 | (0.95 - 1.32) | 1.01 | (0.86 - 1.20) |
| Body mass index (kg/m$^2$) | | | | | | |
| <18.5 | | | | | 1.00 | |
| 18.5-22.9~~3~~ | | | | | 1.25 | (1.08 - 1.46) |
| 23-27.4~~5~~ | | | | | 2.08 | (1.79 - 2.44) |
| 27.5+ | | | | | 2.98 | (2.51 - 3.54) |

Notes: In models 1-3 one SES marker (social caste, household wealth, education) was modelled at a time while adjusting for age, gender, religion, and place of residence. In model 4, all SES markers were included along with covariates form models 1-3. In model 5, BMI was included with markers of SES and covariates from model 4.

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**Table 34:** Variance in self-reported diabetes status between local areas and states in India; expressed as percentage of the contribution to the total variance in diabetes

| | Age & gender adjusted* | | | Fully adjusted** | | |
|---|---|---|---|---|---|---|
| | Variance | SE | % | Variance | SE | % |
| States | 0.231 | 0.076 | 5.9 | 0.204 | 0.068 | 5.4 |
| Local areas | 0.425 | 0.043 | 10.8 | 0.240 | 0.041 | 6.4 |

Notes:
*Multilevel model adjusted for age and gender only
**Multilevel model fully adjusted for age, gender, marital status, religion, social caste, household wealth, education, body mass index, and place of residence

| | | Self-reported diabetes | |
|---|---|---|---|
| State | *n* | Wealth OR | 95% CI* |
| India | 158,936 | 1.31 | (1.20 - 1.42) |
| Jammu and Kashmir | 3,383 | 1.55 | (1.21 - 1.98) |
| Maharashtra | 14,053 | 1.51 | (1.27 - 1.78) |
| Orissa | 4,838 | 1.50 | (1.24 - 1.81) |
| Arunachal Pradesh | 1,798 | 1.49 | (1.14 - 1.94) |
| Uttar Pradesh | 17,555 | 1.47 | (1.28 - 1.70) |
| Sikkim | 2,406 | 1.46 | (1.11 - 1.92) |
| Madhya Pradesh | 7,756 | 1.43 | (1.19 - 1.71) |
| Assam | 3,904 | 1.43 | (1.15 - 1.77) |
| Uttaranchal | 3,120 | 1.42 | (1.12 - 1.81) |
| Punjab | 4,134 | 1.41 | (1.10 - 1.81) |
| Mizoram | 2,089 | 1.40 | (1.07 - 1.85) |
| Karnataka | 9,049 | 1.40 | (1.19 - 1.64) |
| Chhattisgarh | 4,246 | 1.36 | (1.14 - 1.64) |
| Delhi | 3,026 | 1.35 | (1.05 - 1.73) |
| Rajasthan | 4,433 | 1.33 | (1.03 - 1.71) |
| Meghalaya | 2,135 | 1.29 | (1.03 - 1.63) |
| Jharkhand | 3,044 | 1.29 | (1.06 - 1.57) |
| Tamil Nadu | 10,106 | 1.28 | (1.11 - 1.48) |
| Andhra Pradesh | 11,824 | 1.25 | (1.09 - 1.45) |
| Himachal Pradesh | 3,563 | 1.25 | (0.97 - 1.61) |
| Gujarat | 4,322 | 1.25 | (1.00 - 1.56) |
| Goa | 3,883 | 1.20 | (0.98 - 1.48) |
| Nagaland | 6,350 | 1.19 | (0.99 - 1.44) |

| | | | | |
|---|---|---|---|---|
| ~~Tripura~~ | ~~2,089~~ | ~~1.18~~ | ~~(0.96 -~~ | ~~1.45)~~ |
| ~~Manipur~~ | ~~6,941~~ | ~~1.14~~ | ~~(0.95 -~~ | ~~1.37)~~ |
| ~~Haryana~~ | ~~3,173~~ | ~~1.11~~ | ~~(0.90 -~~ | ~~1.38)~~ |
| ~~Bihar~~ | ~~3,882~~ | ~~1.10~~ | ~~(0.93 -~~ | ~~1.30)~~ |
| ~~Kerala~~ | ~~4,018~~ | ~~1.10~~ | ~~(0.89 -~~ | ~~1.35)~~ |
| ~~West Bengal~~ | ~~7,816~~ - | ~~0.95~~ | ~~(0.83 -~~ | ~~1.09)~~ |

~~Notes: Odds ratios (OR) and 95% credible intervals (CI) adjusted for age, gender, marital status, religion, social caste, education, body mass index and place of residence.~~

**FIGURE LEGENDS**

**Figure 1** Flow diagram showing exclusions and final sample sizes, 2005-6 National Family Health Survey (NFHS)

Notes for figure 1: *2,333 individuals reported unknown diabetes status; in 40 individuals diabetes status was not reported/missing. Of the 2,333 individuals who reported unknown diabetes status, 2,210 (94.7%) had complete data for BMI and were included in sensitivity analyses.
**Analyses involving body mass index (BMI) as an independent variable were restricted to 158,936 individuals.

