Prevalence of diabetes and prediabetes in 15 states of India: results from the ICMR–INDIAB population-based cross-sectional study

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Summary

Background Previous studies have not adequately captured the heterogeneous nature of the diabetes epidemic in India. The aim of the ongoing national Indian Council of Medical Research–INdia DIABetes study is to estimate the national prevalence of diabetes and prediabetes in India by estimating the prevalence by state.

Methods We used a stratified multistage design to obtain a community-based sample of 57 117 individuals aged 20 years or older. The sample population represented 14 of India's 28 states (eight from the mainland and six from the northeast of the country) and one union territory. States were sampled in a phased manner: phase I included Tamil Nadu, Chandigarh, Jharkhand, and Maharashtra, sampled between Nov 17, 2008, and April 16, 2010; phase II included Andhra Pradesh, Bihar, Gujarat, Karnataka, and Punjab, sampled between Sept 24, 2012, and July 26, 2013; and the northeastern phase included Assam, Mizoram, Arunachal Pradesh, Tripura, Manipur, and Meghalaya, with sampling done between Jan 5, 2012, and July 3, 2015. Capillary oral glucose tolerance tests were used to diagnose diabetes and prediabetes in accordance with WHO criteria. Our methods did not allow us to differentiate between type 1 and type 2 diabetes. The prevalence of diabetes in different states was assessed in relation to socioeconomic status (SES) of individuals and the per-capita gross domestic product (GDP) of each state. We used multiple logistic regression analysis to examine the association of various factors with the prevalence of diabetes and prediabetes.

Findings The overall prevalence of diabetes in all 15 states of India was 7·3% (95% CI 7·0–7·5). The prevalence of diabetes varied from 4·3% in Bihar (95% CI 3·7–5·0) to 10·0% (8·7–11·2) in Punjab and was higher in urban areas (11·2%, 10·6–11·8) than in rural areas (5·2%, 4·9–5·4; p<0·0001) and higher in mainland states (8·3%, 7·9–8·7) than in the northeast (5·9%, 5·5–6·2; p<0·0001). Overall, 1862 (47·3%) of 3938 individuals identified as having diabetes had not been diagnosed previously. States with higher per-capita GDP seemed to have a higher prevalence of diabetes (eg, Chandigarh, which had the highest GDP of US$ 3433, had the highest prevalence of 13·6%, 12.8–15·2). In rural areas of all states, diabetes was more prevalent in individuals of higher SES. However, in urban areas of some of the more affluent states (Chandigarh, Maharashtra, and Tamil Nadu), diabetes prevalence was higher in people with lower SES. The overall prevalence of prediabetes in all 15 states was 10·3% (10·0–10·6). The prevalence of prediabetes varied from 6·0% (5·1–6·8) in Mizoram to 14·7% (13·6–15·9) in Tripura, and the prevalence of impaired fasting glucose was generally higher than the prevalence of impaired glucose tolerance. Age, male sex, obesity, hypertension, and family history of diabetes were independent risk factors for diabetes in both urban and rural areas.

Interpretation There are large differences in diabetes prevalence between states in India. Our results show evidence of an epidemiological transition, with a higher prevalence of diabetes in low SES groups in the urban areas of the more economically developed states. The spread of diabetes to economically disadvantaged sections of society is a matter of great concern, warranting urgent preventive measures.

Funding Indian Council of Medical Research and Department of Health Research, Ministry of Health and Family Welfare, Government of India.

Lancet Diabetes Endocrinol 2017; 5: 585–96

Published Online
June 7, 2017
http://dx.doi.org/10.1016/S2213-8587(17)30174-2

This online publication has been corrected. The corrected version first appeared at thelancet.com/diabetes-endocrinology on June 8, 2017

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Introduction

Over the past few decades, various studies have been done to attempt to estimate the prevalence of diabetes in India.[1–3] Most of these studies have been small and focused on specific towns, villages, or cities. Because of the size and diversity of India's geography, and the heterogeneous nature of the Asian Indian population, estimates obtained from region-specific studies do not accurately reflect the disease burden in the country as a whole. Moreover, these previous studies have been done at different times with various methods and sampling designs, making it virtually impossible to calculate a national estimate of diabetes prevalence.[4] Even the few multicentre studies that have been done cannot be deemed representative of the whole

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Research in context

Evidence before this study

We did a literature search of studies reporting prevalence of diabetes and prediabetes among Asian Indians. We searched for studies published before Jan 31, 2017, on PubMed, Google Scholar, IndMED, and the Cochrane Database of Systematic Reviews, as well as scanning relevant reference lists and review articles. To ensure a broad search we used the key words "diabetes", "prediabetes", "prevalence", "risk factors", "urban", "rural", "India", "Asian Indians", and "South Asians". We used a combination of MeSH terms and free texts for the search, which was limited to publications in English. We set no date or study design restrictions. The key inclusion criteria were original studies (published or reports), participants aged 20 years or older, and studies conducted in the general population. Existing assumptions about the prevalence of diabetes in India are based on numerous small regional studies and a few national studies (which either only studied large cities or specifically excluded them). These studies have also been done over varying periods of time and have not studied even one whole state of the country. The heterogeneity of India in terms of geography, ethnicity, and sociocultural practices precludes nationwide inferences being drawn from the results of these studies. Additionally, many states of India have been under-represented in these studies, especially the eight states of northeastern India. Evidence from available studies suggests that type 2 diabetes in India is a disease of higher socioeconomic status individuals, and that the diabetes epidemic continues to grow through conversion from the large pool of individuals with prediabetes. The accuracy of these assumptions is likely to have changed following the rapid economic development of India over the past two decades, but until now no evidence was available from large representative studies on the nature and magnitude of this change.

Added value of this study

We report results from the largest nationally representative, government-funded study of diabetes in India (phases I and II and northeastern phase). Our findings for the prevalence of diabetes and prediabetes in 15 states of India (including six northeastern states) represent 50·7% of the country's adult population. This study is the largest ever to investigate diabetes in India, and the first to sample entire states of the country, including in the northeast. Our results show large differences in the prevalence of diabetes between states, with the more economically developed states tending to have higher prevalence. In the urban areas of more prosperous states, the prevalence of diabetes was higher among individuals of lower socioeconomic status than in individuals of higher socioeconomic status, by contrast with the situation in the less developed states. Furthermore, the prevalence of prediabetes continues to exceed that of diabetes in most of the country, except in some of the more prosperous states, where the diabetes-to-prediabetes ratio has equalised or even reversed. Diabetes awareness, as measured by the ratio of known to newly detected diabetes, remains low in rural areas.

Implications of all the available evidence

The diabetes epidemic seems to be maturing in the more economically advanced states of India, with diminution of the prediabetes pool raising the likelihood of stabilisation of diabetes prevalence in the near future in these states. However, the spread of the epidemic to economically disadvantaged sections of society is a matter of great concern in India, where most diabetes treatment expenses are borne out of pocket by patients. Preventive measures need to be directed at these individuals, who have previously been deemed at fairly low risk of developing diabetes, as well as to rural areas where diabetes awareness remains low.

of India.[5,6] The need for a national study of diabetes prevalence in India that includes a truly representative sample of the nation's population,[4] both urban and rural, led to the creation of the Indian Council of Medical Research–INdia DIABetes (ICMR–2) study.

The aim of the ICMR–INDIAB study is to establish the national and state-specific prevalence of diabetes and prediabetes in India.[7] Such data will offer not only a more comprehensive understanding of disease burden, but also provide opportunities to explore state-level and individual-level variation in diabetes and prediabetes. Here, we report on the prevalence of diabetes and prediabetes from 15 states of India and explore heterogeneities in diabetes and prediabetes phenotypes by state, rural and urban setting, and individual characteristics.

