Metabolic non-communicable disease health report of India: the ICMR-INDIAB national cross-sectional study (ICMR-INDIAB-17)

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See Comment page 444

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Summary

Background Non-communicable disease (NCD) rates are rapidly increasing in India with wide regional variations. We aimed to quantify the prevalence of metabolic NCDs in India and analyse interstate and inter-regional variations.

Methods The Indian Council of Medical Research–India Diabetes (ICMR-INDIAB) study, a cross-sectional population-based survey, assessed a representative sample of individuals aged 20 years and older drawn from urban and rural areas of 31 states, union territories, and the National Capital Territory of India. We conducted the survey in multiple phases with a stratified multistage sampling design, using three-level stratification based on geography, population size, and socioeconomic status of each state. Diabetes and prediabetes were diagnosed using the WHO criteria, hypertension using the Eighth Joint National Committee guidelines, obesity (generalised and abdominal) using the WHO Asia Pacific guidelines, and dyslipidaemia using the National Cholesterol Education Program—Adult Treatment Panel III guidelines.

Findings A total of 113 043 individuals (79 506 from rural areas and 33 537 from urban areas) participated in the ICMR-INDIAB study between Oct 18, 2008 and Dec 17, 2020. The overall weighted prevalence of diabetes was 11·4% (95% CI 10·2–12·5; 10 151 of 107 119 individuals), prediabetes 15·3% (13·9–16·6; 15 496 of 107 119 individuals), hypertension 35·5% (33·8–37·3; 35 172 of 111 439 individuals), generalised obesity 28·6% (26·9–30·3; 29 861 of 110 368 individuals), abdominal obesity 39·5% (37·7–41·4; 40 121 of 108 665 individuals), and dyslipidaemia 81·2% (77·9–84·5; 14 895 of 18 492 of 25 647). All metabolic NCDs except prediabetes were more frequent in urban than rural areas. In many states with a lower human development index, the ratio of diabetes to prediabetes was less than 1.

Interpretation The prevalence of diabetes and other metabolic NCDs in India is considerably higher than previously estimated. While the diabetes epidemic is stabilising in the more developed states of the country, it is still increasing in most other states. Thus, there are serious implications for the nation, warranting urgent state-specific policies and interventions to arrest the rapidly rising epidemic of metabolic NCDs in India.

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Introduction

South Asia, home to nearly a quarter of the world's population, is currently undergoing an epidemiological transition with an explosion in the prevalence of non-communicable diseases (NCDs).[1,2] India, the largest country in the region, is also the largest contributor to the NCD burden. Several studies conducted over the last two decades have revealed the high total burden of diabetes, hypertension, and dyslipidaemia in India.[3–6] However, most of these studies have relied on self-report of these conditions, do not use robust methodology for diagnosis, represent secondary analyses of data from surveys not specifically focused on NCDs, or are not truly representative of the population of the country. Also, none of these studies provide information on the prevalence of prediabetes, which limits their utility in assessing the current status of the diabetes epidemic in India and predicting its future trajectory. Furthermore, as regions and states in India differ widely from each other in ethnic composition, dietary habits, and socioeconomic development, overall NCD estimates for the country are likely to mask wide inter-regional and intraregional differences. Provision of health care is the responsibility of states in India; therefore, obtaining granular state-level data is of utmost importance to enable state governments to plan and implement programmes aimed at preventing and managing NCDs in their respective jurisdictions. This assumes particular

Research in context

Evidence before this study

We searched PubMed, Google Scholar, IndMED, and the Cochrane Database of Systematic Reviews, and scanned relevant reference lists and review articles, for studies published before April 10, 2023, reporting on the prevalence of non-communicable diseases (NCDs) among Asian Indians, using the key words "diabetes", "prediabetes", "metabolic NCDs", "hypertension", "obesity", "dyslipidemia", "urban", "rural", "India", "Asian Indians", and "South Asians". We used a combination of MeSH terms and free text for the search, which was limited to publications in English. The key inclusion criteria were original studies (published or reports), participants aged 20 years or older, and studies conducted in Asian Indians. Available evidence suggests a high and increasing prevalence of diabetes, hypertension, dyslipidaemia, and obesity in India. However, many of the studies retrieved relied on self-report of these conditions, lacked robust methodology for diagnosis, or represented secondary analyses of data from surveys not specifically focused on NCDs. Many of them were also not conducted on a truly representative population of India, which limits their utility in assessing intraregional and inter-regional differences in disease prevalence and the generalisability of their results to the whole of a vast and diverse country such as India.

Added value of this study

The present report from the Indian Council of Medical Research–India Diabetes (ICMR-INDIAB) study, the largest nationally representative population-based study on diabetes and metabolic NCDs undertaken in India covering all 28 states of the country, two union territories, and the National Capital Territory of Delhi, shows that India now has a much higher prevalence of metabolic NCDs than shown by previous estimates. The study reports on the prevalence of diabetes and prediabetes in different states of India using robust sampling and diagnostic methods and therefore helps in assessing the present status of the diabetes epidemic and its likely future trajectory. The diabetes epidemic is in transition in India, with some of the states having already peaked while others are still in the early take-off stage. The study also shows that while the prevalence rates of diabetes, hypertension, obesity, and dyslipidaemia are higher in urban areas, the rural prevalence rates are much higher than previously reported.

Implications of all the available evidence

There is a sizeable population in India at risk of cardiovascular disease and other long-term organ complications due to metabolic NCDs, which are likely to pose a major public health challenge in the near future. There is also evidence that the NCD epidemic is spreading to rural areas, which lack the health infrastructure needed to effectively diagnose and manage these conditions. This calls for urgent government-level initiatives for prevention and management of NCDs through strengthening of the public health-care system and reorientation of priorities in provision of health care. The granular state-level data on these NCDs will be of particular interest to state governments in India, which are primarily responsible for providing health care in their respective jurisdictions and will enable them to design evidence-based interventions to effectively arrest the progress of NCDs and manage their complications.

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importance in view of recent evidence that mortality and morbidity due to NCDs is much higher in low-income and middle-income countries such as India, compared with wealthier nations.[7]

The Indian Council of Medical Research–India Diabetes (ICMR-INDIAB) study is the largest survey on diabetes and other metabolic NCDs undertaken in India, and covers all 28 states, two of the union territories, and the National Capital Territory of Delhi (hereafter referred to as states and union territories).[8] The present paper analyses the results of the ICMR-INDIAB study to quantify the prevalence of metabolic NCDs, namely diabetes, hypertension, obesity, and dyslipidaemia in a representative sample of adults in both urban and rural India, and attempts to identify region-wise and state-wise differences in the status of these NCDs in the country.

Methods

Sampling and study population

The ICMR-INDIAB study is a cross-sectional, population-based survey of adults aged 20 years and older.[8–15] The methodological details of the study have been published elsewhere.[8] Briefly, the study sampled urban and rural residents in 31 states and union territories of India using a stratified multistage sampling design.[8] In order to obtain a truly representative sample of the population, we used three-level stratification based on geography, population size, and socioeconomic status 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, one individual was selected based on the WHO Kish method,[16] to avoid selection bias with respect to sex and age. The study was conducted in a phased manner between November, 2008, and December, 2020. In phase 1, four regions representing the south (Tamil Nadu), north (Chandigarh), east (Jharkhand), and west (Maharashtra) of the country were studied from Oct 18, 2008, to April 16, 2010. The remaining states were surveyed as follows: phase 2 consisted of undivided Andhra Pradesh (subsequently divided into Andhra Pradesh and Telangana), Bihar, Gujarat,

Karnataka, and Punjab (survey period, Sept 24, 2012, to July 26, 2013), the north east phase included Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura (survey period, Dec 5, 2011, to Nov 14, 2017), phase 3 included Delhi, Madhya Pradesh, Rajasthan, and Uttar Pradesh (survey period, Aug 24, 2017, to March 8, 2018), phase 4 included Kerala, Goa, Puducherry, Haryana, and Chhattisgarh (survey period, Dec 10, 2018, to July 10, 2019), and phase 5 included Himachal Pradesh, Uttarakhand, Odisha, and West Bengal (survey period, Sept 1, 2019 to Dec 31, 2020). Details of the sampling strategy and phases have been published previously.[8–15]

Individuals who were temporarily away from home during the survey period and those who were terminally ill were excluded.

