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Unveiling the twin epidemics of hypertension and diabetes: a cross-sectional analysis of sex-specific prevalence, risk, and hotspots in India's epidemiological transition zones

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Abstract

Background The prevalence of hypertension and diabetes, which often coexist and significantly contribute to the burden of noncommunicable diseases (NCDs), is increasing in India. This study examines the sex-stratified prevalence, coexistence, and bidirectional risks of hypertension and diabetes across states with varying epidemiological transition levels (ETLs) and identifies high-burden hotspots.

Methods This study analysed data from the fifth round of the National Family Health Survey, covering 614,426 women and 556,199 men aged 30 years and above, with biomarker information on both diabetes and hypertension. The age-standardized prevalence was estimated, and adjusted risk ratios (ARRs) were obtained on multivariate logit scale. Bivariate maps, spatial autocorrelation and hotspot analyses were conducted using ArcGIS Pro to identify geographic clusters associated with twin epidemics.

Results Individuals diagnosed with hypertension or diabetes were, on average, nearly a decade older than those without. Hypertension prevalence was 30.3% (95%CI:30.14–30.48) among men and 28.6% (95%CI:28.47–28.79) among women, whereas diabetes prevalence was at 19.7% (95%CI:19.58–19.88) in men and 17.4% (95%CI:17.22–17.50) in women. Among individuals with diabetes, 43.1% (95%CI:42.67–43.53) of men and 43.9% (95%CI:43.48–44.36) of women had hypertension, whereas 28.1% (95%CI:27.75–28.37) of hypertensive men and 26.6% (95%CI:26.33–26.93) of hypertensive women were diabetic. Hotspots for twin epidemics were identified in coastal regions, including the southern states with high ETLs, as well as the northern states with high-ETLs and the country's northeastern region. ARR estimates revealed that the risk of hypertension among individuals with diabetes was 39% higher (95%CI:1.38–1.40) in men and 41% higher (95%CI:1.39–1.42) in women than in individuals without diabetes. Similarly,

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the risk of diabetes among individuals with hypertension was 51% higher (95%CI:1.49–1.52) in men and 55% higher (95%CI:1.53–1.57) in women than in individuals without hypertension.

Conclusion Our findings highlight the progressive nature of the twin epidemics of diabetes and hypertension, with an increased risk of onset associated with advanced age. The presence of one condition substantially elevates the likelihood of developing the other, highlighting their bidirectional relationship. Achieving Sustainable Development Goal target 3.4 requires addressing these intersecting epidemics as a unified entity for effective management. Targeted interventions should prioritise high-burden hotspots for integrated care strategies to mitigate the twin epidemics of diabetes and hypertension.

Keywords Hypertension, Diabetes, Twin epidemics, Non-communicable diseases (NCDs), Adjusted risk ratios, Hotspots, Epidemiological transition levels

Introduction

The global burden of disease has shifted markedly over the past few decades, with noncommunicable diseases (NCDs) accounting for 43% of disability-adjusted life years (DALYs) in 1990 and increasing sharply to 64% by 2019 [1]. According to projections, NCDs are expected to constitute 77% of the total global disease burden by 2030 [2]. The World Health Organisation (WHO) estimates that NCDs result in approximately 17 million preventable deaths each year, with low- and middle-income countries (LMICs) accounting for 77% of these deaths [3]. The main causes of the increasing burden of NCDs include hypertension, diabetes, cancer, chronic respiratory conditions, and cardiovascular illnesses (including ischaemic heart disease and stroke) [1, 2, 4, 5]. Recognising the growing threat posed by NCDs, one of the core objectives of the Sustainable Development Goals (SDGs), specifically SDG 3.4, is to reduce premature mortality from NCDs by one-third by 2030 through prevention, treatment, and promotion of mental health and well-being [6].

Hypertension has emerged as a major public health challenge, particularly in LMICs, where it accounted for 88% of the 8.5 million global deaths attributable to high blood pressure in 2015 [7]. Despite its increasing prevalence, many LMICs face low rates of awareness, detection, and treatment, which significantly contribute to the escalating burden of cardiovascular and renal diseases in these regions [8, 9]. Globally, the number of adults living with hypertension doubled between 1990 and 2019, affecting more than 1.2 billion individuals aged 30 to 79 years [10]. This upward trend is particularly striking in India, which is home to approximately 18% of the global population. The country has witnessed a rapid epidemiological transition, with a doubling of hypertension cases over the last three decades [11], reflecting a broader shift toward NCDs burdens.