Methods

Sampling and study population

The ICMR–INDIAB study is an ongoing cross-sectional, community-based survey of adults aged 20 years and older. The methodological details of the study have been reported previously.[7] In brief, the aims of the study are to sample rural and urban residents of all the 28 states of India, the National Capital Territory of Delhi, and two Union Territories such that the total estimated sample of 124 000 individuals is representative of the whole country. In phase I, four regions, representing the south (Tamil Nadu), north (Chandigarh), east (Jharkhand), and west (Maharashtra) of the country were studied from Nov 17, 2008, to April 16, 2010. Data for the prevalence of diabetes and prediabetes from this phase of the study have been published previously.[8] Between Sept 24, 2012, and July 26, 2013, five mainland states (Andhra Pradesh, Bihar, Gujarat, Karnataka, and Punjab) and between Jan 5, 2012, and July 3, 2015, six northeastern states (Assam, Mizoram, Arunachal Pradesh, Tripura, Manipur, and Meghalaya) were sampled. In this report, we present data from these 11 states, and cumulatively examine the 15 states sampled, which includes some unpublished

data from the four states surveyed in phase I, such as details on demographic, socioeconomic, clinical, anthropometric, and behavioural characteristics.[8]

In each state, we estimated a sample of 4000 individuals (consisting of 2800 rural and 1200 urban inhabitants), assuming an expected diabetes prevalence of 10% in urban and 4% in rural areas, allowing a relative precision of 20% of the estimated prevalence, an α error of 5%, and a non-response rate of 20%.[7] Thus the total estimated sample size for the 15 states presented here is 60 000 individuals (4000 for each of the 15 states).

We used a stratified multistage sampling design in the study.[7] To obtain a representative sample of the population, we used a three-level stratification based on the geography, population size, and socioeconomic status (SES) of each state. The primary sampling units were villages in rural areas and census enumeration blocks in urban areas. Using a systematic sampling method, 24 and 56 households were selected from urban and rural areas respectively. Door-to-door assessment was done and from each household, we randomly selected one individual, in accordance with the WHO Kish method,[9] thereby avoiding selection bias with respect to sex and age. Details of the sampling strategy are provided in the appendix (pp 3–10).

Demographic, behavioural, social, and economic assessment

For each individual, we administered a detailed questionnaire to collect information about demographic and socioeconomic parameters and behavioural factors. Current smoking was defined as self-reported smoking of tobacco products daily or on some days in the past 6 months, and current alcohol use was defined as self-reported use of alcohol irrespective of duration and quantity consumed. We established SES for urban areas using the 2011 revised Kuppuswamy's scale,[10] which uses occupation, education, and family income per month as parameters. For rural areas, we established SES using house type and the Standard of Living Index (SLI), as per the National Family Health Survey-3 (NFHS–3).[11] We obtained data for gross domestic product (GDP) per capita of individual states from the statistics for 2013–14 released by the Ministry of Finance of the Government of India.[12]

Anthropometric and clinical assessment

We measured bodyweight, height, waist circumference, and blood pressure using standardised techniques.[13] We calculated BMI by dividing bodyweight in kg by the square of height in metres. We diagnosed hypertension if individuals were on antihypertensive medications or had a systolic blood pressure of 140 mm Hg or higher, a diastolic blood pressure of 90 mm Hg or higher, or both.[14] We defined abdominal obesity as a waist circumference of 90 cm or more for men and 80 cm or more for women, with or without generalised obesity.[15] We defined generalised obesity as a BMI of 25 kg/m² or higher for both men and women (definition based on the WHO Asia Pacific Guidelines), with or without abdominal obesity.[15]

Biochemical assessment

We measured fasting capillary blood glucose (CBG) with a glucose meter (One Touch Ultra, Lifescan, Johnson & Johnson, Milpitas, CA, USA) after ensuring at least 8 h of overnight fasting. An oral glucose tolerance test was done using an 82·5 g oral glucose load (equivalent to 75 g of anhydrous glucose) and the 2 h post-load CBG was estimated. In individuals with self-reported diabetes, we only measured fasting glucose. Equipment with same specifications was used throughout the study as a measure of quality assurance. Samples of calibration logs are provided in the appendix (pp 13–18).

Outcome assessment

Our methodological approach did not allow us to differentiate between type 1 and type 2 diabetes. We diagnosed diabetes if individuals had a physician diagnosis of diabetes, satisfied the criteria of the WHO consultation group report on the diagnosis of diabetes mellitus and intermediate hyperglycaemia[16]—ie, fasting CBG of at least 126 mg/dL (7·0 mmol/L) or 2 h post-glucose CBG of at least 220 mg/dL (12·2 mmol/L), or both. Isolated impaired fasting glucose was diagnosed if individuals had fasting CBG of at least 110 mg/dL (6·1 mmol/L) and less than 126 mg/dL (7·0 mmol/L), and 2 h post-glucose CBG less than 160 mg/dL (8·9 mmol/L).[17] We also investigated the American Diabetes Association (ADA) criteria, which defined isolated impaired fasting glucose as fasting CBG of at least 100 mg/dL (5·6 mmol/L) and less than 126 mg/dL (7·0 mmol/L), and 2 h post-glucose CBG less than 160 mg/dL (8·9 mmol/L).[18] Isolated impaired glucose tolerance was diagnosed if individuals had 2 h post-glucose CBG of at least 160 mg/dL (8·9 mmol/L) and less than 220 mg/dL (12·2 mmol/L), and fasting CBG less than 110 mg/dL (6·1 mmol/L).[16] Prediabetes was defined as the presence of impaired fasting glucose, impaired glucose tolerance, or both.[16,17]

See Online for appendix

Statistical analysis

For all estimates, we weighted the study population to the 2011 Census of India, which includes state-specific data. We derived weights on the basis of the design weight (reciprocal of the probability of selection) and individual response rate. We further normalised the sampling weights at the state level to obtain standard state weights. We used the final weights to produce estimates of all population variables (appendix pp 10–12). We expressed estimates as means with SDs or proportions, as appropriate. We used Student's *t* tests to compare continuous variables and χ^2 tests to assess differences in proportions and to measure the linear trend as appropriate. Odds ratios (ORs) were derived from the