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**Figure 2~~1~~** State level prevalence of self-reported diabetes in India for men aged 18-54 (left) and women aged 18-49 (right). Darker colours indicate higher prevalence.

Notes for figure 2: State name abbreviations: AP Andhra Pradesh; AR Arunachal Pradesh; AS Assam; BR Bihir; CT Chhattisgarh; DL Delhi; GA Goa; GJ Gujarat; HR Haryana; HP Himachal Pradesh; JK Jammu & Kashmir; JH Jharkhand; KA Karnataka; KL Kerala; MP Madhya Pradesh; MH Maharashtra; MN Manipur; ML Meghalaya; MZ Mizoram; NL Nagaland; OR Orissa; PB Punjab; RJ Rajasthan; SK Sikkim; TN Tamil Nadu; TR Tripura; UP Uttar Pradesh; UK Uttarakhand (Uttaranchal); WB West Bengal

**Figure 3~~2~~** Odds ratios for self-reported diabetes by state of residence in India

Notes for figure 3: horizontal lines are 95% credible intervals; ~~Notes for~~ adjusted for age, gender, marital status, religion, social caste, household wealth, education, body mass index and place of residence.

**Figure 4** Odds ratio (OR) for self-reported diabetes for a one-quintile increase in household wealth for men (aged 18-54) and women (aged 18-49) in India and 29 states
**4**
Notes for figure 4: Adjusted for age, gender, marital status, religion, social caste, education, body mass index and place of residence.

**Figure 5~~3~~** Mean body mass index across three possible responses for self-reported diabetes ~~(Not known - diabetes status not known, No- do not have diabetes, Yes- have diabetes)~~.

Notes for figure 5: Vertical lines represent 95% confidence intervals. Body mass index (in $kg/m^2$) objectively defined based on calculated from measured height and weight values. Horizontal line represents overall mean body mass index (21.2 $kg/m^2$, SD 3.9).

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## SUPPLEMENTAL MATERIAL

**Supplemental Table 1** Associations between socioeconomic status and self-reported diabetes in India from models restricted to male and female samples; 3rd National family health survey 2005-6

| | Men aged 18-54 | | | | | | Women aged 18-49 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Models 1-3 | | Model 4 | | Model 5 | | Models 1-3 | | Model 4 | | Model 5 | |
| **Variable** | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** |
| Social Caste | | | | | | | | | | | | |
| Other caste | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| Scheduled caste | 0.84 | (0.68 - 1.03) | 1.14 | (0.92 - 1.39) | 1.20 | (0.96 - 1.48) | 0.77 | (0.64 - 0.93) | 0.95 | (0.78 - 1.14) | 0.97 | (0.79 - 1.16) |
| Scheduled tribe | 0.55 | (0.40 - 0.75) | 0.73 | (0.52 - 1.00) | 0.78 | (0.56 - 1.07) | 0.54 | (0.39 - 0.71) | 0.65 | (0.48 - 0.87) | 0.64 | (0.48 - 0.87) |
| Other backward caste | 0.86 | (0.74 - 1.00) | 1.01 | (0.86 - 1.19) | 1.04 | (0.88 - 1.23) | 0.78 | (0.67 - 0.91) | 0.86 | (0.74 - 1.01) | 0.87 | (0.75 - 1.02) |
| No caste | 0.92 | (0.62 - 1.37) | 0.96 | (0.65 - 1.40) | 1.04 | (0.71 - 1.52) | 0.87 | (0.66 - 1.16) | 0.90 | (0.68 - 1.21) | 0.91 | (0.67 - 1.22) |
| Wealth | | | | | | | | | | | | |
| Poorest | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| 2nd quntile | 1.40 | (0.97 - 2.11) | 1.35 | (0.94 - 1.97) | 1.32 | (0.89 - 1.88) | 1.72 | (1.17 - 2.46) | 1.66 | (1.15 - 2.44) | 1.69 | (1.18 - 2.52) |
| 3rd quntile | 1.46 | (1.03 - 2.15) | 1.36 | (0.95 - 1.96) | 1.29 | (0.88 - 1.80) | 1.73 | (1.17 - 2.52) | 1.60 | (1.10 - 2.26) | 1.48 | (1.07 - 2.25) |
| 4th quntile | 2.10 | (1.51 - 3.10) | 1.87 | (1.34 - 2.62) | 1.65 | (1.14 - 2.28) | 2.66 | (1.79 - 3.87) | 2.34 | (1.64 - 3.32) | 1.89 | (1.38 - 2.83) |
| Richest | 4.55 | (3.22 - 6.81) | 3.82 | (2.73 - 5.37) | 3.04 | (2.05 - 4.27) | 3.67 | (2.42 - 5.41) | 3.16 | (2.19 - 4.47) | 2.24 | (1.62 - 3.32) |
| Education | | | | | | | | | | | | |
| No education | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| Primary | 1.1 | (0.86 1.3 | 0.9 | (0.75 1.2 | 0.9 | (0.70 1.2 | 1.3 | (1.16 1.6 | 1.1 | (0.98 1.4 | 1.1 | (0.92 1.3 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | - | 8) | 6 | - | 1) | 2 | - | 0) | 9 | - | 7) | 7 | - | 0) | 1 | - | 3) |
| Secondary | 1.66 | (1.37- | 2.01) | 1.13 | (0.90- | 1.44) | 1.07 | (0.85- | 1.36) | 1.76 | (1.52- | 2.02) | 1.28 | (1.08- | 1.50) | 1.21 | (1.02- | 1.43) |
| Higher | 2.36 | (1.87- | 2.92) | 1.27 | (0.98- | 1.70) | 1.13 | (0.86- | 1.48) | 1.40 | (1.12- | 1.73) | 0.91 | (0.72- | 1.15) | 0.85 | (0.66- | 1.08) |
| Body mass index (kg/m$^2$) | | | | | | | | | | | | | | | | | | |
| <18 | | | | | | | 1.00 | | | | | | | | | 1.00 | | |
| 18.5-22.9 | | | | | | | 1.25 | (0.99- | 1.55) | | | | | | | 1.24 | (1.01- | 1.53) |
| 23-27.4 | | | | | | | 2.00 | (1.59- | 2.50) | | | | | | | 2.12 | (1.75- | 2.68) |
| 27.5+ | | | | | | | 2.15 | (1.65- | 2.86) | | | | | | | 3.58 | (2.89- | 4.56) |