Similarly, the global prevalence of diabetes has risen dramatically. According to the Global Burden of Disease (GBD) study, the age-standardised prevalence of diabetes increased by 90.5% between 1990 and 2021, rising from 3.2–6.1% [12]. An estimated 529 million individuals were living with diabetes globally in 2021, a number expected to reach 700 million by 2045 [13]. Approximately 94% of this projected increase will occur in LMICs, with the Southeast Asia region alone accounting for 68% of the burden [13]. In 2021, nearly 45% of individuals living with diabetes were unaware of their condition, with LMICs contributing to 90% of the undiagnosed population [14]. India, which is already the second-highest country in terms of diabetes prevalence after China, is projected to see its diabetic population rise from 74.2 million in 2021 to 124.9 million by 2045 [15].

Hypertension and diabetes, which often co-exist due to shared pathogenic mechanisms, significantly increase the burden of NCDs [16–19]. Hypertensive patients are more likely to develop diabetes, compared to normotensive patients, while diabetes patients are twice likely to experience hypertension compared to non-diabetic patients [20]. The co-existence of the diseases increased DALYs and the risk of premature mortality due to cardiovascular diseases, retinopathy and renal failure [18]. India faces a growing challenge with rapid urbanisation, accelerated ageing, and improved standards of living contributing to increased obesity rates-an inherent risk factor for both hypertension and diabetes [21]. Moreover, evidence suggests that there is unequal distribution of shared risk factors for NCDs across populations, with significant gender disparities arising from biological, cultural, lifestyle, environmental, and socioeconomic factors. These disparities are further influenced by genetic predispositions, epigenetic mechanisms, nutritional factors, and sedentary lifestyles, which modulate risks and complications differently in males and females [22].

Effectively addressing the growing burden of hypertension and diabetes in India requires a comprehensive understanding of their prevalence, coexistence, and the bidirectional risk they pose across diverse population groups and geographies. Despite India's vast demographic and epidemiological diversity, most existing studies remain confined to specific regions, age groups, or clinical settings [23–25], limiting their generalizability. While multicentric studies have explored these conditions independently, few have systematically examined their coexistence using a consistent operational definition across a nationally representative population. Critically, there is a glaring gap in population-level evidence on the risk of developing hypertension among individuals with diabetes and vice versa which is essential for guiding targeted prevention and integrated disease management strategies.

Using nationally representative data, this study aims to bridge these gaps through four key contributions. First, it provides prevalence estimates of hypertension and diabetes, along with their coexistence i.e. hypertension in diabetes (HID) and diabetes in hypertension (DIH), at the national and sub-national levels. Second, it disaggregates the outcomes by gender to account for the unequal distribution of NCD risk factors between men and women. Third, it identifies hotspots for HID and DIH to highlight regions with the highest burden, stratified by epidemiological transition levels (ETLs) facilitating targeted interventions. Finaly, it estimates the risk of having hypertension among diabetic individuals and diabetes among hypertensive individuals, enabling more effective management strategies for both conditions.

Methods

Data source

This study utilised publicly available data from the fifth round of the National Family Health Survey (NFHS-5), the Indian version of the Demographic and Health Survey (DHS), which provides nationally representative cross-sectional data. The survey was conducted in two phases: Phase I, covering 17 states and 5 Union Territories (UTs), was carried out from June 17, 2019, to January 30, 2020, while Phase II, covering 11 states and 3 UTs, took place from January 2, 2020, to April 30, 2021. Data collection was conducted by 17 Field Agencies, covering 636,699 households with an impressive response rate of 98%. The NFHS-5 employed a multistage, stratified sampling design to ensure national representativeness. In the first stage, the country is divided into distinct regions based on administrative or geographical boundaries, which are further stratified by urban and rural areas. Within each stratum, enumeration areas (EAs) are randomly selected from the most recent population census using probability proportional to size (PPS) sampling. In the second stage, a complete listing of households within each selected EA is conducted, from which approximately 25 households are systematically selected using equal-probability sampling for interviews. The survey was designed to provide population-representative estimates for each of the 707 districts. A detailed description of the survey's methodology, sampling strategy, sample size determination, and key findings has been published elsewhere [26].

Given the higher risk among older individuals, this study focused exclusively on men and women aged 30 years and above. This age threshold aligns with the National Programme for Prevention and Control of Non-Communicable Diseases (NP-NCD) in India, which prioritises the screening and management of NCDs from this age group as part of its public health strategy [27, 28]. Our analytical sample was defined based on the following inclusion and exclusion criteria:

a) Individuals aged 30 years and above were included in the analysis.
b) Individuals who self-reported as transgender were excluded to maintain consistency in sex-disaggregated analyses.
c) Only those with complete biomarker information for both hypertension and diabetes were retained in the final sample.