The study was approved by the Institutional Ethics Committee of the Madras Diabetes Research Foundation and individual states, and written informed consent was obtained from all study participants.

Procedures

In all individuals, a standardised, structured questionnaire was used to collect information on demographic and socioeconomic characteristics. Weight, height, waist circumference, and blood pressure were measured and BMI calculated using standardised techniques (details in appendix p 14).[17] In all individuals, capillary blood glucose (CBG) measurement was performed using a glucose meter (One Touch Ultra, LifeScan Johnson & Johnson, Milpitas, CA, USA) after ensuring an overnight fast of at least 8 h. In individuals without a previous diagnosis of diabetes, an oral glucose tolerance test (OGTT) 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, whereas in those with self-reported diabetes, only fasting blood glucose was measured. In all individuals with diabetes and on every fifth individual, a venous sample was drawn for assessment of HbA_{1c} and lipids. Samples were centrifuged within 1 h at the survey site, and serum was transferred to separate labelled vials and temporarily stored in –20°C freezers until they were transferred to the central laboratory in Chennai. All biochemical assays were carried out by the same team of laboratory technicians using standardised methods throughout the study period.

See Online for appendix

HbA_{1c} was estimated by high-pressure liquid chromatography using the Variant II Turbo machine (Bio-Rad, Hercules, CA, USA), which is certified by the National Glycohemoglobin Standardization Program as having documented traceability to the Diabetes Control and Complications Trial reference method.[18] Serum cholesterol (cholesterol esterase oxidase–peroxidase–amidopyrine method), serum triglycerides (glycerol phosphate oxidase–peroxidase–amidopyrine method), and high-density lipoprotein cholesterol (direct method: immunoinhibition) were measured using the Olympus 2700/480 automated biochemistry analyser (Fullerton, CA, USA) from 2008 to 2015, and Beckman Coulter AU 680 clinical chemistry analyser (Fullerton, CA, USA) from 2016 to 2021.

Outcomes

Outcomes of interest were diabetes, prediabetes, dysglycaemia, hypertension, generalised obesity, abdominal obesity, and dyslipidaemia. Projection estimates for each of the metabolic NCDs were also reported for the year 2021. Self-reported or known diabetes was defined based on a physician diagnosis of diabetes or current (in the past 6 months) use of medications for diabetes (insulin or oral hypoglycaemic agents). Physician diagnosis of diabetes was checked against medical reports or prescription for validity, which also helped to define the date and year of diagnosis. In those without a self-reported diagnosis, diabetes and prediabetes (impaired fasting glucose [IFG] and impaired glucose tolerance [IGT]) were diagnosed using OGTT, HbA_{1c}, or a combination of OGTT and HbA_{1c}. For the OGTT, diabetes was defined as per the WHO consultation group report recommendations[19]—ie, fasting CBG of 126 mg/dL (7·0 mmol/L) or higher, or 2-h post-oral glucose load CBG of 220 mg/dL (12·2 mmol/L) or higher. Isolated IFG was diagnosed if individuals had a fasting CBG of 110 mg/dL (6·1 mmol/L) or higher but less than 126 mg/dL (7·0 mmol/L), and 2-h post-glucose CBG of less than 160 mg/dL (8·9 mmol/L).[20] Isolated IGT was diagnosed if individuals had a 2-h post-oral glucose load CBG of 160 mg/dL (8·9 mmol/L) or higher but less than 220 mg/dL (12·2 mmol/L), and fasting CBG of less than 110 mg/dL (6·1 mmol/L).[19] Prediabetes was defined as the presence of IFG, IGT, or both.[19,20] Dysglycaemia was defined as the presence of prediabetes or diabetes. We also assessed the prevalence of IFG using the American Diabetes Association (ADA) criteria[21]—ie, fasting CBG 100–125 mg/dL (5·6–6·9 mmol/L)—and of diabetes and prediabetes using HbA_{1c} cutoffs of 6·5% (48 mmol/mol) or higher and 5·7–6·4% (39–46 mmol/mol), respectively.[22]

Generalised obesity was defined as a BMI of 25 kg/m² or higher, and abdominal obesity was defined as a waist circumference of 90 cm or higher for men and 80 cm or higher for women (based on WHO Asia Pacific guidelines).[23] Hypertension was defined as a systolic blood pressure of 140 mm Hg or higher, or a diastolic blood pressure of 90 mm Hg or higher, or treatment with antihypertensive drugs (Eighth Joint National Committee criteria).[24] For defining dyslipidaemia, National Cholesterol Education Programme—Adult Treatment Panel III guidelines[25] were used as follows: hypercholesterolaemia—serum cholesterol concentrations of 200 mg/dL (5·2 mmol/L) or higher; hypertriglyceridaemia—serum triglyceride concentrations of 150 mg/dL (1·7 mmol/L)

or higher; low HDL cholesterol—HDL cholesterol concentrations of less than 40 mg/dL (1·04 mmol/L) for men and less than 50 mg/dL (1·3 mmol/L) for women; high LDL cholesterol—LDL cholesterol concentrations of 130 mg/dL (3·4 mmol/L) or higher calculated using the Friedewald equation.[26] The intra-assay and inter-assay coefficients of variation for biochemical assays conducted at the central laboratory ranged between 3·1% and 7·6%.

Statistical analysis

The sample size was calculated separately for urban and rural areas, as previous studies have shown large variations between urban and rural prevalence of diabetes. Assuming a prevalence of 10% in urban areas and 4% in rural areas, allowing for margin of error of 20% of prevalence, a non-response rate of 20%, and level of significance of 5%, the sample size was estimated to be 1200 in urban areas and 2800 in rural areas in each of the states studied, with a total of 4000 individuals per state (details in appendix pp 1–8). Estimates for continuous variables are shown as mean (SE) and for categorical variables as proportions (95% CI). Sampling weights were calculated to account for sampling at different levels within each state (appendix pp 1–10). We used the proc survey (frequency/mean) procedure, an approach that produces *n*-way tables from complex multistage survey designs with stratification, clustering, and weighting. To account for the multistage complex survey design of the study, all the key survey elements were used in the statistical analysis.[27] The primary sampling unit was accounted for as the cluster, the normalised weight was accounted for as the final study weight, and the state was accounted for as the stratum to estimate population means, variance, and proportions. To compare the mean and percentage of variables between two groups (urban and rural, and male and female), survey-adjusted linear regression and the Wald χ^2 test were applied, respectively.

For subgroup analysis, the Indian states were divided into six geographical zones: north (Chandigarh, Delhi, Haryana, Himachal Pradesh, Punjab, and Rajasthan), south (Andhra Pradesh, Telangana, Karnataka, Kerala, Puducherry, and Tamil Nadu), east (Bihar, Jharkhand, Odisha, and West Bengal), west (Goa, Gujarat, and Maharashtra), central (Chhattisgarh, Madhya Pradesh, Uttar Pradesh, and Uttarakhand), and northeast (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

To account for the different time periods of the survey, the analytical strategy we used is akin to standardising estimates according to age, sex, and region to obtain the current prevalence of cardiometabolic risk factors in each state. The information from the National Family Health Survey-5 (NFHS-5) was used for the standardisation.[28] Similar assumptions have been made by the International Diabetes Federation while making future projections for diabetes.[29] The purpose of this standardisation was to ensure that population ageing and other demographic trends were accounted for when estimating diabetes in states that were sampled in earlier time periods. Minimal assumptions were made about changes in the population that possibly affected diabetes prevalence during the study period. We therefore focus only on region, sex, and age, as these are known factors that contribute to diabetes prevalence that are themselves changing in the population, and therefore could drive secular changes in diabetes prevalence.

NFHS-5 study weights were computed for subgroups defined by region, sex, and age (10-year intervals) following the complex survey design. The weights assigned to each subgroup based on the NFHS-5 household dataset were multiplied by the weighted prevalence in the respective subgroup. The prevalence of each cardiometabolic risk factor in the specific state was calculated by adding the re-weighted prevalence of all subgroups. The weighting procedure using information from NFHS-5 is illustrated in detail in the appendix (pp 11–13).