Notes: OR odds ratio; In models 1-3 one SES marker (social caste, household wealth, education) was modelled at a time while adjusting for age, gender, religion, and place of residence. In model 4, all SES markers were included along with covariates form models 1-3. In model 5, BMI was included with markers of SES and covariates from model 4.

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**Supplemental Table 2** Odds ratio (OR) for self-reported diabetes for a one-quintile increase in household wealth for men (aged 18-54) and women (aged 18-49) in India and 29 states

| State | *n* | Self-reported diabetes | |
|---|---|---|---|
| | | Wealth OR | 95% CI* |
| India | 158,936 | 1.31 | (1.20 - 1.42) |
| Jammu and Kashmir | 3,383 | 1.55 | (1.21 - 1.98) |
| Maharashtra | 14,053 | 1.51 | (1.27 - 1.78) |
| Orissa | 4,838 | 1.50 | (1.24 - 1.81) |
| Arunachal Pradesh | 1,798 | 1.49 | (1.14 - 1.94) |
| Uttar Pradesh | 17,555 | 1.47 | (1.28 - 1.70) |
| Sikkim | 2,406 | 1.46 | (1.11 - 1.92) |
| Madhya Pradesh | 7,756 | 1.43 | (1.19 - 1.71) |
| Assam | 3,904 | 1.43 | (1.15 - 1.77) |
| Uttaranchal | 3,120 | 1.42 | (1.12 - 1.81) |
| Punjab | 4,134 | 1.41 | (1.10 - 1.81) |
| Mizoram | 2,089 | 1.40 | (1.07 - 1.85) |
| Karnataka | 9,049 | 1.40 | (1.19 - 1.64) |
| Chhattisgarh | 4,246 | 1.36 | (1.14 - 1.64) |
| Delhi | 3,026 | 1.35 | (1.05 - 1.73) |
| Rajasthan | 4,433 | 1.33 | (1.03 - 1.71) |
| Meghalaya | 2,135 | 1.29 | (1.03 - 1.63) |
| Jharkhand | 3,044 | 1.29 | (1.06 - 1.57) |
| Tamil Nadu | 10,106 | 1.28 | (1.11 - 1.48) |
| Andhra Pradesh | 11,824 | 1.25 | (1.09 - 1.45) |
| Himachal Pradesh | 3,563 | 1.25 | (0.97 - 1.61) |
| Gujarat | 4,322 | 1.25 | (1.00 - 1.56) |
| Goa | 3,883 | 1.20 | (0.98 - 1.48) |
| Nagaland | 6,350 | 1.19 | (0.99 - 1.44) |
| Tripura | 2,089 | 1.18 | (0.96 - 1.45) |
| Manipur | 6,941 | 1.14 | (0.95 - 1.37) |
| Haryana | 3,173 | 1.11 | (0.90 - 1.38) |
| Bihar | 3,882 | 1.10 | (0.93 - 1.30) |
| Kerala | 4,018 | 1.10 | (0.89 - 1.35) |
| West Bengal | 7,816 | 0.95 | (0.83 - 1.09) |

Notes: Odds ratios (OR) and 95% credible intervals (CI) adjusted for age, gender, marital status, religion, social caste, education, body mass index and place of residence.