	Mainland									Northeast					
	Phase I				Phase II										
	Chandigarh* (n=3356)	Jharkhand* (n=3337)	Maharashtra* (n=3920)	Tamil Nadu* (n=3664)	Andhra Pradesh† (n=3825)	Bihar† (n=3898)	Gujarat† (n=3916)	Karnataka† (n=3908)	Punjab† (n=3754)	Arunachal Pradesh‡ (n=4036)	Assam‡ (n=3891)	Manipur‡ (n=3959)	Meghalaya‡ (n=3767)	Mizoram‡ (n=4080)	Tripura‡ (n=3806)
Age (years)	35·8 (12·2)	39·6 (14·2)	41·3 (14·6)	42·3 (14·5)	42·7 (15·2)	41·5 (14·6)	43·2 (14·7)	42·2 (14·9)	42·5 (15·2)	39·5 (12·9)	41·1 (14·2)	43·9 (15·1)	40·1 (14·4)	42·2 (15·0)	41·2 (14·5)
Sex															
Male	1700 (51%)	1686 (51%)	1953 (50%)	1771 (48%)	1686 (44%)	1650 (42%)	1841 (47%)	1446 (37%)	1629 (43%)	1945 (48%)	1535 (39%)	1798 (45%)	1631 (43%)	1872 (46%)	1675 (44%)
Female	1656 (49%)	1651 (49%)	1967 (50%)	1893 (52%)	2139 (56%)	2248 (58%)	2075 (53%)	2462 (63%)	2125 (57%)	2091 (52%)	2356 (61%)	2161 (55%)	2136 (57%)	2208 (54%)	2131 (56%)
BMI (kg/m²)	23·2 (4·6)	20·2 (3·9)	21·0 (4·0)	22·3 (4·2)	22·4 (4·6)	21·1 (3·9)	22·2 (4·4)	22·0 (4·4)	24·3 (4·5)	22·7 (3·5)	21·0 (3·8)	23·3 (3·8)	21·5 (3·5)	22·6 (3·6)	..
Waist circumference (cm)															
Male	82·9 (11·9)	77·0 (11·7)	78·5 (11·4)	80·4 (11·5)	81·3 (12·8)	80·2 (11·4)	79·6 (10·8)	81·2 (11·5)	87·8 (11·6)	81·5 (9·8)	78·1 (10·9)	82·4 (10·4)	77·0 (9·8)	79·6 (11·2)	78·7 (0·5)
Female	78·7 (13·0)	70·9 (10·9)	69·7 (11·1)	74·8 (11·4)	75·3 (12·9)	75·4 (11·8)	77·3 (11·7)	76·3 (11·8)	86·6 (11·7)	79·5 (10·8)	74·9 (11·4)	82·0 (11·4)	77·1 (10·7)	77·6 (11·0)	77·2 (11·1)
Overall	80·8 (12·7)	74·0 (11·7)	74·1 (12·1)	77·5 (11·8)	80·0 (13·1)	77·4 (11·9)	78·4 (11·4)	78·2 (11·9)	87·1 (11·7)	80·5 (10·4)	76·1 (11·3)	82·2 (10·9)	77·1 (10·3)	78·5 (11·1)	77·9 (10·9)
Systolic blood pressure (mm Hg)	126 (17)	128 (19)	127 (18)	129 (19)	129 (18)	128 (18)	127 (20)	124 (25)	136 (18)	130 (18)	130 (20)	129 (18)	124 (18)	126 (17)	128 (19)
Diastolic blood pressure (mm Hg)	77 (11)	77 (11)	78 (11)	79 (11)	78 (11)	77 (10)	78 (12)	75 (14)	82 (10)	83 (11)	78 (11)	83 (11)	79 (11)	79 (11)	79 (11)
Current smokers															
Male	480 (28%)	299 (18%)	309 (16%)	584 (33%)	428 (25%)	201 (12%)	397 (22%)	317 (22%)	75 (5%)	471 (24%)	397 (26%)	566 (31%)	996 (61%)	1172 (63%)	727 (43%)
Female	15 (1%)	56 (3%)	34 (2%)	8 (<1%)	32 (1%)	47 (2%)	14 (1%)	1 (<1%)	2 (<1%)	82 (4%)	18 (1%)	91 (4%)	92 (4%)	574 (26%)	105 (5%)
Current alcohol use															
Male	496 (29%)	671 (40%)	359 (18%)	626 (35%)	513 (30%)	292 (18%)	118 (6%)	262 (18%)	472 (29%)	887 (46%)	498 (32%)	688 (38%)	417 (26%)	500 (27%)	332 (20%)
Female	1 (<1%)	190 (12%)	2 (<1%)	7 (<1%)	45 (2%)	4 (<1%)	2 (<1%)	34 (1%)	2 (<1%)	442 (21%)	145 (6%)	10 (<1%)	12 (1%)	32 (1%)	39 (2%)
Socioeconomic status															
Low	370 (11%)	731 (22%)	790 (20%)	591 (16%)	1032 (27%)	1569 (40%)	509 (13%)	769 (20%)	198 (5%)	836 (21%)	972 (25%)	261 (7%)	788 (21%)	973 (24%)	1087 (29%)
Middle	1059 (32%)	1659 (50%)	1652 (42%)	1772 (48%)	1976 (52%)	1711 (44%)	1654 (42%)	2088 (53%)	1295 (34%)	1973 (49%)	1909 (49%)	2119 (54%)	2061 (55%)	1554 (38%)	2056 (54%)
High	1920 (57%)	932 (28%)	1449 (37%)	1272 (35%)	817 (21%)	618 (16%)	1753 (45%)	1051 (27%)	2261 (60%)	1222 (30%)	1010 (26%)	1577 (40%)	918 (24%)	1553 (38%)	663 (17%)
Gross domestic product per capita (US$)	3433	1009	2561	2464	1780	682	2337	1959	2020	1870	968	909	1346	1665	1525

Data are mean (SD) or n (%). None of the data presented here are published elsewhere. *Phase I (Nov 17, 2008, to April 16, 2010). †Phase II (Sept 24, 2012, to July 26, 2013). ‡Northeastern phase (Jan 5, 2012, to July 3, 2015).

Table 1: **General characteristics of the study population, by state**

multiple logistic regression analysis to examine the association between various exposures (age, sex, BMI, systolic blood pressure, SES, place of residence, family history of diabetes, generalised and abdominal obesity, hypertension, alcohol consumption, and smoking) and outcome (diabetes). We deemed p values less than 0·05 to be significant. We used SAS version 9.0 for all statistical analyses.

Role of the funding source

Some of the authors who were employed by the funding source contributed to the study design, provided scientific input for the study, were involved in quality control, and helped to revise the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Of an estimated 60 918 individuals approached, 57 117 (16 909 urban and 40 208 rural) individuals participated in the study (94% response rate), including 54 128 who provided blood samples. The statewise comparison of responders versus non-responders is presented in the appendix (pp 19–20).

Table 1 shows the state-specific characteristics of the study population. Overall, the mean age of participants was 41·3 years (SD 14·6), with little difference between states, with Chandigarh having the youngest participants. 25 818 (45%) of 57 117 individuals were male and this value was similar across states (ranging from 37% in Karnataka to 51% in Chandigarh). The state-wise sex distribution was also similar to the value of 50·8% that was reported in the 2011 census. Overall, the mean BMI of participants was 22·1 kg/m² (4·2), varying from 21·0 kg/m² (3·8) in Assam to 24·3 kg/m² (4·5) in Punjab. The overall mean waist circumference of participants was 78·7 cm (11·9), with the highest values in Punjab among both men and women. Mean blood pressure was lowest in Karnataka and highest in Punjab, with an overall mean blood pressure of 128 (19)/79 (11) mm Hg.

The prevalence of smoking was substantially higher in northeastern states compared with the mainland states, both among men and women (4322 [41%] of 10 447 men in northeastern states *vs* 3090 [20%] of 15 358 men in mainland states; 962 [7%] of 13 078 women in northeastern states *vs* 209 [1%] of 18 211 women in mainland states) with the highest smoking prevalence reported in Mizoram (1172 [63%] of 1872 men and 574 [26%] of 2208 women). Alcohol consumption was also higher in northeastern states compared with the mainland among both genders (3325 [32%] of 10 452 men in northeastern states *vs* 3564 [23%] of 15 354 men in mainland states; 680 [5%] of 13 077 women in northeastern states *vs* 286 [2%] of 18 211 women in mainland states) with the highest in Arunachal Pradesh (887 [46%] of 1945 men and 442 [21%] of 2091 women).

Of the 15 states studied, Chandigarh had the highest GDP (US$3433) and Bihar had the lowest ($682). The overall spread of individuals belonging to various socioeconomic strata was: low 20% (1475/57 117), middle 46% (26 538/57 117), and high 33% (19 016/57 117).