A detailed description of the study sample is presented in Fig. 1.

Variables considered for the study

Outcome variable

Estimating the prevalence of diabetes and hypertension, as well as the prevalence of hypertension in those with diabetes and vice versa, was our main goal. Biomarker data on diabetes and hypertension in men and women aged 15 and older were gathered from the NFHS-5 study. According to established criteria, people were considered hypertensive if their diastolic blood pressure (DBP) was 90 mmHg or their systolic blood pressure (SBP) was 140 mmHg, or if they were taking blood pressure medication at the time of the survey [26, 29, 30]. Similarly, people were labelled diabetic if their random blood glucose levels were greater than 140 mg/dl or if they were taking medication to decrease their blood glucose [26, 31]. On the basis of these criteria, we estimated the prevalence of hypertension only, diabetes only, and the coexistence of both conditions-HID and DIH.

Independent variable

We considered socio-demographic and economic variables including age (30–39, 40–49, 50–59, 60–69, and 70 & above years), education (illiterate, up to the 8th standard i.e. elementary education, and 9th and above), household's wealth quintile (poorest, poorer, middle, richer, and richest), along with contextual variables such as place of residence (rural and urban), districts, and states. The selection of independent variables was informed by previous studies [29, 31–36] along with the frequency distribution of selected variables in the dataset.

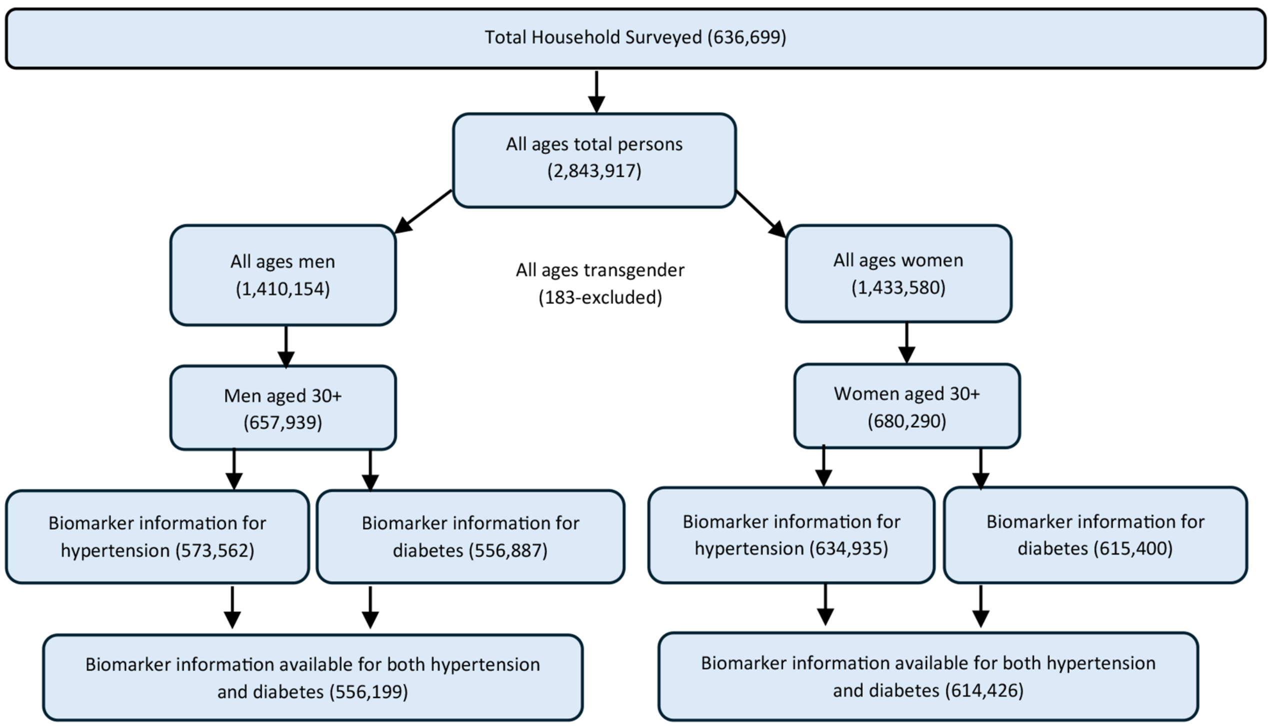

Fig. 1 Flowchart of sample selection in the study, NFHS-5 (2019-21)