**Supplemental Table ~~1~~3** Associations between socioeconomic status and body mass index ~~,~~ for self-reported diabetics and those with ~~es, and~~ unknown diabetes status compared to self-reported non-diabetics using a multilevel multinomial regression model.

| | **~~Diabetes~~Self-reported diabetes** | | **~~Diabetes not known~~Unknown diabetes status** | |
|---|---|---|---|---|
| Variable | Odds ratio | 95% CI* | Odds ratio | 95% CI |
| Social Caste | | | | |
| Other caste | 1.00 | | 1.00 | |
| Scheduled caste | 1.07 | (0.93 - 1.24) | 1.13 | (0.96 - 1.31) |
| Scheduled tribe | 0.73 | (0.58 - 0.91) | 1.52 | (1.25 - 1.84) |
| Other backward caste | 0.96 | (0.86 - 1.08) | 1.07 | (0.93 - 1.23) |
| No caste | 0.95 | (0.75 - 1.18) | 0.76 | (0.58 - 0.99) |
| Wealth | | | | |
| Poorest | 1.00 | | 1.00 | |
| 2nd quintile | 1.51 | (1.14 - 2.03) | 0.90 | (0.77 - 1.05) |
| 3rd quintile | 1.41 | (1.07 - 1.89) | 0.86 | (0.73 - 1.01) |
| 4th quintile | 1.82 | (1.38 - 2.44) | 0.82 | (0.68 - 0.98) |
| Richest | 2.63 | (1.97 - 3.56) | 0.64 | (0.51 - 0.79) |
| Education | | | | |
| No education | 1.00 | | 1.00 | |
| Primary | 1.00 | (0.87 - 1.17) | 0.86 | (0.76 - 0.99) |
| Secondary | 1.12 | (0.98 - 1.28) | 0.71 | (0.63 - 0.81) |
| Higher | 1.01 | (0.85 - 1.21) | 0.45 | (0.36 - 0.57) |
| Body mass index | | | | |
| <18.5 | 1.00 | | 1.00 | |
| 18.5-22.9~~3~~ | 1.26 | (1.08 - 1.46) | 1.03 | (0.93 - 1.15) |
| 23-27.4~~5~~ | 2.09 | (1.79 - 2.45) | 1.17 | (1.01 - 1.36) |
| 27.5+ | 2.99 | (2.52 - 3.55) | 1.33 | (1.06 - 1.66) |