The general characteristics of individuals in urban and rural areas of each state are shown in the appendix

	Mainland (phase II)					Northeast					
	Andhra Pradesh*	Bihar*	Gujarat*	Karnataka*	Punjab*	Arunachal pradesh†	Assam†	Manipur†	Meghalaya†	Mizoram†	Tripura†
Overall											
n	3633	3713	3760	3773	3597	3979	3630	3849	3556	4053	3531
Self-reported diabetes	5·8% (5·0–6·6)	2·0% (1·6–2·5)	4·7% (3·8–5·6)	3·9% (2·3–4·6)	6·3% (5·2–7·4)	2·0% (1·6–2·5)	3·1% (2·5–3·6)	3·3% (2·7–3·8)	2·3% (1·8–2·8)	2·9% (2·2–3·5)	4·5% (3·8–5·1)
Newly diagnosed diabetes	2·6% (2·1–3·1)	2·3% (1·8–2·8)	2·4% (1·9–3·0)	3·8% (3·2–4·5)	3·7% (3·0–4·4)	3·1% (2·5–3·7)	2·4% (1·9–3·0)	1·8% (1·4–2·2)	2·2% (1·8–2·7)	2·9% (2·3–3·5)	4·9% (4·2–5·6)
Ratio of self-reported diabetes to newly diagnosed diabetes	1:0·4	1:1·2	1:0·5	1:1	1:0·6	1:1·6	1:0·8	1:0·5	1:1	1:1	1:1·1
Total diabetes	8·4% (7·5–9·3)	4·3% (3·7–5·0)	7·1% (6·1–8·2)	7·7% (6·8–8·7)	10·0% (8·7–11·2)	5·1% (4·4–5·8)	5·5% (4·7–6·2)	5·1% (4·4–5·8)	4·5% (3·7–5·0)	5·8% (4·9–6·7)	9·4% (8·4–10·3)
Impaired fasting glucose	7·3% (6·4–8·1)	5·6% (4·8–6·4)	7·8% (6·9–8·8)	7·8% (6·9–8·6)	6·5% (5·5–7·5)	9·7% (8·7–10·6)	8·1% (7·1–9·0)	3·4% (2·8–3·9)	2·4% (1·9–2·9)	3·8% (3·1–4·4)	9·5% (8·5–10·5)
Impaired glucose tolerance	1·9% (1·5–2·4)	3·5% (2·9–4·1)	1·8% (1·3–2·3)	2·6% (2·0–3·1)	1·0% (0·7–1·4)	1·8% (1·3–2·2)	2·8% (2·2–3·3)	3·4% (2·8–4·0)	6·7% (5·8–7·6)	1·6% (1·2–2·1)	3·5% (2·9–4·1)
Impaired fasting glucose and impaired glucose tolerance	0·9% (0·6–0·2)	0·9% (0·6–1·2)	0·5% (0·2–0·8)	1·4% (1·0–1·7)	0·7% (0·3–1·1)	1·3% (0·9–1·7)	1·0% (0·7–1·4)	0·7% (0·4–0·9)	0·9% (0·6–1·2)	0·6% (0·3–0·9)	1·8% (1·4–2·2)
Prediabetes	10·1% (9·1–11·1)	10·0% (9·0–11·0)	10·2% (9·1–11·3)	11·7% (10·6–12·8)	8·2% (7·1–9·3)	12·8% (11·7–13·8)	11·9% (10·7–13·0)	7·5% (6·6–8·3)	10·0% (9·0–11·0)	6·0% (5·1–6·8)	14·7% (13·6–15·9)
Total diabetes-to-prediabetes ratio	1:1·2	1:2·3	1:1·4	1:1·5	1:0·8	1:2·5	1:2·2	1:1·5	1:2·2	1:1·0	1:1·6

(Table 2 continues on next page)

	Mainland (phase II)					Northeast					
	Andhra Pradesh*	Bihar*	Gujarat*	Karnataka*	Punjab*	Arunachal pradesh†	Assam†	Manipur†	Meghalaya†	Mizoram†	Tripura†
(Continued from previous page)											
Urban											
n	1099	1124	1142	1101	1075	1151	1018	1160	1026	1170	1077
Self-reported diabetes	9·1% (7·4–10·8)	5·4% (4·1–6·8)	7·1% (5·2–9·1)	6·1% (4·7–7·6)	8·9% (6·4–11·4)	2·5% (1·7–3·3)	8·4% (6·7–10·1)	4·8% (3·4–5·9)	5·6% (4·5–7·1)	4·3% (3·1–5·4)	8·8% (7·1–10·5)
Newly diagnosed diabetes	3·5% (2·4–4·6)	5·4% (4·1–6·7)	2·7% (1·6–3·7)	5·0% (3·7–6·3)	3·1% (1·8–4·5)	3·3% (2·3–4·4)	4·0% (2·7–5·2)	2·5% (1·6–3·4)	3·2% (2·1–4·3)	3·6% (2·5–4·7)	6·7% (5·2–8·2)
Ratio of self-reported diabetes to newly diagnosed diabetes	1:0·4	1:1	1:0·4	1:0·8	1:0·3	1:1·3	1:0·5	1:0·6	1:0·6	1:0·8	1:0·8
Total diabetes	12·6% (10·7–14·6)	10·8% (9·0–12·7)	9·8% (7·6–12·0)	11·1% (9·2–13·0)	12·0% (9·2–14·8)	5·8% (4·6–7·1)	12·4% (10·3–14·4)	7·1% (5·6–8·7)	8·9% (7·1–10·6)	7·9% (6·3–9·4)	15·5% (13·4–17·7)
Impaired fasting glucose	7·4% (5·9–9·0)	9·5% (7·7–11·2)	6·0% (4·4–7·7)	8·2% (6·6–9·9)	6·1% (4·1–8·2)	12·3% (10·3–14·4)	9·4% (7·6–11·2)	3·4% (2·3–4·6)	3·0% (2·0–4·1)	3·3% (2·3–4·4)	11·0% (9·1–12·9)
Impaired glucose tolerance	2·0% (1·2–2·9)	4·0% (2·8–5·1)	1·9% (0·9–2·8)	4·0% (2·8–5·1)	1·3% (0·3–2·3)	1·1% (0·5–1·7)	2·8% (1·7–3·8)	3·2% (2·2–4·2)	3·4% (2·3–4·5)	2·1% (1·2–2·9)	3·2% (2·1–4·2)
Impaired fasting glucose and impaired glucose tolerance	1·6% (0·8–2·4)	2·0% (1·2–2·9)	0·5% (0–1·1)	1·9% (1·1–2·6)	1·2% (0·2–2·1)	0·7% (0·2–1·2)	1·5% (0·8–2·3)	0·6% (0·1–1·1)	1·0% (0·4–1·6)	0·8% (0·2–1·3)	2·0% (1·1–2·8)
Prediabetes	11·1% (9·2–13·0)	15·5% (13·3–17·6)	8·4% (6·5–10·3)	14·1% (12·0–16·1)	8·6% (6·2–11·0)	14·2% (12·0–16·3)	13·6% (11·5–15·8)	7·2% (5·6–8·9)	7·4% (5·8–9·0)	6·2% (4·7–7·6)	16·2% (13·9–18·4)
Total diabetes-to-prediabetes ratio	1:0·9	1:1·4	1:0·9	1:1·3	1:0·7	1:2·4	1:1·1	1:1·0	1:0·8	1:0·8	1:1·0
Rural											
n	2534	2589	2618	2672	2522	2828	2612	2689	2530	2883	2454
Self-reported diabetes	4·2%§ (3·4–4·9)	1·6%§ (1·1–2·1)	2·9%§ (2·2–3·5)	2·5%§ (1·9–3·1)	4·7%§ (3·9–5·5)	1·9% (1·4–2·4)	2·2%§ (1·6–2·8)	2·8%‡ (2·2–3·4)	1·5%§ (1·0–2·0)	1·4%§ (0·9–1·8)	2·9%§ (2·2–3·6)
Newly diagnosed diabetes	2·1%‡ (1·5–2·7)	1·9%§ (1·4–2·4)	2·2% (1·7–2·8)	3·1%‡ (2·4–3·8)	4·0% (3·2–4·8)	3·0% (2·4–3·7)	2·2%‡ (1·6–2·8)	1·6%‡ (1·1–2·0)	2·0%‡ (1·5–2·6)	2·2%‡ (1·6–2·7)	4·3%‡ (3·5–5·1)
Ratio of self-reported diabetes to newly diagnosed diabetes	1:0·5	1:1·2	1:0·8	1:1·2	1:0·9	1:1·6	1:1	1:0·6	1:1·3	1:1·6	1:1·5
Total diabetes	6·3%§ (5·3–7·2)	3·5%§ (2·8–4·2)	5·1%§ (4·2–6·0)	5·6%§ (4·8–6·5)	8·7%‡ (7·6–9·8)	4·9% (4·1–5·7)	4·4%§ (3·6–5·2)	4·4%‡ (3·6–5·1)	3·5%§ (2·8–4·2)	3·6%§ (2·9–4·2)	7·2%§ (6·2–8·2)
Impaired fasting glucose	7·2% (6·2–8·2)	5·1%§ (4·3–6·0)	9·2%§ (8·1–10·3)	7·5% (6·5–8·5)	6·7% (5·7–7·7)	8·9%‡ (7·8–10·0)	7·9% (6·8–9·0)	3·3% (2·7–4·0)	2·2% (1·7–2·8)	4·2% (3·5–4·9)	8·9% (7·8–10·1)
Impaired glucose tolerance	1·9% (1·3–2·4)	3·4% (2·7–4·1)	1·8% (1·3–2·3)	1·7%§ (1·2–2·2)	0·8% (0·5–1·2)	2·0%‡ (1·4–2·5)	2·7% (2·1–3·4)	3·5% (2·8–4·2)	7·5%§ (6·4–8·5)	1·2%‡ (0·8–1·6)	3·6%‡ (2·8–4·3)
Impaired fasting glucose and impaired glucose tolerance	0·6%‡ (0·2–0·9)	0·7%‡ (0·4–1·1)	0·6% (0·3–0·8)	1·0%‡ (0·7–1·4)	0·4%‡ (0·2–0·7)	1·5% (1·0–1·9)	0·9% (0·5–1·3)	0·7% (0·4–1·0)	0·9% (0·5–1·3)	0·4% (1·2–0·6)	1·7% (1·2–2·2)
Prediabetes	9·6% (8·4–10·8)	9·3%§ (8·2–10·4)	11·5%‡ (10·3–12·7)	10·2%§ (9·1–11·4)	7·9% (6·9–8·0)	12·3% (11·1–13·6)	11·6% (10·3–12·8)	7·5% (6·5–8·5)	10·6%‡ (9·4–11·8)	5·8% (4·9–6·6)	14·2% (12·9–15·6)
Total diabetes-to-prediabetes ratio	1:1·5	1:2·7	1:2·3	1:1·8	1:0·9	1:2·5	1:2·6	1:1·7	1:3·0	1:1·6	1:2·0