Analytical plan and analysis

Epidemiological transition zone

Given the vast socio-economic and demographic diversity of India, states are at varying stages of development and health transitions. To account for these variations, states were categorised based on their ETL, defined as the ratio of DALYs from communicable, maternal, neonatal, and nutritional diseases to those from NCDs and injuries combined [37]. Following the approach adopted in the GBD Study 2016 [37], states were grouped into four ETL categories:

i. Low ETL (ratio 0.56–0.75): Bihar, Jharkhand, Uttar Pradesh, Rajasthan, Meghalaya, Assam, Chhattisgarh, Madhya Pradesh, and Odisha.
ii. Lower-middle ETL (ratio 0.41–0.55): Arunachal Pradesh, Mizoram, Nagaland, Uttarakhand, Gujarat, Tripura, Sikkim, and Manipur.
iii. Higher-middle ETL (ratio 0.31–0.40): Haryana, Delhi, Telangana, Andhra Pradesh, Jammu and Kashmir, Karnataka, West Bengal, Maharashtra, and the union territories (excluding Delhi).
iv. High ETL (ratio < 0.31): Himachal Pradesh, Punjab, Tamil Nadu, Goa, and Kerala.

Statistical analysis

We calculated mean and standard deviation of age by type of disease (i.e. hypertension and diabetes) and gender. Age-standardised estimates were calculated for the prevalence of diabetes, hypertension, and the coexistence of both conditions. When calculating the prevalence estimates, we considered the NFHS-5 dataset's sampling design and sampling weights using the survey analysis technique. To determine the risk of diabetes in the hypertensive population and the risk of hypertension in the diabetic population, we computed the Adjusted Risk Ratios (ARRs). Using basic algebraic operations, the ARR is the ratio of the mean predicted probabilities derived from logit or probit models. We used the *adjrr* command [38] in Stata version 16.0, which can compute the 95% CIs, delta-method standard errors, and point estimates for certain values of the variable of interest. Like the fit model, it automatically adapts to complex survey designs. The variables for the multivariate regression analysis were based on the selection of available information for the men and women aged 30 & above from household member file.

Spatial analysis

We used ArcGIS Pro to map the district- and state-level prevalence of hypertension and diabetes for men and women across India. To visualise the spatial relationship between two key variables, a bivariate choropleth map was developed. The variables were first standardised and classified separately into three categories each using the quantile classification method to ensure equal distribution of observations across classes. A new attribute field was then created to combine the class values of both variables, resulting in nine unique bivariate categories (3 × 3 classification matrix). Symbology was assigned using the unique values renderer based on the combined attribute field. A custom 3 × 3 bivariate colour palette was applied, where one variable was represented by a gradient from light to dark along the vertical axis and the other along the horizontal axis, allowing for an intuitive interpretation of co-occurrence and intensity levels. The legend was designed in the layout view using a manually constructed matrix to reflect the bivariate classification scheme and enhance interpretability.

To identify the district wise clustering of hypertension among diabetics and diabetes among hypertensives, a spatial autocorrelation analysis was applied. Using the Getis-Ord Gi* technique [39], we identified high-risk hotspots and low-risk cold spots by calculating z-scores and p-values for each district, with closer districts weighted more heavily through the inverse distance squared function.

Table 1 Percent distribution of those individuals aged 30 and above who have given blood sample for both diabetes and hypertension test by socio-economic characteristics in India, 2019-21

Background Characteristics	Men aged 30 & above		Women aged 30 & above	
	Weighted %	Un-weighted Sample	Weighted %	Un-weighted Sample
Age-groups				
30–39	29.3	164,944	30.9	192,924
40–49	24.9	139,365	25.7	157,544
50–59	19.7	110,678	20.3	126,020
60–69	16.6	89,592	14.9	89,099
70+	9.6	51,620	8.2	48,839
Education				
Illiterate	22.4	131,972	46.9	298,710
Upto-8th	33.7	187,003	28.5	172,278
9th-above	43.9	236,717	24.7	143,217
Wealth quintile				
Poorest	17.8	113,653	18.5	127,009
Poorer	19.1	118,914	19.3	131,095
Middle	20.5	114,779	20.3	125,998
Richer	21.3	108,798	20.7	118,291
Richest	21.3	100,055	21.2	112,033
Place of residence				
Urban	32.4	137,299	32.4	153,184
Rural	67.7	418,900	67.6	461,242
Group of states				
Low ETL group	43.5	252,998	43.5	277,151
Lower-middle ETL	7.1	85,946	6.8	91,356
Higher-middle ETL group	36.3	155,931	35.4	171,627
High ETL group	13.1	61,324	14.3	74,292
India	100	556,199	100	614,426

Results

Sample characteristics

A total of 5,56,199 men and 6,14,426 women aged 30 years and above were included in the study. Among both genders, the age group of 40–49 years constituted the largest share, accounting for approximately one-fourth of the study population. Around 68% of the participants, both men and women, were from rural areas. Individuals from low ETLs formed the largest proportion of the sample, representing 44% of both men and women (Table 1).