The estimated adult population (≥20 years) of India for the year 2021 from the population projections published by the Ministry of Health and Family Welfare, Government of India,[30] was used for estimating the numbers of individuals with diabetes, prediabetes, dysglycaemia, hypertension, obesity, and dyslipidaemia. Projection estimates were calculated among adults aged 20 years or older by the direct method to the 2021 India Census projected population. For the direct method, we used the region, age, and sex standardised prevalence obtained from the pooled results from the 31 states and union territories and multiplied it by the 2021 India Census projected population. α was set at 0·05 to determine statistical significance. To analyse data, we used SAS (version 9.4).

Role of the funding source

This study was funded by Indian Council of Medical Research and Department of Health Research, Ministry of Health and Family Welfare, Government of India. Some members of the funding source provided scientific inputs for the study, were involved in quality control, and helped to revise the manuscript.

Results

Overall, from all 31 states and union territories, 119 022 individuals were assessed for eligibility, of whom 113 043 individuals (33 537 from urban areas and 79 506 from rural areas) participated in the study (response rate: 95·0%) between Oct 18, 2008 and Dec 17, 2020. A total of 5979 individuals were not included in the study due to the following reasons: refused to participate (n=3780), not available (n=1369), or their house was locked (n=830) during the survey period.

We have included data from the following numbers of individuals for analysis of various cardiometabolic risk factors: diabetes or prediabetes—107 119; hypertension—111 439; generalised obesity—110 368; abdominal obesity—108 665; and dyslipidaemia—18 492 (available only in every fifth participant).

The mean age of the 113 043 individuals studied was 43·0 years, 52 602 (46·5%) were male, and 30 119 (weighted proportion 26·9%) had no formal education (table 1). Compared with their rural counterparts, urban residents were significantly younger, and had higher BMI, waist circumference, diastolic blood pressure, and educational attainment. The glycaemic (urban *vs* rural: fasting blood glucose 105 mg/dL *vs* 100 mg/dL, p<0·0001) and lipid parameters (total cholesterol 175 mg/dL *vs* 167 mg/dL, p<0·0001; LDL cholesterol 104 mg/dL *vs* 99 mg/dL, p<0·0001) were significantly higher among urban residents. Males were older, were better educated, and had lower BMI but higher blood pressure, triglycerides, and HbA_{1c} compared with females.

The overall weighted prevalence of diabetes by OGTT was 11·4% (95% CI 10·2–12·5; 10 151 of 107 119 individuals), with significantly higher prevalence in urban compared with rural areas (urban areas 4272 [16·4%] of 31 560 individuals *vs* rural areas 5879 [8·9%] of 75 559, p<0·0001), and among males compared with females (males 4978 [12·1%] of 49 706 individuals *vs* females 5173 [10·7%] of 57 413, p<0·0001) (table 2). The weighted prevalence of diabetes was higher when diagnosed using HbA_{1c} (13·3% [10·4–16·2]; 2082 of 18 090 individuals) and highest when using a combination of OGTT and HbA_{1c} (21·1% [17·6–24·5]; 3368 of 18 366 individuals; appendix p 18).

The weighted prevalence of IFG (by WHO cutoff) was 10·1% (95% CI 9·0–11·2; 10 449 of 107 119 individuals) and that of IGT was 3·3% (2·6–4·0; 3276 of 107 119 individuals). IFG prevalence was significantly higher among females and IGT among males. Prevalence of IFG and IGT was similar in urban and rural areas. The overall weighted prevalence of prediabetes was 15·3% (13·9–16·6; 15 496 of 107 119 individuals; table 2). Sensitivity analysis using the ADA criteria[21] for diagnosing IFG (ie, fasting glucose 100–125 mg/dL) demonstrated a nearly three-fold increase in prevalence of IFG to 27·6% (26·0–29·3; 29 073 of 107 119 individuals). Using the ADA criteria, the overall prevalence of prediabetes was 32·8% (31·1–34·6; 34 120 of 107 119 individuals; appendix p 15). The weighted prevalence of prediabetes by HbA_{1c} was 21·0% (17·5–24·6; 3561 of 18 090 individuals) and by using a combination of OGTT and HbA_{1c} was 26·6% (22·8–30·4; 4733 of 18 366 individuals; appendix p 18).

	Urban (n=33 537)	Rural (n=79 506)	p value*	Male (n=52 602)	Female (n=60 441)	p value†	Overall (n=113 043)
Age, years	42·1 (0·15)	43·4 (0·10)	p<0·0001	44·0 (0·11)	42·1 (0·09)	p<0·0001	43·0 (0·09)
Education							
No formal schooling	16·2% (15·3–17·1)	32·0% (31·2–32·7	p<0·0001	17·2% (16·6–17·8)	35·3% (34·5–36·0)	p<0·0001	26·9% (26·3–27·5)
Primary school, high school, or higher secondary school	64·4% (63·4–65·3)	60·3% (59·6–61·0)	p<0·0001	67·5% (66·8–68·1)	56·6% (55·9–57·3)	p<0·0001	61·6% (61·1–62·2)
Technical, undergraduate, or postgraduate education	19·4% (18·3–20·5)	7·7% (7·3–8·1)	p<0·0001	15·3% (14·7–15·9)	8·1% (7·7– 8·5)	p<0·0001	11·5% (11·0–11·9)
Anthropometry							
BMI, kg/m²	24·0 (0·06)	22·2 (0·03)	p<0·0001	22·5 (0·03)	23·1 (0·04)	p<0·0001	22·8 (0·03)
Waist circumference, cm	84·3 (0·17)	79·5 (0·11)	p<0·0001	82·5 (0·10)	79·8 (0·11)	p<0·0001	81·1 (0·10)
Blood pressure							
Systolic blood pressure, mm Hg	129 (0·24)	129 (0·15)	p=0·054	131 (0·14)	127 (0·15)	p<0·0001	129 (0·13)
Diastolic blood pressure, mm Hg	82 (0·15)	81 (0·09)	p<0·0001	82 (0·09)	80 (0·08)	p<0·0001	81 (0·07)
Glycaemic parameters							
Fasting blood glucose (mg/dL)	105 (0·34)	100 (0·18)	p<0·0001	101 (0·21)	102 (0·21)	p=0·016	102 (0·17)
2-h post-glucose blood glucose, mg/dL	123 (0·39)	118 (0·28)	p<0·0001	119 (0·29)	120 (0·26)	p=0·013	120 (0·23)
HbA_{1c}‡	5·8% (0·03)	5·5% (0·01)	p<0·0001	5·7% (0·02)	5·6% (0·02)	p=0·27	5·6% (0·01)
Lipid parameters‡							
Total serum cholesterol, mg/dL	175 (0·78)	167 (0·53)	p<0·0001	169 (0·57)	170 (0·59)	p<0·0001	170 (0·44)
Serum triglycerides, mg/dL	149 (2·05)	136 (1·07)	p<0·0001	153 (1·41)	128 (1·29)	p<0·0001	140 (0·98)
Serum HDL cholesterol, mg/dL	40·8 (0·22)	41·1 (0·14)	p=0·0011	39·7 (0·16)	42·3 (0·15)	p<0·0001	41·0 (0·12)
Serum LDL cholesterol, mg/dL	104 (0·70)	99 (0·43)	p<0·0001	99 (0·47)	103 (0·52)	p<0·0001	101 (0·37)
Total cholesterol to HDL cholesterol ratio	4·56 (0·03)	4·28 (0·02)	p<0·0001	4·52 (0·02)	4·21 (0·02)	p<0·0001	4·36 (0·02)

Data are mean (SE) or percentage (95% CI). *For urban *vs* rural residence. †For male *vs* female. ‡Data available only in a subset of the population (data collected in every fifth individual, HbA_{1c}, n=18 090; lipid parameters, n=18 492).

Table 1: **Baseline characteristics of the study population**

The overall weighted prevalence of dysglycaemia (by OGTT) was 26·6% (95% CI 25·0–28·3; 25 647 of 107 119 individuals) using the WHO criteria (table 2) and 44·2% (42·3–46·0; 44 271 of 107 119 individuals) using the ADA criteria (appendix p 15). The weighted prevalence of dysglycaemia by HbA_{1c} was 34·3% (30·3–38·4; 5643 of 18 090 individuals) and by using a combination of OGTT (by WHO criteria) and HbA_{1c} was 47·7% (43·5–51·8; 8101 of 18 366 individuals; appendix p 18).