Data are % (95% CI) or ratios. Data for the prevalence of diabetes and prediabetes for the states of Chandigarh, Jharkhand, Maharashtra, and Tamil Nadu (phase I; Nov 17, 2008, to April 16, 2010) have been reported previously.[5] *Phase II (Sept 24, 2012, to July 26, 2013). †Northeastern phase (Jan 5, 2012, to July 3, 2015). ‡p<0·05 compared with participants in urban areas. §p<0·0001 compared with participants in urban areas.

Table 2: **Weighted prevalence of diabetes and prediabetes in phase II and the northeastern phase of the study, by state and urban versus rural**

(pp 21–22). Overall, age, sex distribution, and blood pressure were similar between urban and rural areas. Mean BMI and waist circumference were higher in urban areas (BMI: 23·4 kg/m² [SD 4·4] in urban areas *vs* 21·5 kg/m² [4·0] in rural areas; waist circumference 84 cm [12] among urban men in areas *vs* 79 cm [11] among men in rural areas and 81 cm [12] in women in urban areas *vs* 75 cm [12] in women in rural areas), whereas the prevalence of smoking was higher in rural areas (1839 [25%] of 7438 men and 210 [2%] of 9471 women in urban areas *vs* 5580 [30%] of 18 380 men and 961 [4%] of 21 828 women in rural areas), as was alcohol consumption (1955 [26%] of 7438 men and 149 [2%] of 9471 women in urban areas *vs* 5176 [28%] of 18 380 men and 820 [4%] of 21 828 women in rural areas).

A higher proportion of the rural population than the urban population belonged to the low-income group (9407 [23%] of 40 208 rural inhabitants *vs* 2068 [12%] of 16 909 urban inhabitants), whereas urban areas had a substantially higher proportion of individuals in the

high-income group (7382 [44%] of 16 909 urban inhabitants) than did rural areas (11 634 [29%] of 40 208 rural individuals).

Table 2 shows the weighted prevalence of diabetes and prediabetes in urban and rural areas of the 11 states sampled in phase II and the northeastern phase. The overall prevalence of diabetes in all the 15 states studied was 7·3% (95% CI 7·0–7·5), varying from 4·3% (3·7–5·0) in Bihar to 10·0% (8·7–11·2) in Punjab. The prevalence was substantially higher in the mainland (8·3%, 7·9–8·7) than in the northeast (5·9%, 5·5–6·2). Overall, the prevalence in urban areas (11·2%, 10·6–11·8) was about double that in rural areas (5·2%, 4·9–5·4). Compared with their rural counterparts, men in urban areas had an OR for diabetes of 1·84 (1·66–2·04, p<0·0001) and women in urban areas had an odds ratio of 1·58 (1·42–1·75, p<0·0001), after adjustment for age, BMI, systolic blood pressure, SES, and smoking status.

The overall ratio of self-reported diabetes to newly diagnosed diabetes was 1:0·9, but this ratio was lower in the rural areas (1:1·5) than in urban areas (1:0·7). The ratios were similar between the mainland states (1:0·8) and the northeast states (1:0·9). Overall, 1862 [47%] of 3938 individuals identified as having diabetes had not been diagnosed previously (895 [42%] of 2115 in urban areas *vs* 967 [53%] of 1823 in rural areas; 1206 [46%] of 2608 in mainland states *vs* 655 [49%] of 1330 in northeast states).

The overall prevalence of prediabetes in all 15 states studied was 10·3% (95% CI 10·0–10·6), varying from 6·0% (5·1–6·8) in Mizoram to 14·7% (13·6–15·9) in Tripura. Prediabetes was more prevalent than diabetes in all of the states studied in phase II, apart from Punjab, and in the northeast. The prevalence of isolated impaired fasting glucose was 6·5% (6·3–6·7), which was more than twice that of isolated impaired glucose tolerance (2·8%, 2·7–3·0) in all states studied except for Bihar, Manipur, and Meghalaya. If we applied the ADA fasting glucose cutpoint[18] of 100 mg/dL (5·6 mmol/L), the prevalence of isolated impaired fasting glucose would increase to 20·8% (20·5–21·3), and that of prediabetes to 24·7% (24·3–25·1). The diabetes-to-prediabetes ratio was substantially lower in the northeast (1:1·8) than in the mainland states (1:1·2) and lower in rural (1:1·9) than in urban areas (1:1). In phase I, the diabetes-to-prediabetes ratios were 1:1 in Chandigarh, 1:1·6 in Jharkhand, 1:1·4 in Maharashtra, and 1:0·8 in Tamil Nadu.