Age gradient in hypertension and diabetes prevalence

An analysis of NFHS-5 data for individuals aged 30 years and above revealed distinct age profiles associated with the presence of hypertension and diabetes among both men and women in India (Fig. 2) (Supplementary Table ST-1). The median age for individuals with either hypertension or diabetes is substantially higher than for those without these conditions. The mean ages closely mirror the medians, indicating a relatively symmetric age distribution among disease groups. For hypertensive individuals, the mean age was 54 years for men and 55 years for women, compared to 47 and 46 years respectively among non-hypertensives. Similarly, the mean age among diabetics stood at 54 years for both men and women, significantly higher than the 48 years (men) and 47 years (women) observed among non-diabetics. The standard deviation bands are wide (± 13 to 14 years), reflecting substantial variability in age of onset, even as central tendencies cluster around the mid-50s.

Prevalence of hypertension and diabetes

Results showed that 30% (95% CI: 30.14–30.48) of men and 29% of women (95% CI: 28.47–28.79) aged 30 & above were hypertensive (Table 2). However, significant regional disparities were observed, with prevalence rates ranging from as low as 5% in districts of Jammu and Kashmir to as high as 38% in districts of West Bengal and Tamil Nadu (Figs. 3 and 4) (Supplementary Figure SF-1 & SF-2, and Supplementary Table ST-2). Hypertension prevalence increased consistently with age and educational attainment across ETL groups, with the highest rates recorded among populations in High ETL states for both men and women. Geographic factors also influenced prevalence, wherein it was more prevalent among urban men (34%, 95% CI: 33.46–34.18) as compared to rural men (29%, 95% CI: 28.45–28.82).

The prevalence of diabetes was lower than hypertension in the study population and recorded as 20% (95% CI: 19.58–19.88) and 17% (95% CI: 17.22–17.50) for men and women respectively at the national level (Table 3).