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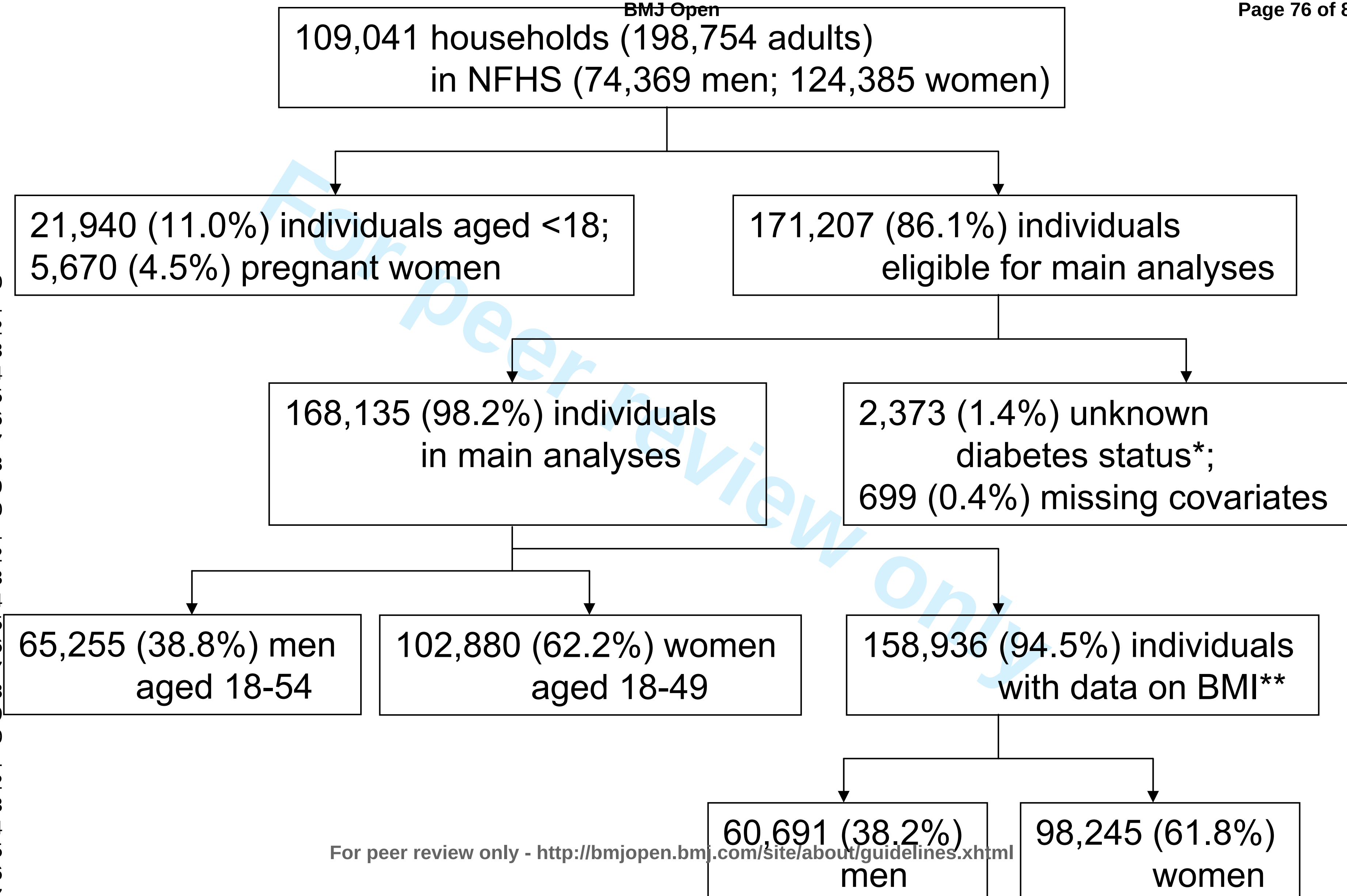
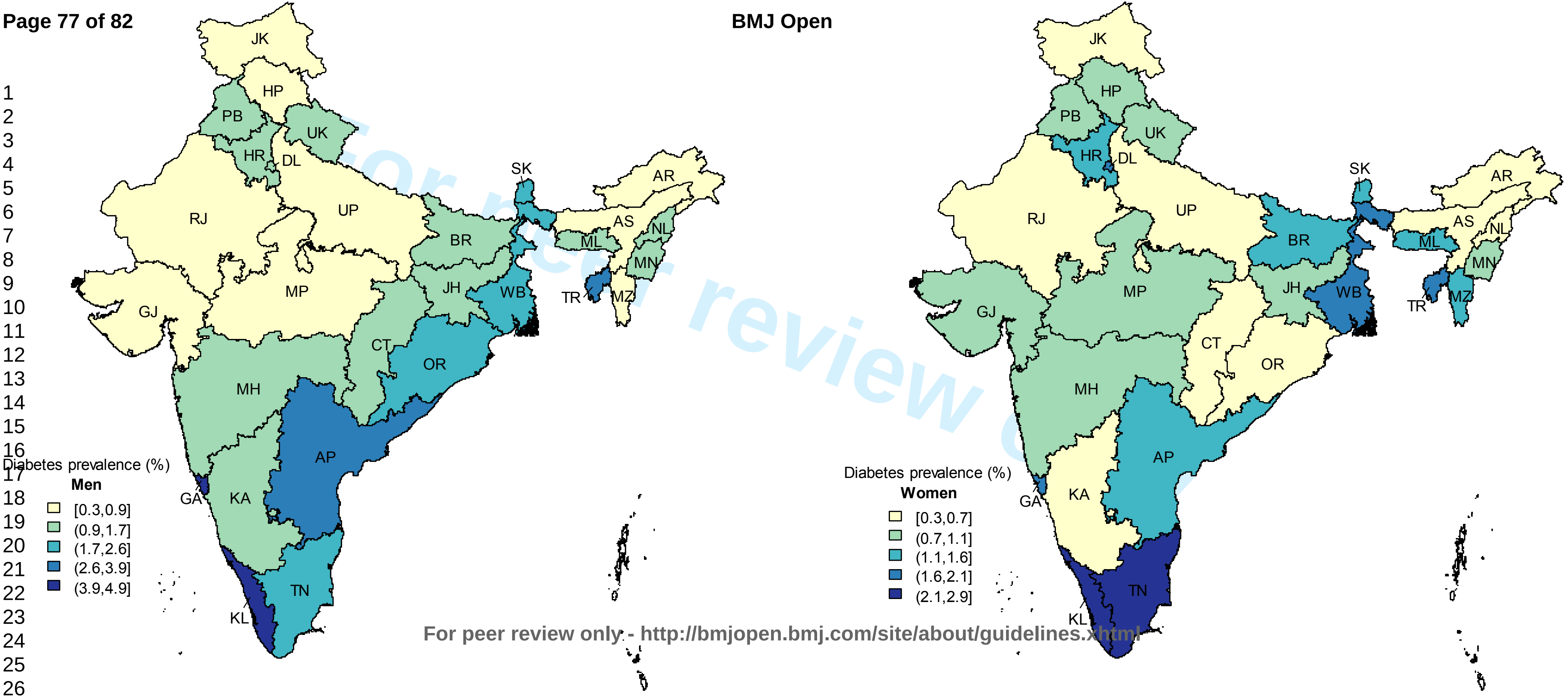