Figure 1A shows the age-stratified prevalence of diabetes in urban and rural areas and among men and women in all 15 states pooled together. The prevalence of diabetes was significantly higher in urban than in rural areas in all age groups and higher in men than in women between the ages of 35 and 65 years, beyond which age, the prevalence was slightly higher in women than in men. The take-off point for diabetes was in the age group of 25–34 years in both urban and rural areas. The prevalence of prediabetes was also higher in urban areas among all age groups except in the 65 year or older age group, where the trend is reversed. There were no significant differences between men and women (figure 1B).

Figure 2 shows the comparison of the prevalence of diabetes between individuals of middle and high SES and individuals of low SES within rural and urban areas of each of the 15 states. In rural areas, diabetes was more prevalent among individuals in the higher SES categories in both the mainland and northeast states. However, in urban areas of Chandigarh, Andhra Pradesh, Tamil Nadu, Maharashtra, and Punjab in the mainland and Tripura, Manipur and Assam in the northeast, prevalence of diabetes was higher among individuals of low SES than among individuals of higher SES.

Figure 3 shows the prevalence of diabetes plotted against the GDP per-capita of each state. The prevalence of

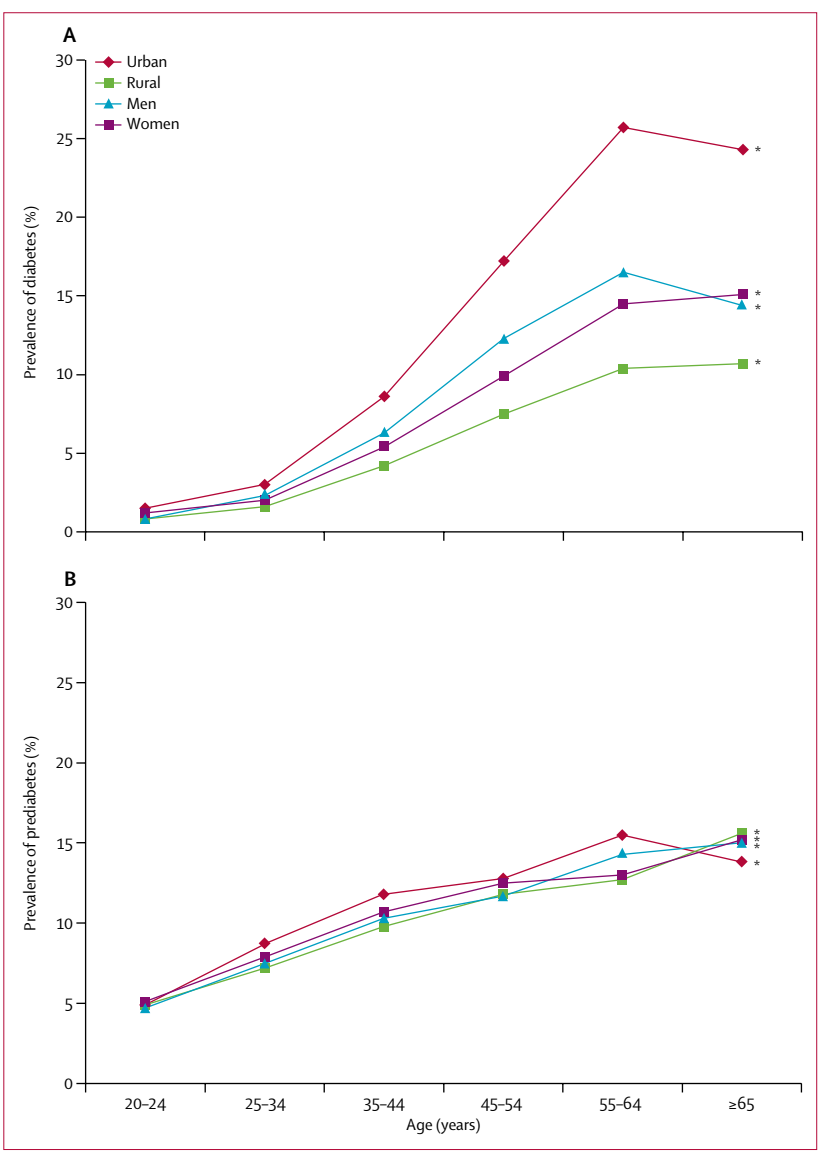

Figure 1: **Age, gender, and area-specific prevalence of diabetes (A) and prediabetes (B) in 15 states in India**
*p for trend <0·0001.

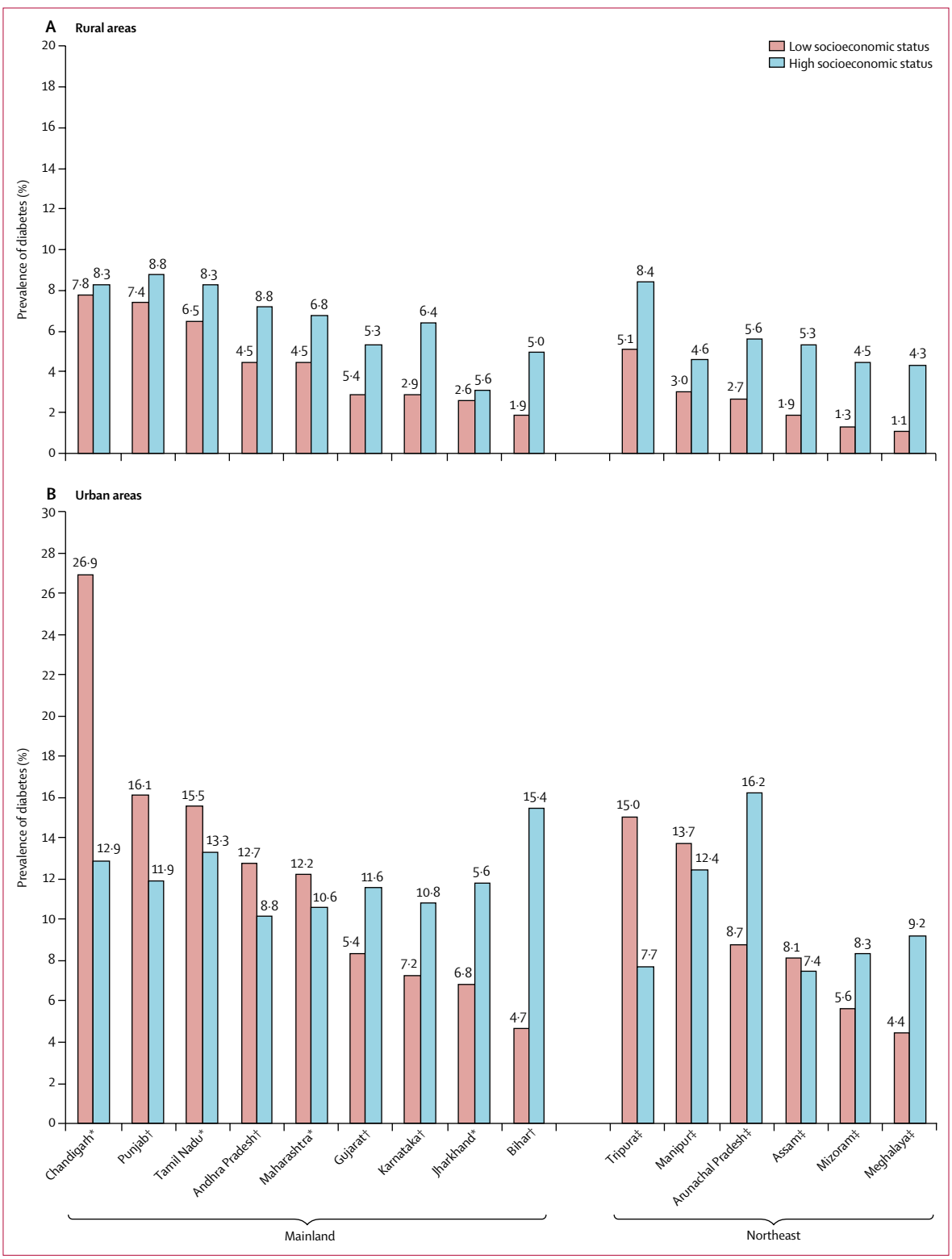

Figure 2: **Prevalence of diabetes stratified by socioeconomic status**
The high socioeconomic status groups include individuals of both high and middle socioeconomic status. *Phase I. †Phase II. ‡Northeast phase.