The weighted prevalence of hypertension was 35·5% (95% CI 33·8–37·3; 35 172 of 111 439 individuals), which was higher in urban areas and among males. When sensitivity analysis was done using American College of Cardiology/American Heart Association (ACC/AHA) criteria[31] (≥130/80 mm Hg), the prevalence of hypertension nearly doubled to 66·3% (64·6–67·9%; 69 702 of 111 439 individuals). Generalised obesity and abdominal obesity were present in 28·6% (26·9–30·3; 29 861 of 110 368 individuals) and 39·5% (37·7–41·4; 40 121 of 108 665 individuals) of the population, respectively. Dyslipidaemia was found in 81·2% (77·9–84·5; 14 895 of 18 492 individuals), mainly driven by low HDL cholesterol (66·9%; 62·9–70·9; 12 411 of 18 492 individuals). Dyslipidaemia and generalised and abdominal obesity were significantly higher among urban compared with rural residents. Generalised obesity was significantly higher in females. Of the lipid parameters, only hypertriglyceridaemia was significantly higher in males, while hypercholesterolaemia, low HDL cholesterol, and high LDL cholesterol were significantly higher in females.

The state-wise weighted prevalence of diabetes ranged from 4·8% (154 of 3421 individuals; in Uttar Pradesh) to 26·4% (886 of 3744 individuals; in Goa) and that of prediabetes from 6·8% (236 of 4053 individuals) to 31·3% (1240 of 3925 individuals). Diabetes prevalence (figure 1A) was highest in the southern and northern regions of India, with urban areas having high prevalence throughout. The central and northeastern regions had lower prevalence. Conversely, prevalence of prediabetes (figure 1B) was highest in the central and northern regions of India and lowest in Punjab, Jharkhand, and some parts of the northeastern region. The prevalence of prediabetes was not significantly different between urban and rural areas. The ratio of diabetes to prediabetes was 1:2 or less in Arunachal Pradesh, Bihar, Madhya Pradesh, Meghalaya, Chhattisgarh, Rajasthan, Sikkim, and Uttar Pradesh (most of which are states with a lower human development index). The ratio was 1:1 or more in Chandigarh, Goa, Delhi, Kerala, Mizoram, Puducherry, Punjab, and Tamil Nadu (all states with a high human development index; appendix pp 19–22).

	Urban (n=33 537)	Rural (n=79 506)	p value*	Male (n=52 602)	Female (n=60 441)	p value†	Overall (n=113 043)
Dysglycaemia (diabetes and prediabetes)	9055/31 560 (31·8%; 29·4–34·2)	16 592/75 559 (24·1%; 22·7–25·4)	p<0·0001	11 948/49 706 (27·2%; 25·4–28·9)	13 699/57 413 (26·2%; 24·6–27·7)	p<0·0001	25 647/107 119 (26·6%; 25·0–28·3)
Diabetes	4272/31 560 (16·4%; 14·6–18·2)	5879/75 559 (8·9%; 8·1–9·7)	p<0·0001	4978/49 706 (12·1%; 10·9–13·3)	5173/57 413 (10·7%; 9·6–11·8)	p<0·0001	10 151/107 119 (11·4%; 10·2–12·5)
Prediabetes	4783/31 560 (15·4%; 13·6–17·2)	10 713/75 559 (15·2%; 14·1–16·3)	p=0·41	6970/49 706 (15·0%; 13·6–16·5)	8526/57 413 (15·5%; 14·2–16·7)	p=0·023	15 496/107 119 (15·3%; 13·9–16·6)
Impaired fasting glucose	3138/31 560 (9·9%; 8·4–11·5)	7311/75 559 (10·1%; 9·3–11·0)	p=0·32	4525/49 706 (9·4%; 8·3–10·6)	5924/57 413 (10·7%; 9·6–11·7)	p<0·0001	10 449/107 119 (10·1%; 9·0–11·2)
Impaired glucose tolerance	1030/31 560 (3·4%; 2·5–4·3)	2246/75 559 (3·3%; 2·7–3·8)	p=0.41	1668/49 706 (3·7%; 3·0–4·5)	1608/57 413 (2·9%; 2·3– 3·5)	p<0·0001	3276/107 119 (3·3%; 2·6–4·0)
Hypertension	11 588/33 063 (40·7%; 38·2–43·2)	23 584/78 376 (33%; 31·6–34·3)	p<0·0001	17 768/51 801 (38·7%; 36·8–40·7)	17 404/59 639 (32·6%; 31·0–34·2)	p<0·0001	35 172/111 439 (35·5%; 33·8–37·3)
Generalised obesity (BMI ≥25 kg/m²)	12 135/32 784 (39·6%; 37·1–42·1)	17 726/77 584 (23·1%; 21·8–24·4)	p<0·0001	12 311/51 784 (25·4%; 23·7–27·1)	17 550/58 584 (31·6%; 30·0–33·3)	p<0·0001	29 861/110 368 (28·6%; 26·9–30·3)
Abdominal obesity (waist ≥90 cm [males], ≥80 cm [females])	15 566/32 293 (51·6%; 49·0–54·1)	24 555/76 372 (33·5%; 32·0–34·9)	p<0·0001	13370/51 800 (28·8%; 27·0–30·7)	26 751/56 865 (49·6%; 47·8–51·4)	p<0·0001	40 121/108 665 (39·5%; 37·7–41·4)
Dyslipidaemia‡	4493/5415 (82·9%; 78·3–87·5)	10 402/13 077 (80·3%; 77·7–83·0)	p<0·0001	6954/9283 (75·1%; 71·3–79·0)	7941/9209 (86·8%; 84·0–89·6)	p<0·0001	14 895/18 492 (81·2%; 77·9–84·5)
Hypercholesterolaemia (≥200 mg/dL)	1367/5415 (27·4%; 21·6–33·3)	2701/13 077 (22·3%; 19·5–25·0)	p<0·0001	2023/9283 (23·2%; 19·5–26·9)	2045/9209 (24·8%; 20·9–28·6)	p=0·011	4068/18 492 (24·0%; 20·2–27·8)
Hypertriglyceridaemia (≥150 mg/dL)	1834/5415 (36·4%; 30·6–42·1)	3851/13 077 (30·0% (27·0–33·0)	p<0·0001	3347/9283 (37·5%; 33·4–41·6)	2338/9209 (27·1%; 23·4–30·8)	p<0·0001	5685/18 492 (32·1%; 28·2–36·0)
Low HDL cholesterol (<40 mg/dL [males]; <50 mg/dL [females])	3751/5415 (68·1%; 62·4–73·8)	8660/13 077 (66·3%; 63·1–69·4)	p=0·018	5298/9283 (56·3%; 51·9–60·7)	7113/9209 (76·8%; 73·2–80·4)	p<0·0001	12 411/18 492 (66·9%; 62·9–70·9)
High LDL cholesterol (≥130 mg/dL)	1191/5415 (23·5%; 17·9–29·1)	2369/13 077 (19·6%; 16·9–22·3)	p<0·0001	1690/9283 (19·4%; 15·9–22·9)	1870/9209 (22·3%; 18·6–26·1)	p<0·0001	3560/18 492 (20·9%; 17·3–24·5)

Data are n/N (weighted prevalence %; 95% CI). The absolute numbers (n/N) do not correspond exactly to the percentages, because the percentages represent weighted prevalences. *For urban *vs* rural residence. †For male *vs* female. ‡Data available only in a subset of the population (data collected in every fifth individual, n=18 492; urban, n=5415; rural, n=13 077; male, n=9283; female, n=9209).