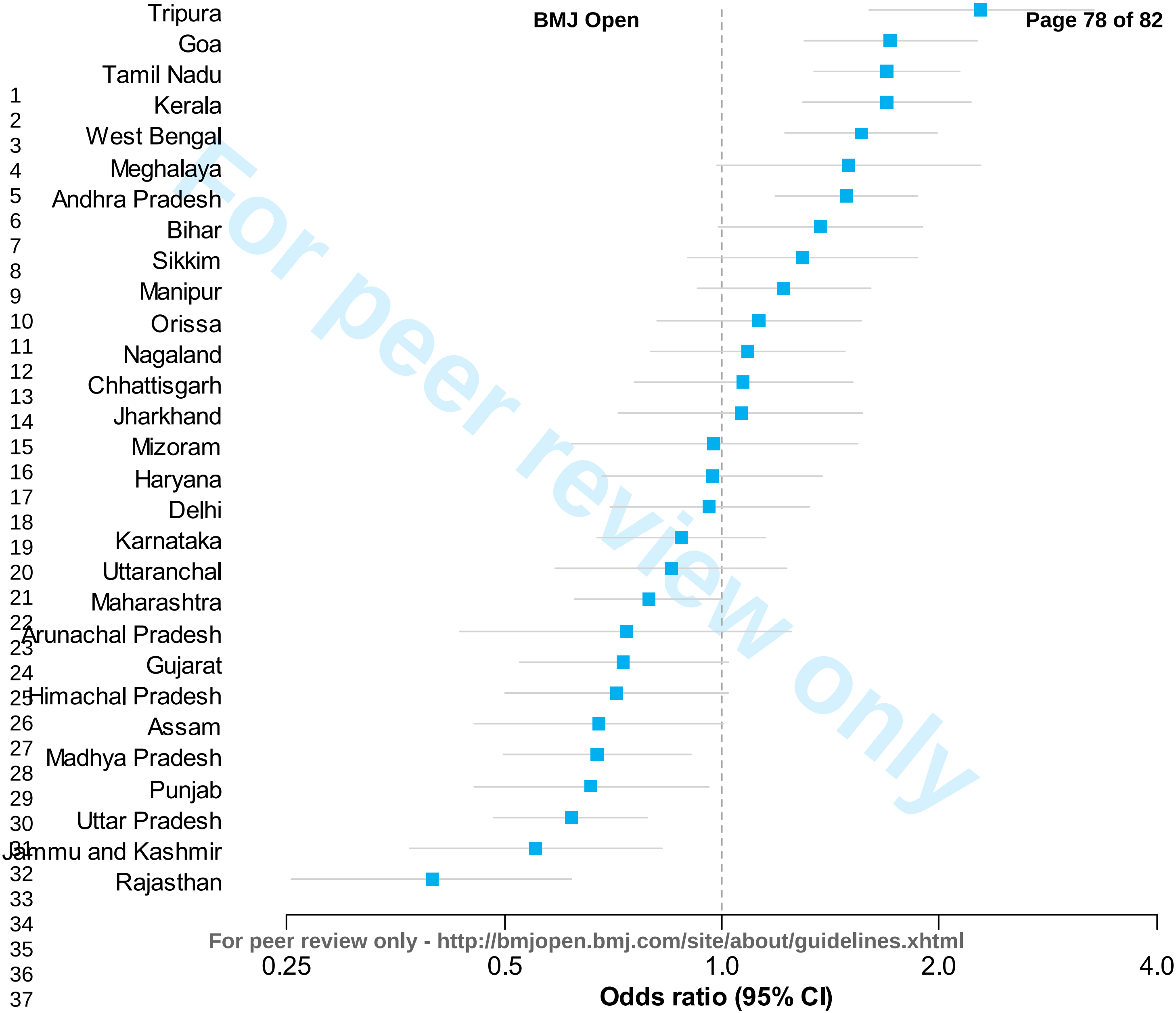
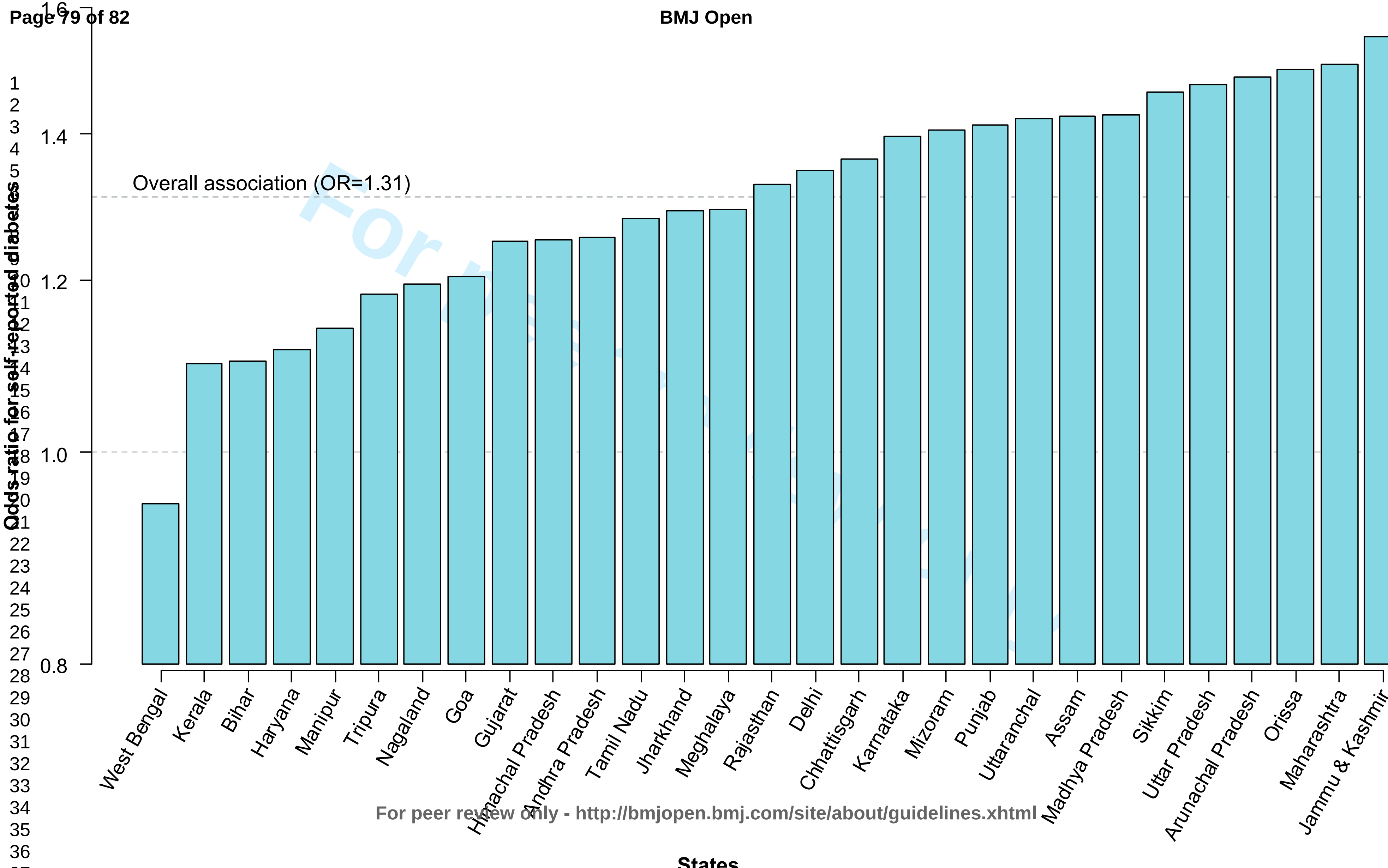
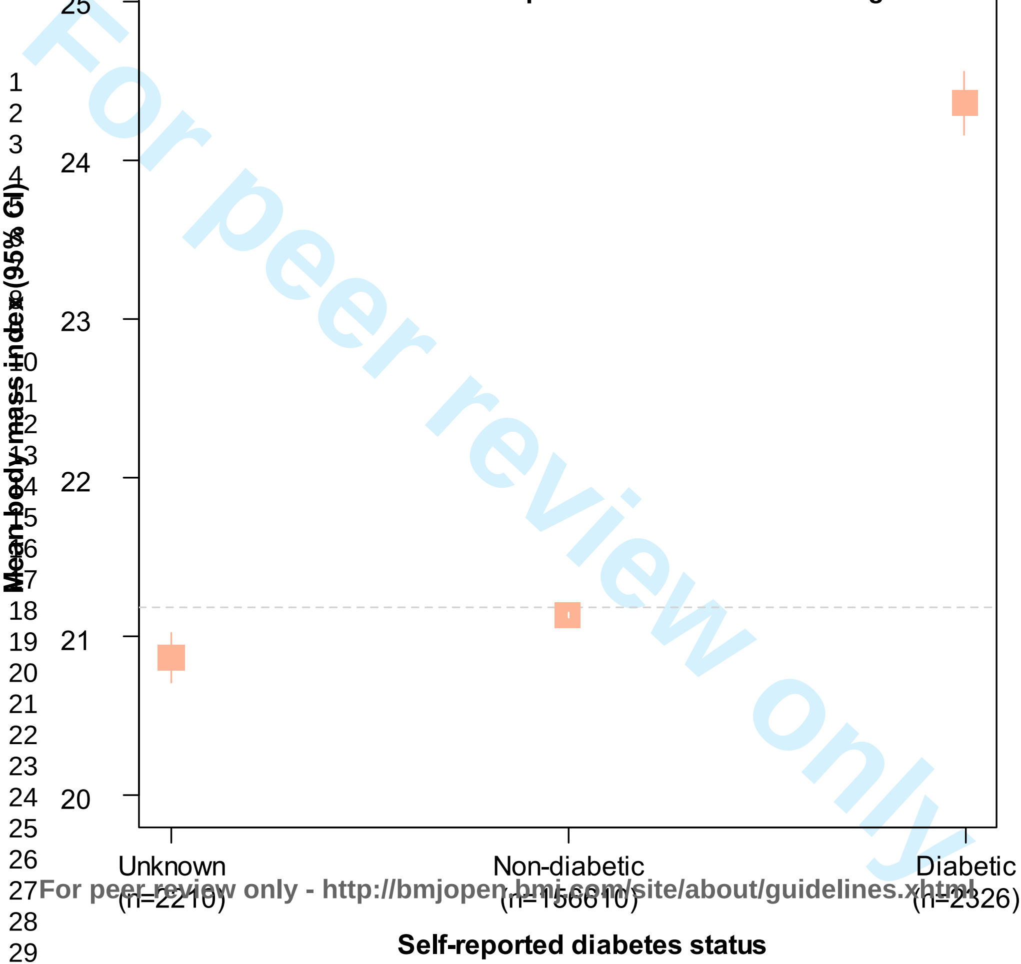
Notes: model adjusted for age, gender, religion, marital status, place of residence
*95% credible interval