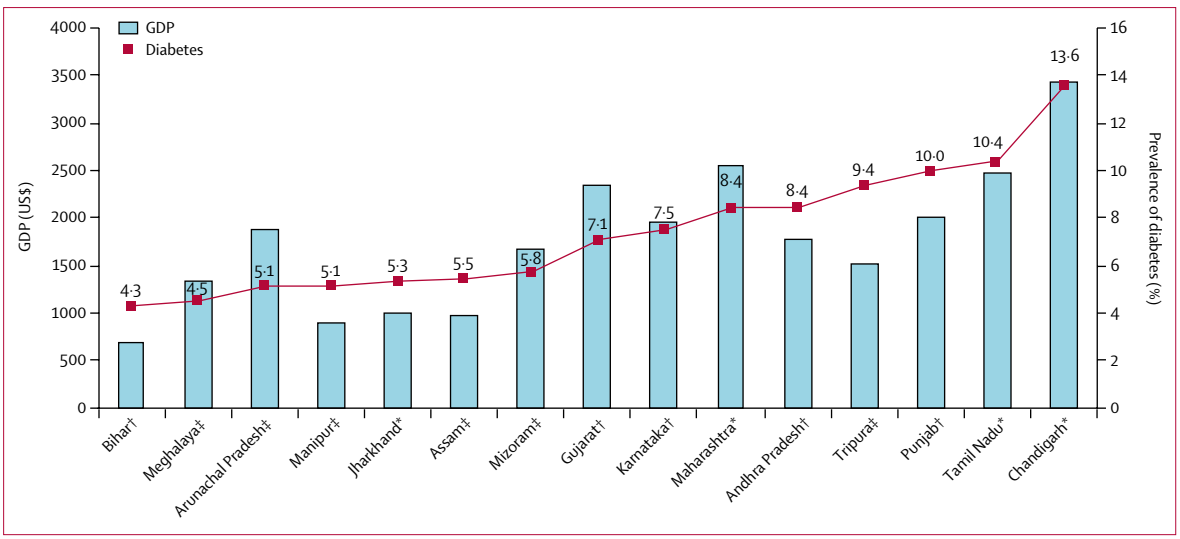

Figure 3: **Prevalence of diabetes and GDP per capita by state**
GDP=gross domestic product. *Phase I. †Phase II. ‡Northeast phase.

diabetes seems to be higher in states with greater per-capita income. For example, Chandigarh, which has the highest per-capita income of the 15 states studied, had the highest prevalence of diabetes, whereas Bihar, the state with the lowest per-capita income, had the lowest prevalence; however this association was not assessed statistically.

Table 3 shows the results of multiple logistic regression analysis in both urban and rural areas in which diabetes was the dependent variable. Age, male sex, obesity (abdominal and generalised), hypertension, and a family history of diabetes were independent risk factors for diabetes in both urban and rural areas. High SES was a risk factor for diabetes in rural, but not urban areas. Smoking and alcohol consumption were not related to diabetes in this analysis.

	Rural		Urban	
	Odds ratio (95% CI)	p value	Odds ratio (95% CI)	p value
Age (per year)	1·04 (1·04–1·05)	<0·0001	1·06 (1·05–1·06)	<0·0001
Male sex	1·33 (1·20–1·48)	<0·0001	1·44 (1·27–1·64)	<0·0001
Abdominal obesity (present)	2·11 (1·87–2·38)	<0·0001	2·12 (1·84–2·44)	<0·0001
Generalised obesity (present)	1·59 (1·41–1·80)	<0·0001	1·57 (1·38–1·80)	<0·0001
Hypertension (present)	1·66 (1·50–1·84)	<0·0001	1·66 (1·47–1·86)	<0·0001
Family history of diabetes (present)	3·13 (2·71–3·61)	<0·0001	2·52 (2·21–2·89)	<0·0001
High socioeconomic status* (present)	1·28 (1·19–1·37)	<0·0001	1·09 (0·99–1·19)	0·06
Smoking (yes)	0·88 (0·76–1·01)	0·07	1·11 (0·93–1·33)	0·25
Alcohol consumption (yes)	0·90 (0·77–1·04)	0·16	0·88 (0·73–1·06)	0·17

The analyses were done with pooled data from all 15 states studied. *Includes middle and high socioeconomic status.

Table 3: **Multiple logistic regression with diabetes as the dependent variable, in urban and rural populations**

Discussion

To our knowledge, the ICMR–INDIAB study is the largest nationally representative study of diabetes in India. The cumulative data from 15 states presented here represent a total adult population of 363·7 million people (51% of India's adult population). We estimated the overall prevalence of diabetes in India to be 7·3% and the prevalence of prediabetes to be 10·3% (WHO criteria) or 24·7% (ADA criteria), depending on which definition was used. However, these estimates are based on data from 15 states out of a total of 31 to be studied, and cannot be considered as final, especially since the states yet to be sampled include the National Capital Territory of Delhi, Kerala (the state with the highest reported prevalence of diabetes in India so far[19]), Uttar Pradesh (the most populous state in India), and Goa (the state with the highest per capita income).

Among the 15 states studied, there was large variation in state-specific diabetes prevalence. The differences in the prevalence of diabetes between states might be explained by factors such as differences in SES, physical activity, dietary patterns, obesity prevalence, and possibly genetic variation.

The overall prevalence of diabetes was higher in the mainland than in the northeast states. However, even within the northeast, we found wide variations in prevalence (ranging from 4·5% in Meghalaya to 9·4% in Tripura). This variation might reflect the ethnic heterogeneity of this region; for example, 70% of Tripura's population is of Bengali origin and is thus more similar to the population of mainland India than to the rest of the northeast, where the population is mostly of Sino-Tibetan ethnicity.[20]

Diabetes prevalence was higher in the more economically developed states, and even within states diabetes was more common in individuals of medium or high SES than in individuals of low SES, which agrees with results from

earlier studies in India.[21,22] However, the prevalence of diabetes was higher in individuals of low SES in the urban areas of seven states, most of which are also ranked among the more economically advanced states of India. Conversely, in rural areas, the prevalence of diabetes was higher in individuals of higher SES in all the states studied. This finding suggests that the urban areas of more affluent states have transitioned further along the diabetes epidemic, such that less affluent individuals have a higher prevalence of diabetes than their more affluent counterparts. However, in rural areas throughout India, diabetes continues to be a disease of more affluent sections of society, suggesting that the epidemiological transition is less advanced in these areas. These results suggests that as the overall prosperity of states and India as a whole increases, the diabetes epidemic is likely to disproportionately affect the poorer sections of the society, a transition that has already been noted in high-income countries.[23] This trend is worrying because it suggests that the diabetes epidemic is spreading to those individuals who can least afford to pay for its management.