Table 2: **Weighted prevalence of cardiometabolic risk factors among the study population**

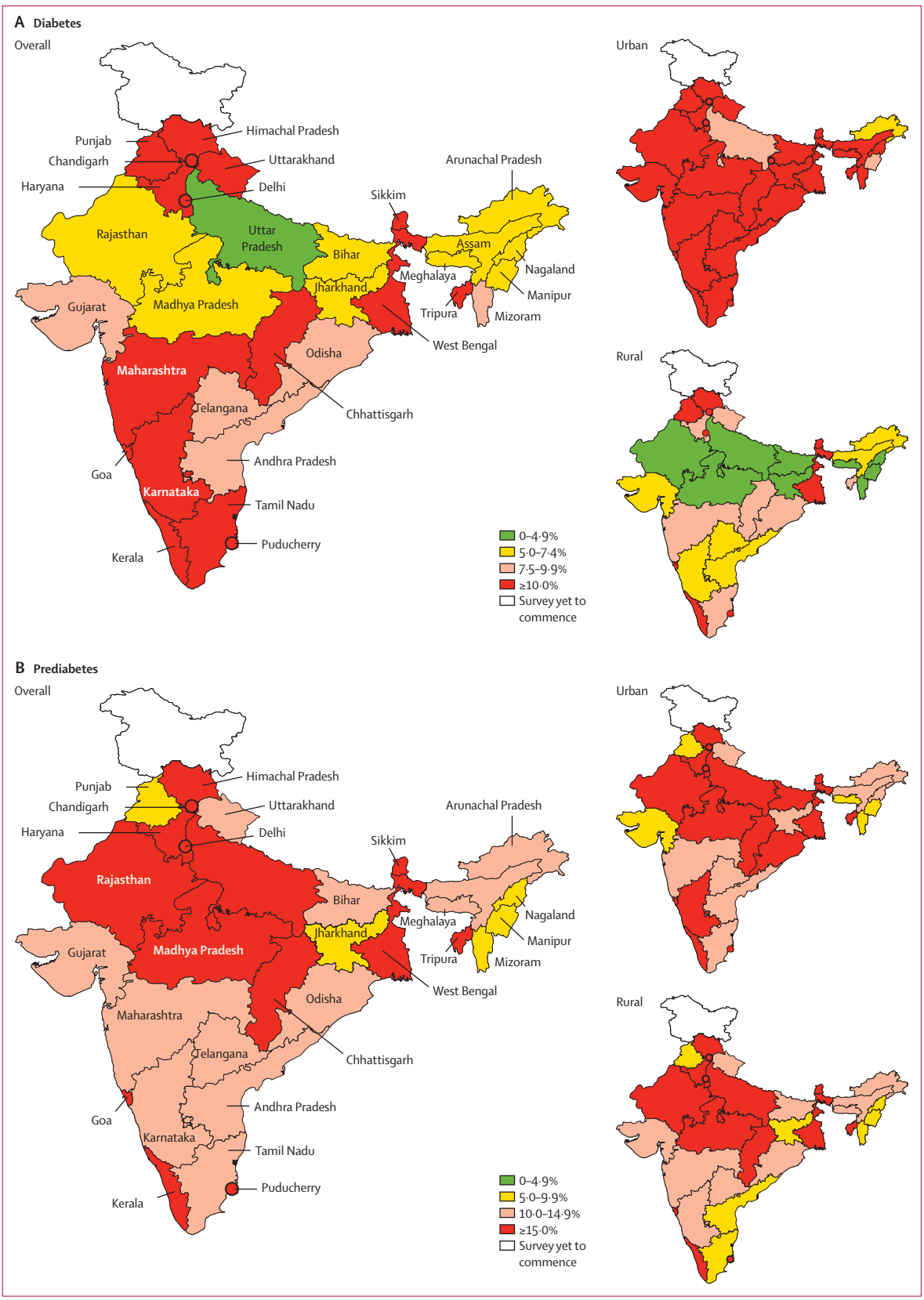
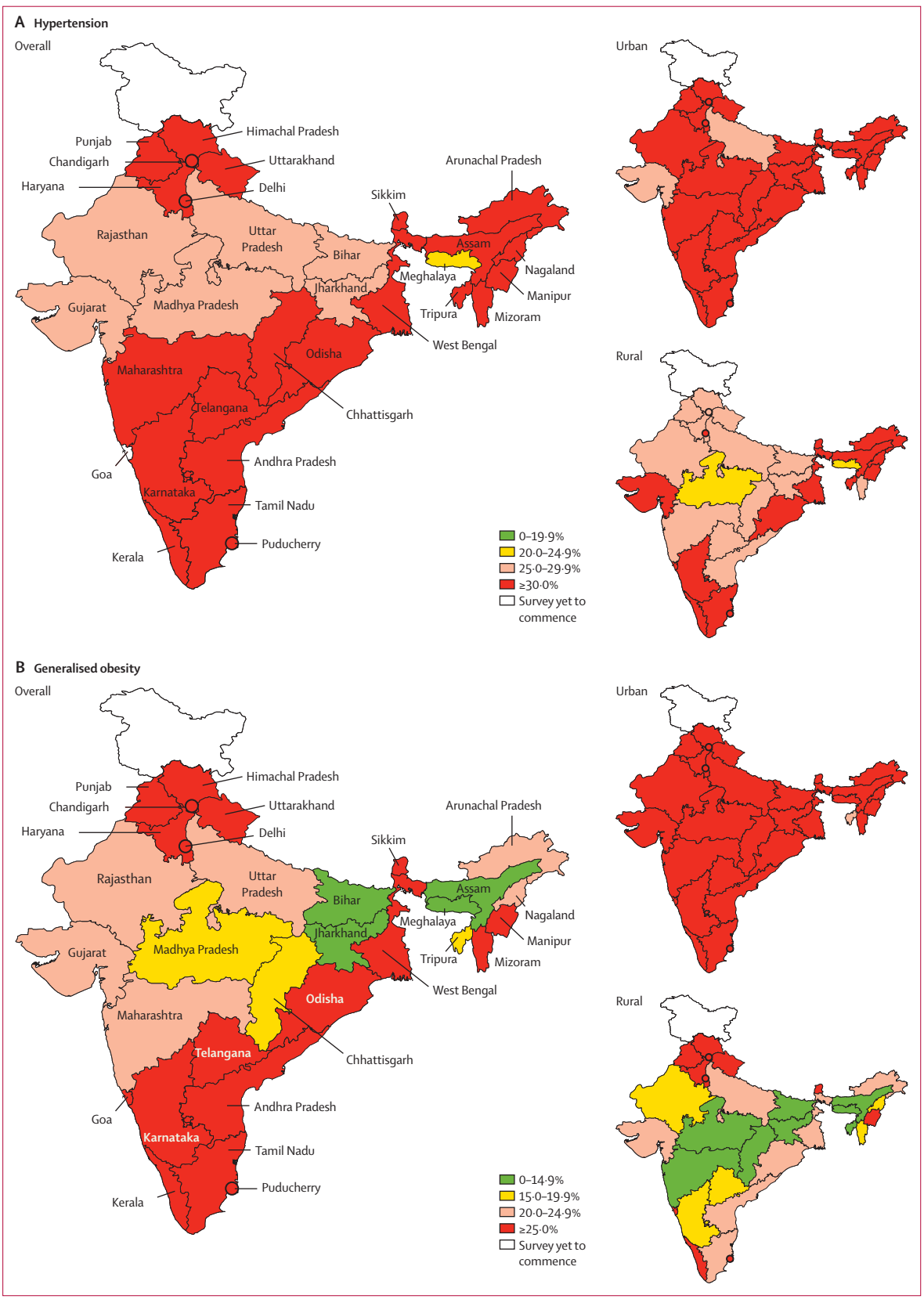


Figure 1: **Overall and area-wise weighted prevalence of diabetes and prediabetes**
(A) Diabetes. (B) Prediabetes.