109,041 households (198,754 adults) in NFHS (74,369 men; 124,385 women)
21,940 (11.0%) individuals aged <18; 5,670 (4.5%) pregnant women
171,207 (86.1%) individuals eligible for main analyses
168,135 (98.2%) individuals in main analyses
2,373 (1.4%) unknown diabetes status*; 699 (0.4%) missing covariates
65,255 (38.8%) men aged 18-54
102,880 (62.2%) women aged 18-49
158,936 (94.5%) individuals with data on BMI**
60,691 (38.2%) men
98,245 (61.8%) women


JK
HP
PB
UK
HR
DL
RJ
UP
SK
AR
AS
NL
ML
BR
MN
TR
MZ
JH
WB
GJ
MP
CT
OR
MH
AP
GA
KA
TN
KL
Diabetes prevalence (%)
Men
[0.3,0.9]
(0.9,1.7]
(1.7,2.6]
(2.6,3.9]
(3.9,4.9]
Diabetes prevalence (%)
Women
[0.3,0.7]
(0.7,1.1]
(1.1,1.6]
(1.6,2.1]
(2.1,2.9]


Tripura
Goa
Tamil Nadu
Kerala
West Bengal
Meghalaya
Andhra Pradesh
Bihar
Sikkim
Manipur
Orissa
Nagaland
Chhattisgarh
Jharkhand
Mizoram
Haryana
Delhi
Karnataka
Uttaranchal
Maharashtra
Arunachal Pradesh
Gujarat
Himachal Pradesh
Assam
Madhya Pradesh
Punjab
Uttar Pradesh
Jammu and Kashmir
Rajasthan
0.25
0.5
1.0
2.0
4.0
Odds ratio (95% CI)


Odds ratio for self-reported diabetes
1.6
1.4
1.2
1.0
0.8
Overall association (OR=1.31)
West Bengal
Kerala
Bihar
Haryana
Manipur
Tripura
Nagaland
Goa
Gujarat
Himachal Pradesh
Andhra Pradesh
Tamil Nadu
Jharkhand
Meghalaya
Rajasthan
Delhi
Chhattisgarh
Karnataka
Mizoram
Punjab
Uttaranchal
Assam
Madhya Pradesh
Sikkim
Uttar Pradesh
Arunachal Pradesh
Orissa
Maharashtra
Jammu & Kashmir
States


Mean body mass index (95% CI)
25
24
23
22
21
20
Unknown
(n=2210)
Non-diabetic
(n=156610)
Diabetic
(n=2326)
Self-reported diabetes status

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

**Article: Association between socioeconomic status and diabetes in India**

**Authors: Daniel J Corsi, SV Subramanian**

| | Item No | Recommendation |
|---|---|---|
| **Title and abstract** | 1 | (*a*) Design cross-sectional study, listed in abstract |
| | | (*b*) abstract and article summary (page 3) |
| **Introduction** | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported, (abstract, page 3, page 4-5) |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses (abstract, page 3, page 4-5) |
| **Methods** | | |
| Study design | 4 | Present key elements of study design early in the paper (abstract, page 6) |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection (abstract, page 5-7) |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants (page 6) |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable (page 7) |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group (page 7-8) |
| Bias | 9 | Describe any efforts to address potential sources of bias (page 8-9; page 12) |
| Study size | 10 | Explain how the study size was arrived at (page 7) |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why (page 8) |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding (page 8-9) |
| | | (*b*) Describe any methods used to examine subgroups and interactions (page 12) |
| | | (*c*) Explain how missing data were addressed (page 7) |
| | | (*d*) If applicable, describe analytical methods taking account of sampling strategy (page 8) |
| | | (*e*) Describe any sensitivity analyses (page 12) |
| **Results** | | |
| Participants | 13 | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (page 8) |
| | | (b) Give reasons for non-participation at each stage (n/a) |
| | | (c) Consider use of a flow diagram (n/a) |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (page 9-10, table 1) |
| | | (b) Indicate number of participants with missing data for each variable of interest (page 7; page 12) |
| Outcome data | 15* | Table 1 |
| Main results | 16DJC | (*a*) Tables 1 (unadjusted), 2 (age, gender, marital status, religion, place of residence adjusted; and fully adjusted model) |

| | | |
|---|---|---|
| | | (*b*) Report category boundaries when continuous variables were categorized (in methods, e.g. for BMI) |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period (n/a) |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses (Page 12) |
| **Discussion** | | |
| Key results | 18 | Summarise key results with reference to study objectives (page 13) |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias (page 13) |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence (page 16) |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results (pages 14-15) |
| **Other information** | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based (title page) |

*Give information separately for exposed and unexposed groups.

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