The prevalence of diabetes continues to be higher in urban areas than in rural areas, as has been shown previously.[24,25] However, the rural prevalence estimates that we report here are much higher than identified in earlier studies. Given that about 70% of India's population resides in rural areas,[26] even a small increase in the rural prevalence of diabetes will translate into several millions of individuals requiring chronic care. Factoring in the additional burden that arises because of the overall younger age of onset type 2 diabetes in south Asian people compared with other populations,[27] the strain on the country's health-care system is likely to be immense. People in rural areas are already contending with poor access to health services.

The main factors driving the diabetes epidemic in both urban and rural areas of India are obesity, age, and family history of diabetes. Although we identified male sex as an independent risk factor for diabetes, other studies have shown conflicting results.[28] Unlike in earlier studies from wealthier nations,[29,30] smoking and alcohol consumption did not seem to independently increase the risk of diabetes in India. It is not entirely clear why smoking and alcohol use were not related to diabetes risk in this population, but similar findings have been shown in a previous study from Chennai in southern India.[31] Although differences in patterns of use (eg, type and quantity of alcohol) might help to account for this finding, further studies are needed to explore these hypotheses.

Notably, high SES seemed to be a risk factor for diabetes in rural areas, but not urban areas. This difference could be related to improved awareness about diabetes in urban areas, and because individuals of higher SES can afford to adopt health-promoting behavioural changes. This finding is a classic example of the economic transition in India and its relation with the diabetes epidemic.

Our prevalence estimates of prediabetes were high across the country, exceeding those of diabetes in most states and implying the existence of a huge number of individuals who could conceivably develop type 2 diabetes in the near future. This finding is all the more important because Asian Indians have been shown to progress faster through the prediabetes stage than do people of other ethnic groups.[32,33] We noted that in several states (especially in urban areas), the prevalence of prediabetes was lower than or similar to the prevalence of diabetes, which might be suggestive of fast conversion to diabetes. These states might also have moved further along the epidemiologic transition and the epidemic of diabetes might therefore have peaked or be in the process of peaking. Declines have previously been noted in the prevalence of prediabetes in Chennai and other south Asian populations.[34,35] Whereas the equalisation of the diabetes-to-prediabetes ratio could represent stabilisation of the diabetes epidemic in urban areas, there continues to be a large pool of individuals at risk of developing type 2 diabetes in rural areas, as suggested by a diabetes-to-prediabetes ratio of almost 1:2.

Among the categories of prediabetes, the prevalence of impaired fasting glucose was substantially higher than that of impaired glucose tolerance. Results from an earlier study have shown similar prevalences of impaired fasting glucose and impaired glucose tolerance in the urban population of south India.[36] Our findings, however, are in line with evidence attributing a greater role to insulin secretory defects in the pathogenesis of type 2 diabetes in Asian Indians compared with people of other ethnic groups, given that impaired fasting glucose has been shown to chiefly arise from defects in first phase insulin release.[37–39] Although the reasons for β-cell insufficiency have not been fully elucidated, intrauterine malnutrition leading to an innately small pancreas could be a possible explanation.[38]

A higher ratio of known to newly diagnosed diabetes, as shown in our results for urban areas in most states, suggests better awareness of diabetes compared with rural areas. This improved awareness and diagnosis is possibly the results of concerted efforts by the Government (through programmes such as the National Programme for Control and Prevention of Cancer, Diabetes, Cardiovascular Disease and Strokes) and non-governmental organisations. However, the ratio of known to newly diagnosed diabetes remains less than 1:1 in the rural areas of many states, emphasising the need to expand awareness programmes to these underserved areas.

Our study has several strengths. It is the first study on diabetes to include 15 whole states in India, both rural and urban populations, and it is the largest epidemiological study of diabetes in the country to date. We have used a representative sampling frame and robust methods, with oral glucose tolerance tests used for the detection of diabetes in a sample of about 60 000 people. We have also provided the first ever data on the status of the diabetes epidemic in the northeastern states of India.

However, our study also has some limitations. The cross-sectional nature of the study does not allow for inferences of causality to be made. Additionally, although venous plasma glucose estimations would have been ideal, logistical considerations such as the non-availability of quality-controlled laboratories, varied methods of glucose estimation, and poor compliance to venous blood collection precluded its use in many parts of India.[7,8] Several studies have compared CBG measurements with venous plasma glucose measurements in screening for diabetes and prediabetes and have reported that CBG is a feasible alternative for screening in epidemiological studies in which obtaining venous samples might be difficult.[40,41] Moreover, the study was done by the same team of investigators using the same methods and standardised techniques with stringent quality control, so any differences in prevalence noted probably cannot be attributed to this methodological limitation. Although WHO recommends repeating blood tests for the diagnosis of diabetes, we were unable to do so because of logistic difficulties. Furthermore, the prevalence of diabetes based on HbA_{1c} (now an accepted diagnostic tool) could not be estimated, as this parameter was measured only in a subset of the study population because of high costs. Moreover, the high prevalence of anaemia in this population and of haemoglobinopathies (especially in the northeast region), preclude use of HbA_{1c} measurement as a diagnostic tool in an epidemiological setting.[42]

Our results also do not provide information on the prevalence of diabetes in individuals younger than 20 years because this was beyond the scope of the study. Furthermore, our methodological approach did not allow us to differentiate between type 1 and type 2 diabetes. An additional limitation is that the different phases of the study were done during different periods of time, which is inevitable when sampling a country of India's size. These differences in time of data collection could have led to underestimation of prevalence in the states that were sampled in the earlier phase, particularly since the GDP of these states could have improved in the lag time of 4 years. Finally, because different SES scales were used for urban and rural areas, we could not make direct comparisons of SES between urban and rural areas.

In conclusion, the diabetes epidemic in India is in a state of transition. The pool of people with prediabetes seems to be shrinking in many of the more economically advanced states, raising the possibility of stabilisation of the epidemic in the near future. However, we can expect further increases in diabetes prevalence among the people of low SES in urban areas, as well as in rural India, which accounts for the majority of the country's population. The spread of the diabetes epidemic to these economically disadvantaged and vulnerable sections of society has serious implications for the country's health and socioeconomic development, and warrants the urgent implementation of effective preventive measures.

Contributors

RMA and VM conceived the study, designed it, and were involved in implementation of the study, training the team, designing quality assurance measures, interpretation of the data, and drafting and revision of the report. MD, RP, and RU were involved in the design and coordination of the study, interpretation of the data, and drafting of the report. MKA provided critical revision of the report. HKD, PA, PVR, BS, AK, AB, MJ, RL, TR, SN, LJ, and ROB were responsible for the supervision of the study in their respective states. JM, KN, AKD, SVM, AP, RSD, TK, and SS provided scientific input for the study, were involved in the quality control, and helped to revise the report. NE helped in the field coordination of the study. RS and UV were responsible for data management and statistical analyses. All authors contributed to revision of the report and approved the final submitted version. RMA and VM take full responsibility for the overall content of this work. AKD, PVR, SVM, and AP are members of ICMR–INDIAB Expert Group (other members listed below).

ICMR–INDIAB Expert Group

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Declaration of interests

We declare no competing interests.

Acknowledgments

We thank the Indian Council of Medical Research (ICMR), New Delhi and the Department of Health Research (DHR), Ministry of Health and Family Welfare, Government of India, New Delhi for providing financial support to the study and the ICMR–INDIAB Expert Group for their valuable suggestions and scientific input. We also thank the ICMR–INDIAB quality managers, quality supervisors, and the field team for smooth conduct of the study, and the participants for their cooperation. This is the ninth paper from the ICMR–INDIAB study (ICMR–INDIAB-9).

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