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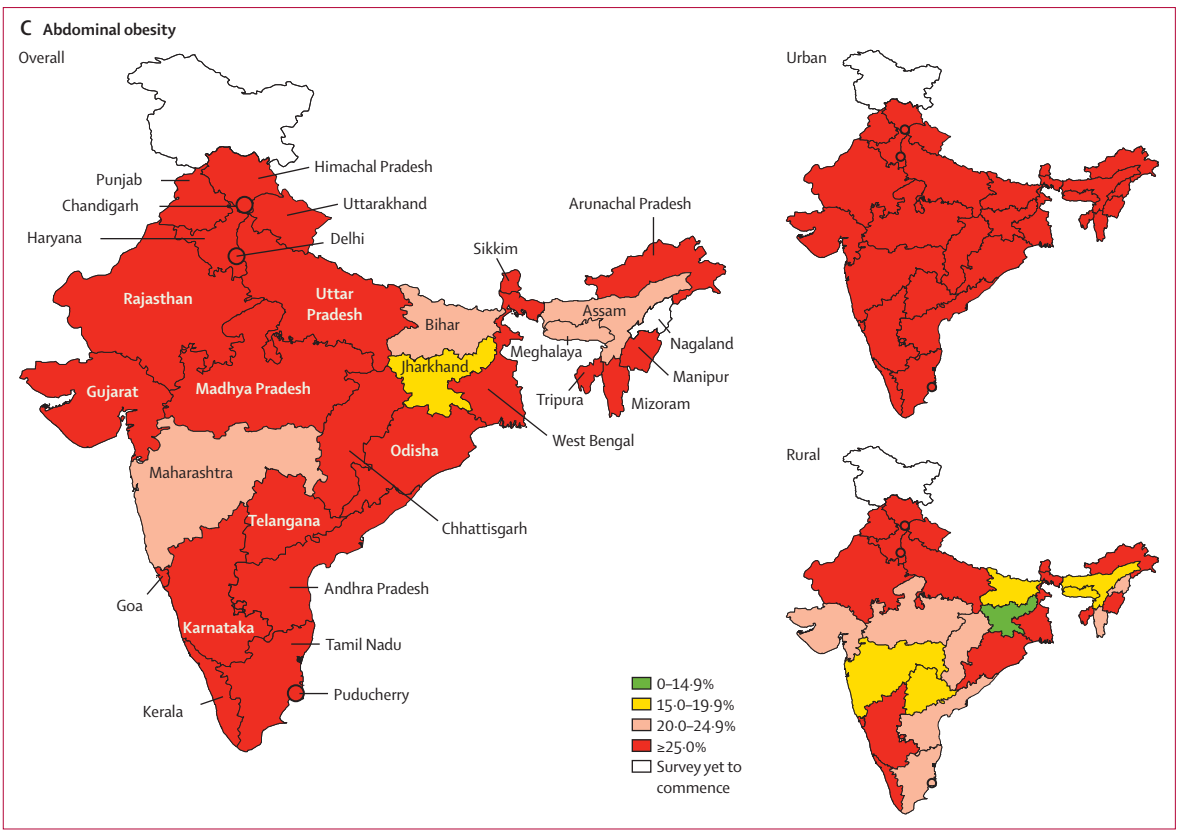


Figure 2: **Overall and area-wise weighted prevalence of hypertension, generalised obesity, and abdominal obesity**
(A) Hypertension. (B) Generalised obesity. (C) Abdominal obesity.

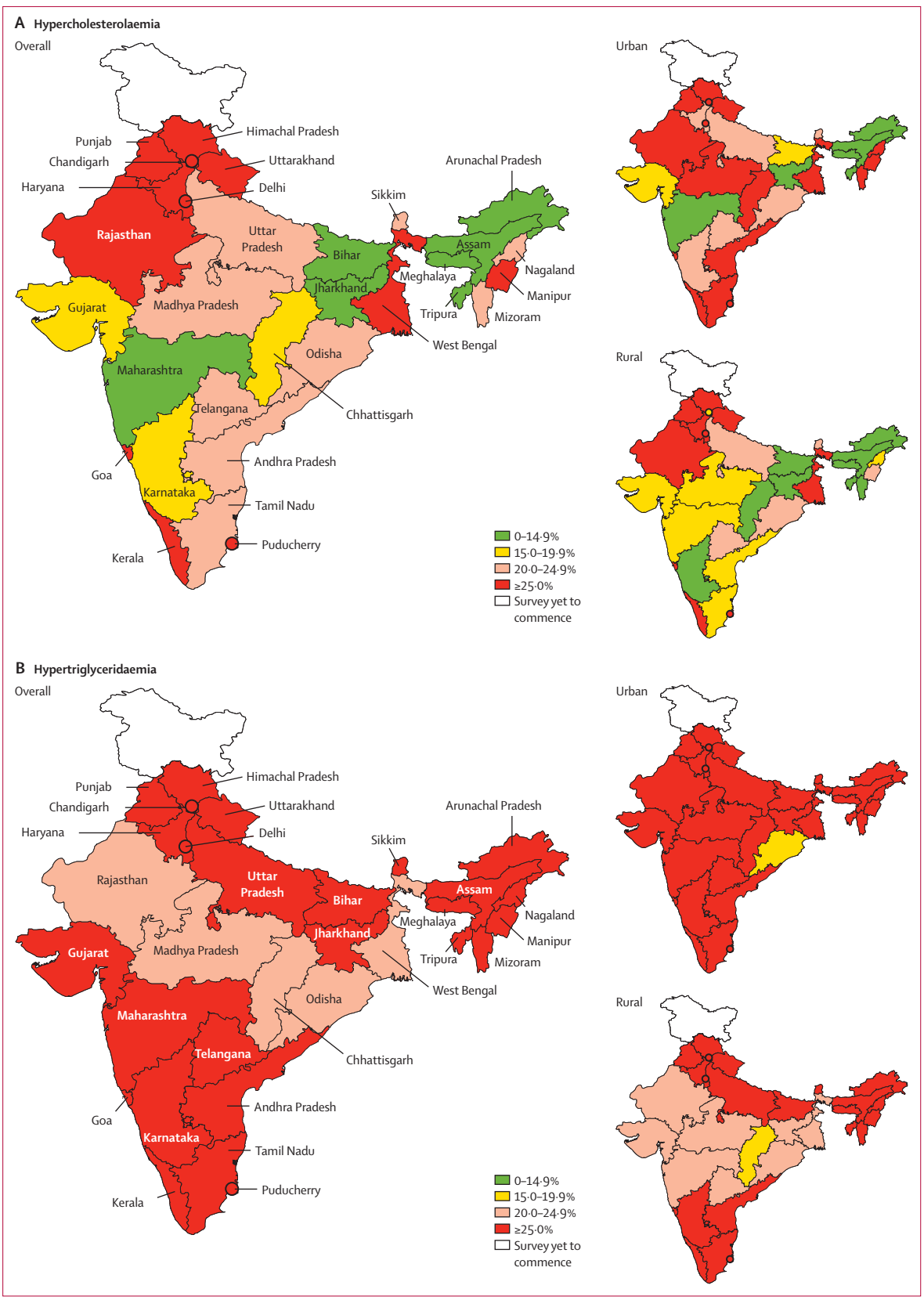
The state-wise weighted prevalence of hypertension ranged from 24·3% (851 of 3641 individuals) to 51·8% (1644 of 3709 individuals), generalised obesity from 11·6% (377 of 3219 individuals) to 53·3% (1741 of 3790 individuals), and abdominal obesity from 18·4% (541 of 3212 individuals) to 61·2% (1958 of 3781 individuals; appendix pp 19–20). Weighted prevalence of hypercholesterolaemia ranged from 4·6% (20 of 411 individuals) to 50·3% (289 of 579 individuals), hypertriglyceridaemia from 21·2% (135 of 661 individuals) to 47·9% (275 of 613 individuals), low HDL cholesterol from 51·8% (374 of 627 individuals) to 83·1% (488 of 650 individuals), and high LDL cholesterol from 3·2% (14 of 411 individuals) to 52·1% (303 of 579 individuals; appendix pp 21–22).

Overall, hypertension was highly prevalent throughout the country except in the central region, more so in the urban areas (figure 2A). High prevalence rates of both generalised and abdominal obesity were observed in urban areas compared with rural areas (figures 2B, C). Overall, abdominal obesity was high in all the regions of India, while generalised obesity was more prevalent in the south followed by the northern and eastern regions. The prevalence of hypertriglyceridaemia (figure 3B) and low HDL cholesterol (figure 3C) was high in all the regions of India with very little urban–rural difference, whereas hypercholesterolaemia (figure 3A) and high LDL cholesterol (figure 3D) showed wide interstate and inter-regional variability, with highest prevalence in the northern region, Kerala, and Goa.

Figure 4 presents the 2021 projections for cardiometabolic risk factors for the entire country. We estimated that in 2021, 101 million people had diabetes, and the number with prediabetes was 136 million. About 315 million people in India had hypertension, 254 million had generalised obesity, and 351 million had abdominal obesity. In addition, 213 million people had hypercholesterolaemia and 185 million had high LDL cholesterol.