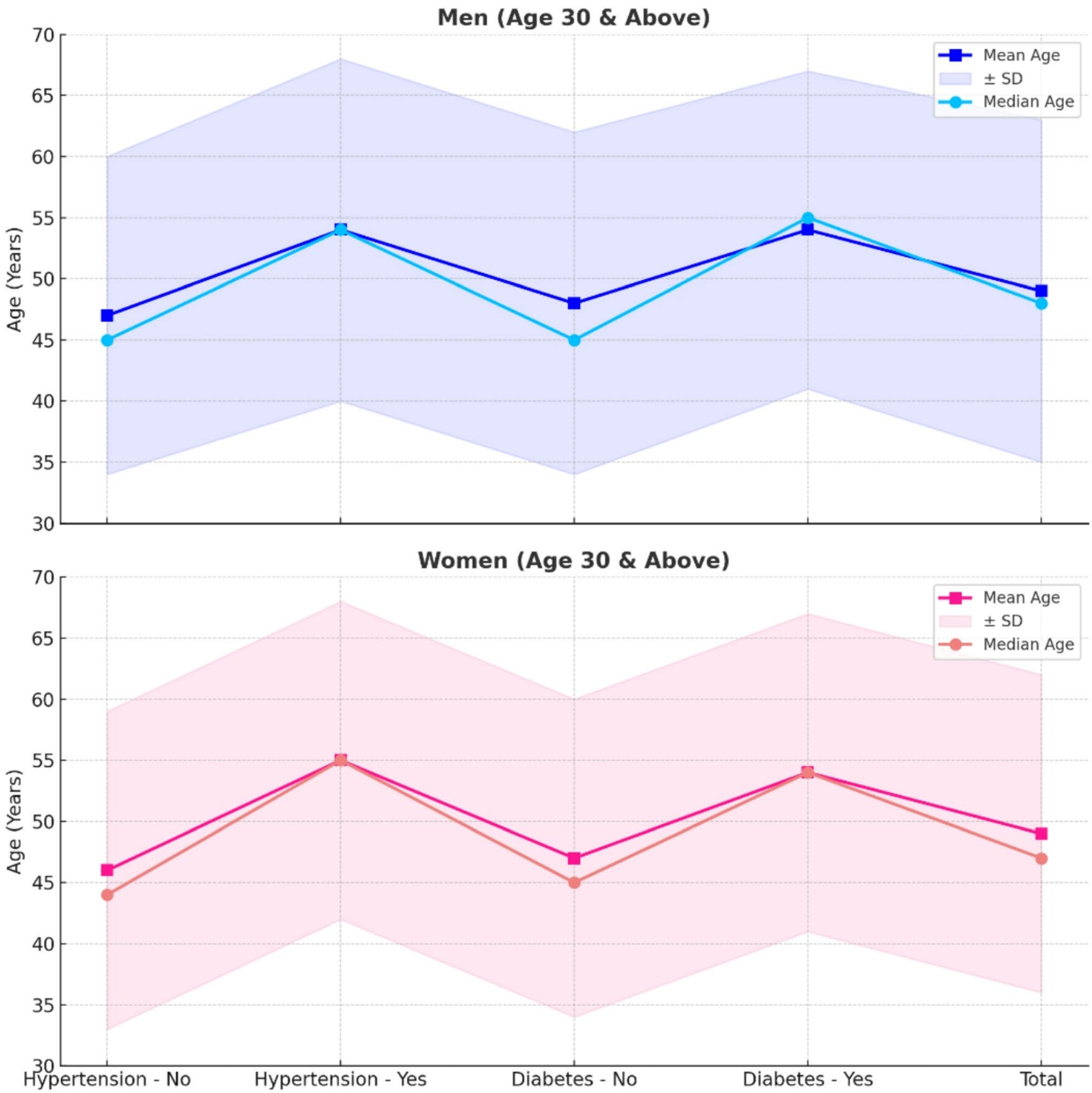

Fig. 2 Mean and median age of the study population by disease type and gender, NFHS-5 (2019-21)

In terms of regional variation, the prevalence of diabetes followed a similar pattern observed for hypertension for both men and women (Supplementary Figures SF-3 & SF-4). Across the ETLs, we noticed that the prevalence of diabetes increased with age, level of education and economic status and was more prevalent in urban areas as compared to rural. Higher and High ETLs recorded higher prevalence across all the selected indicators. The difference in diabetes prevalence was more than double between the age groups 30–39 years (16.3%, 95% CI: 15.69–16.94) and 70 + years (34%, 95% CI: 33.18–34.87) among men.

Hypertension in diabetes (HID)

At national level 43.1% (95% CI: 42.67–43.53) of men and 43.9% (95% CI: 43.48–44.36) of women showed prevalence of hypertension among diabetic population. The Higher-Middle and High ETLs have higher prevalence of hypertension than national average among diabetic population. Among the 36 States/UTs, 23 and 22 states reported hypertension prevalence among men

Table 2 Prevalence of hypertension among individuals aged 30 and above by socio-economic characteristics in the group of States as per the epidemiological transition level, India, 2019-21