Discussion

This report from the ICMR-INDIAB study highlights the enormous burden of NCDs faced by India. Our estimates of the prevalence of diabetes and prediabetes in India (101 million and 136 million, respectively) are much higher than earlier reported figures,[32] which have been collated from several sources, including an earlier report from ICMR-INDIAB.[10] This earlier report, however, included only 15 states of the country



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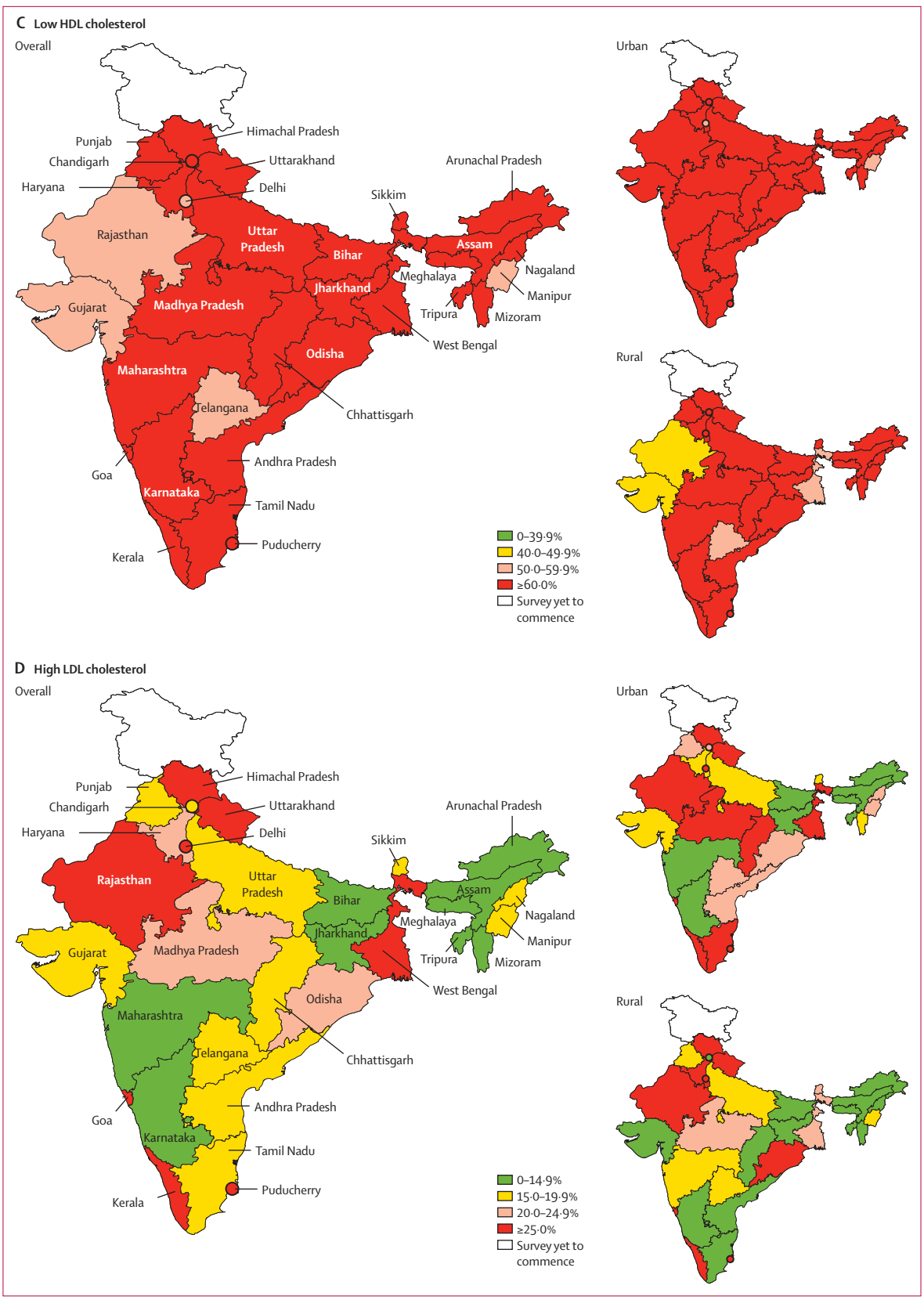
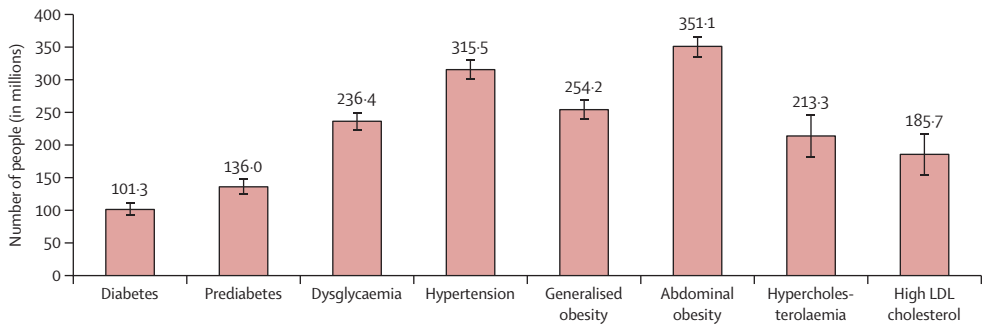


***Figure 3*: Overall and area-wise weighted prevalence of hypercholesterolaemia, hypertriglyceridaemia, low HDL cholesterol, and high LDL cholesterol**
(A) Hypercholesterolaemia. (B) Hypertriglyceridaemia. (C) Low HDL cholesterol. (D) High LDL cholesterol.



	Projections (in millions)	95% CI
Diabetes	101·3	90·7–111·1
Prediabetes	136·0	123·5–147·5
Dysglycaemia	236·4	222·2–251·5
Hypertension	315·5	300·4–331·5
Generalised obesity	254·2	239·1–269·3
Abdominal obesity	351·1	335·1–367·9
Hypercholesterolaemia	213·3	179·5–247·1
High LDL cholesterol	185·7	153·8–217·7

Figure 4: **Projections for metabolic disease prevalence in India**

(including seven of the northeastern states with low prevalence of diabetes) and had not yet sampled some of the more socioeconomically developed states of India (eg, Kerala, Goa, and Puducherry), which could have led to the reported prevalence rates being lower.[10] The present report, on the other hand, uses data from all states of India which have been age-standardised for the current time period and, therefore, we believe that our estimates are a more accurate reflection of the actual numbers.

We also found that using HbA_{1c} in addition to OGTT for diagnosis led to nearly half the population being diagnosed with dysglycaemia. This has been reported in earlier studies also and has been attributed to the high prevalence of iron-deficiency anaemia in India.[33,34] National guidelines do not, therefore, recommend the use of HbA_{1c} as the sole diagnostic criterion for diabetes and prediabetes.[35] Similarly, use of the ADA cutoffs led to a near doubling of prevalence of prediabetes compared with the WHO criteria. Considering the relatively low risks of progression to diabetes and of cardiovascular disease among individuals diagnosed with prediabetes using the ADA criteria compared with the less stringent WHO criteria,[36] the Indian National Guidelines have recommended the use of the latter for diagnosing prediabetes.[35] We have therefore used the OGTT and the WHO criteria for estimating the prevalence of diabetes and prediabetes in India.

Our results also emphasise the interstate and inter-regional variations in diabetes prevalence in India, a phenomenon that has already been reported in earlier studies on NCDs from India, such as the Annual Health Survey and the District-Level Household Survey conducted between 2012 and 2014,[6] the NFHS-5 conducted between 2019 and 2021,[28] and the India State-Level Disease Burden Initiative published in 2018.[3]

With regard to other metabolic risk factors, we document the presence of dyslipidaemia in more than 80%, hypertension in more than one-third (nearly two-thirds if the ACC/AHA criteria are used), and obesity in nearly a third of the population. It is of interest that low HDL cholesterol accounted for the majority of the dyslipidaemia burden in the country, with an overall prevalence of 66·9%. Previous research has shown that low concentrations of HDL cholesterol are more common in Asian Indians or south Asians compared with other ethnic groups.[37–39] Gupta and colleagues[40] reported low HDL cholesterol in 54·9% of Asian Indian men and 64·4% women,[38] and an analysis from the INTERHEART study reported that low HDL cholesterol was present in over 80% of the Asian Indian participants studied,[41] a number comparable to our results. This phenomenon appears to be a component of the Asian Indian phenotype, which also includes low adiponectin concentrations, increased visceral fat, increased waist circumference, and increased insulin resistance. Both low HDL cholesterol and high triglycerides were uniformly prevalent across India in our study. On the other hand, the prevalence of high LDL cholesterol showed significant interstate variation. Whether ethnic differences or dietary patterns (eg, different cooking oils used) are responsible for the heterogeneity in hypercholesterolaemia needs further elucidation, and these studies are of particular importance given the pre-eminent role of LDL cholesterol in cardiovascular risk.

Our results, in general, are in line with those of other recent large studies on cardiometabolic risk factors in India. The prevalence of diabetes was 7·5% and that of hypertension 25·3% in a pooled analysis of data from the Annual Health Survey and the District-Level Household Survey.[6] Another recent analysis of the NFHS-5 data reported a diabetes prevalence of 6·5%.[42] However, this analysis used self-report and random blood glucose measurements for diagnosis of diabetes, with less than 1·5% of the population having a fasting capillary sample. NFHS-5 also showed a lower prevalence of obesity compared with our findings, perhaps due to the higher cutoffs used, and a lower prevalence of hypertension, probably on account of the younger age of the population studied.[28] Other large studies on the prevalence of hypertension in India have reported numbers similar to our results.[43,44] There is also sufficient evidence for an increasing trend in the prevalence of these risk factors in India; a series of five cross-sectional epidemiological studies from Jaipur,

India showed a secular trend of increase in BMI, hypertension, and total and non-HDL cholesterol over a 20-year period,[5,45] while clear increases in diabetes prevalence have been reported in serial studies from different parts of India using uniform diagnostic criteria.[46,47]

These results have multiple implications for the planning and provision of health care in India. There is a very high prevalence of diabetes and related NCDs in the country, which translates to a large population of individuals at risk of not only cardiovascular disease but also of chronic complications of diabetes such as kidney, foot, and eye disease, the costs of treating which are crippling to the individual, society, and country as a whole. Moreover, the high prevalence rates of obesity and prediabetes across the country (even in regions where the prevalence of diabetes is currently low) suggest that the epidemic will continue to accelerate, especially since Asian Indians tend to develop diabetes at lower levels of obesity, and to progress faster from prediabetes to diabetes compared with white Caucasians.[48,49] In particular, the uniformly high prevalence of prediabetes in rural areas is of grave concern since these areas, in general, lack the infrastructure to care for increasing numbers of people with diabetes and its complications.

Prevention, early diagnosis, and prompt treatment of hyperglycaemia, hypertension, and dyslipidaemia are the cornerstones of preventing morbidity and mortality due to cardiovascular disease and other chronic complications of diabetes. Unfortunately, only around 7% of people with previously diagnosed diabetes in India meet treatment targets for blood glucose, lipids, and blood pressure,[15] and the proportion is likely to be even lower among those with undiagnosed diabetes. Therefore, there needs to be a thorough reorientation of health-care priorities towards caring for individuals with metabolic NCDs, particularly in states where the disease burden is found to be high. As a significant proportion of India's population (particularly in rural areas) depends on the government for provision of health care, strengthening the public health-care system is an essential step towards improving diabetes and NCD care in these regions. The incorporation of NCD detection and control into the primary health-care system as part of the National Program for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (recently renamed as the National Programme for Prevention and Control of Non-Communicable Diseases [NP-NCD]),[50] and the provision of NCD care through setting up of Health and Wellness Centres under the Ayushman Bharat scheme by the Government of India, are therefore steps in the right direction.

For the **Ayushman Bharat scheme** see https://ab-hwc.nhp.gov.in/

Provision of health care is primarily the responsibility of state governments in India. As different states in India are at different stages in the trajectory of the diabetes pandemic, state-specific strategies are the need of the hour. States with a high prevalence of diabetes will need to put in place systems to ensure optimal risk factor control, so as to effectively prevent long-term complications. On the other hand, the ratio of diabetes to prediabetes is less than 1:2 in many of the less economically developed states, suggesting that these states can expect large increases in the prevalence of diabetes in the near future. Urgent measures are indicated to prevent or delay such an eventuality, since these states have limited availability of resources for provision of optimal diabetes care. There needs to be a focus on evidence-based approaches to prevent the progression of prediabetes to diabetes or even to reverse it to normal in these states.

There were multiple challenges in implementing such a large nationwide study on diabetes and other metabolic NCDs in India. These can be broadly classified under manpower and team cohesion, religious and cultural misconceptions, topography and climatic conditions, transporting biological samples, obtaining permissions, linguistic barriers, and safety and security threats. In each region, local manpower was recruited with the help of the state principal investigator. Field data collection challenges such as religious and cultural misconceptions among the participants were addressed with the help of religious leaders and community elders from the local communities in the surveyed regions. Participant unavailability and unwillingness to spend time were overcome through multiple visits to the primary sampling units to collect the data. Linguistic barriers were overcome through translating the study documents into 15 vernacular languages. The strategies devised with the assistance of the state principal investigators and health authorities enabled successful implementation of the study, obtaining response rates of more than 90% in every state.

Our study has a few limitations. Since the study is cross-sectional, causal implications cannot be drawn from it. The use of CBG, which has a greater coefficient of variation than venous plasma, is another limitation of this study. However, we have earlier shown good correlation between CBG and venous plasma estimations.[51] Also, our methodological approach did not allow us to differentiate between type 1 and type 2 diabetes. A further limitation of this study is that different phases of the study were conducted at different times, which is inevitable when sampling such a large country. To overcome this limitation, the current prevalence of cardiometabolic risk factors was estimated in each state by doing weighted analysis accounting for region-specific and sex-specific changes in age structure using 2019 population estimate information from NFHS-5. Nevertheless, our estimates did not account for potential long-term changes in lifestyle-based risk factors for diabetes. In particular, this means that states

measured in phases 1–3 might have even higher metabolic disease prevalence than what is reported here. The major strengths of the current study are that it was performed on a nationally representative sample that was geographically and ethnically diverse, and truly representative of the regions studied. This study is perhaps the first to specifically look at the prevalence of metabolic NCDs by studying all states and union territories of India. Compared with other recent large surveys, our study used robust methods for diagnosis of diabetes and prediabetes, such fasting blood glucose and OGTT. Moreover, HbA_{1c} was available in a subset of the population, which adds to the validity of the diagnosis. The learnings from this study with respect to field-level operational challenges and the means of overcoming them will provide impetus and direction to future nationwide epidemiological studies of such magnitude.

In summary, this report on India's metabolic health from the ICMR-INDIAB study reiterates the significant NCD burden in the country. While the diabetes epidemic seems to have peaked in some of the more developed states, most of the less developed states are still in the initial take-off phase. The prevalence of other cardiometabolic risk factors such as obesity, hypertension, and dyslipidaemia is uniformly high across the country, particularly in the urban areas. The focus should therefore be on implementing interventions to minimise the progression of prediabetes to diabetes in states where the diabetes epidemic has yet to peak, and providing optimal care to ensure comprehensive risk factor reduction in individuals with diabetes so as to prevent complications in those states where the epidemic has already stabilised.

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Contributors

RMA, RU, and VM conceived the study, designed it, and were involved in implementation of the study, training the team, designing quality assurance measures, and interpretation of the data. MD and RP were involved in the design and coordination of the study and interpretation of the data. NT, AKD, SB, PKJ, HKD, AK, VKD, AB, PVR, AD, SK, AG, RL, SVM, and SC were responsible for the supervision of the study in their respective states. SJ, TK, and RSD 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. UV and RS were responsible for data management and statistical analyses. RMA, RU, MD, RP, and VM drafted the manuscript and all authors contributed to the critical revision of the manuscript for important intellectual content. RMA and VM take full responsibility for the overall content of this work. RMA is the guarantor of this work and, as such, takes responsibility for the integrity of the data and the accuracy of the data analysis. RMA, RU, MD, RP, UV, RS, and VM had full access to all the data in the study and all authors had final responsibility for the decision to submit for publication. MD, RP, UV, and RS accessed and verified the data.

Declaration of interests

We declare no competing interests.

Data sharing

Raw data are available on reasonable request to the corresponding author. All data relevant to the study are included in this Article or the appendix.

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Editorial note: The Lancet Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

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