Background Characteristics	Low ETL		Lower-middle ETL		Higher-middle ETL		High ETL		Total	
	%	95%CI	%	95%CI	%	95%CI	%	95%CI	%	95%CI
Men aged 30 and above										
Age-groups										
30–39	17.3	16.99–17.65	17.4	16.62–18.23	18.9	18.39–19.43	23.0	22.10-23.82	18.6	18.3-18.84
40–49	24.6	24.16–24.97	25.6	24.64–26.66	28.0	27.33–28.6	33.5	32.53–34.52	27.0	26.69–27.35
50–59	31.4	30.95–31.94	31.6	30.39–32.75	35.9	35.13–36.68	42.8	41.63–43.99	34.7	34.27–35.07
60–69	36.5	35.93–37.03	39.7	38.21–41.12	43.8	42.87–44.64	50.6	49.41–51.79	41.2	40.72–41.61
70+	42.0	41.26–42.78	45.4	43.47–47.41	49.8	48.61–50.95	55.8	54.27–57.26	47.0	46.43–47.61
Education										
Illiterate	26.6	26.26–27.04	27.2	26.05–28.46	31.6	30.91–32.26	41.1	39.8-42.51	29.5	29.18–29.85
Upto-8th	27.0	26.66–27.38	27.8	26.95–28.66	31.0	30.4-31.56	39.4	38.6-40.29	30.2	29.94–30.52
9th-above	28.5	28.14–28.84	28.7	27.96–29.53	31.2	30.73–31.75	36.7	36-37.44	30.8	30.51–31.05
Wealth quintile										
Poorest	24.0	23.61–24.32	25.6	24.43–26.83	24.2	23.35–25.15	32.9	30.19–35.66	24.3	23.98–24.66
Poorer	25.2	24.8-25.61	25.5	24.49–26.5	27.0	26.3-27.74	33.9	32.48–35.44	26.5	26.12–26.82
Middle	27.6	27.13–28.12	28.2	27.17–29.29	29.8	29.17–30.46	35.1	33.99–36.17	29.6	29.23–29.96
Richer	31.0	30.45–31.6	28.3	27.24–29.42	33.4	32.68–34.05	37.9	36.9-38.83	33.0	32.63–33.42
Richest	33.9	33.25–34.52	30.6	29.46–31.87	37.4	36.58–38.18	42.5	41.69–43.39	36.8	36.35–37.2
Place of residence										
Urban	31.3	30.76–31.82	28.4	27.44–29.39	34.5	33.87–35.12	39.3	38.45–40.06	33.8	33.46–34.18
Rural	26.4	26.19–26.64	28	27.41–28.55	29.2	28.82–29.57	37.6	36.92–38.22	28.6	28.45–28.82
Total Men 30+	27.5	27.3-27.72	28.2	27.63–28.68	31.2	30.9-31.57	38.3	37.8-38.82	30.3	30.14–30.48
Women aged 30 and above										
Age-groups										
30–39	12.3	12.06–12.58	11.8	11.19–12.47	12.6	12.16–12.99	12.6	11.98–13.19	12.4	12.2-12.62
40–49	21.8	21.43–22.16	22.3	21.38–23.24	26.2	25.61–26.8	25.7	24.88–26.5	24.0	23.68–24.28
50–59	32.3	31.89–32.81	34.3	33.13–35.45	39.8	39.07–40.61	40.4	39.44–41.44	36.3	35.89–36.64
60–69	40.6	40.06–41.22	45	43.58–46.49	50.0	49.15–50.92	54.6	53.39–55.73	46.4	45.92–46.83
70+	46.7	45.92–47.56	50.5	48.59–52.35	56.2	55.06–57.41	63.3	61.87–64.77	53.2	52.62–53.83
Education										
Illiterate	27.5	27.25–27.77	30.8	30.05–31.59	35.9	35.39–36.34	42.2	41.32–43.17	31.5	31.29–31.75
Upto-8th	24.2	23.8-24.58	26.7	25.76–27.56	29.6	29.04–30.21	36.9	36.16–37.73	28.6	28.34–28.96
9th-above	20.8	20.33–21.24	23.3	22.38–24.31	23.4	22.76–23.96	25.6	24.94–26.23	23.1	22.76–23.4
Wealth quintile										
Poorest	22.7	22.37–23.03	25.5	24.33–26.64	28.2	27.37–29.13	33.3	30.91–35.74	24.5	24.15–24.8
Poorer	24.1	23.74–24.5	25	24.05–25.98	28.0	27.33–28.7	30.9	29.61–32.3	26.0	25.7-26.36
Middle	26.2	25.78–26.71	27	25.94–27.99	29.8	29.16–30.41	31.7	30.78–32.71	28.5	28.2-28.89
Richer	28.3	27.75–28.83	28.3	27.26–29.41	31.9	31.19–32.52	33.4	32.56–34.26	30.8	30.38–31.12
Richest	29.8	29.22–30.4	29.5	28.41–30.69	33.2	32.5-33.98	36.4	35.67–37.15	32.6	32.22-33
Place of residence										
Urban	28.1	27.6-28.59	28.6	27.71–29.61	32.5	31.95–33.13	34.9	34.17–35.59	31.3	31.01–31.67
Rural	24.8	24.61–25.03	26.7	26.16–27.25	29.3	28.93–29.65	32.9	32.36–33.51	27.3	27.15–27.5
Total Women 30+	25.5	25.35–25.74	27.5	26.98–27.98	30.6	30.24–30.88	33.8	33.33–34.23	28.6	28.47–28.79

and women respectively who were diabetic exceeding the national average (Supplementary Table ST-3). In High ETLs, Punjab recorded 60.9% and 62.9% hypertension among diabetic men and women respectively. In the Higher-Middle ETLs, among diabetics, 60% of men in Delhi and 56% of women in Lakshadweep were hypertensive, marked the highest prevalence within this group of states. In Lower-Middle ETLs, Sikkim had the highest prevalence (58.9% in men and 52.9% in women) and Tripura (36.3% in men and 36.7% in women) had the lowest prevalence of hypertension among diabetic population. In Low ETLs, Chhattisgarh recorded the highest hypertension prevalence along with diabetes in 45.9% of men and 46.7% women, while Bihar reported the lowest, at 33.5% in men and 35.1% in women (Table 4).

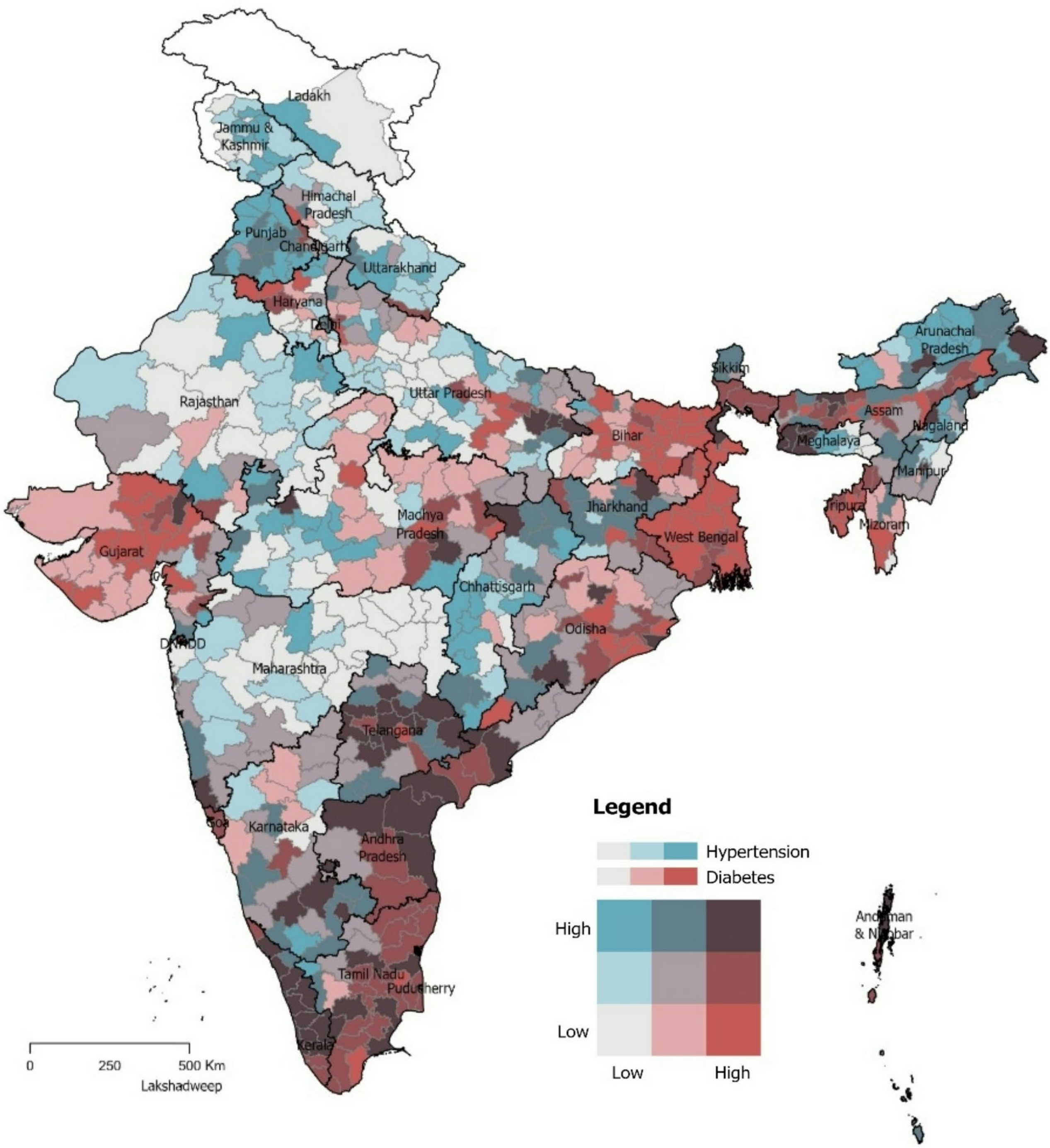

Fig. 3 Bivariate map showing the prevalence of hypertension and diabetes among men aged 30 and above, NFHS-5 (2019-21)

Diabetes in hypertension (DIH)

At the national level, 28.1% (95% CI: 27.75–28.37) of hypertensive men and 26.6% (95% CI: 26.33–26.93) of hypertensive women had diabetes. The Higher-Middle and High ETL groups exhibit prevalence rates of diabetes among hypertensives above the national average. Among hypertensive individuals, 16 States/UTs for men and 17 States/UTs for women recorded diabetes prevalence rates above the national average (Supplementary Table ST-3). The prevalence of diabetes among hypertensive individuals showed positive associations with higher income, educational attainment and increasing age, with urban populations exhibiting higher rates than their rural counterparts. In High ETLs, Kerala recorded the highest prevalence of diabetes among both men (42%) and women (40%) with hypertension. In Low ETLs, among

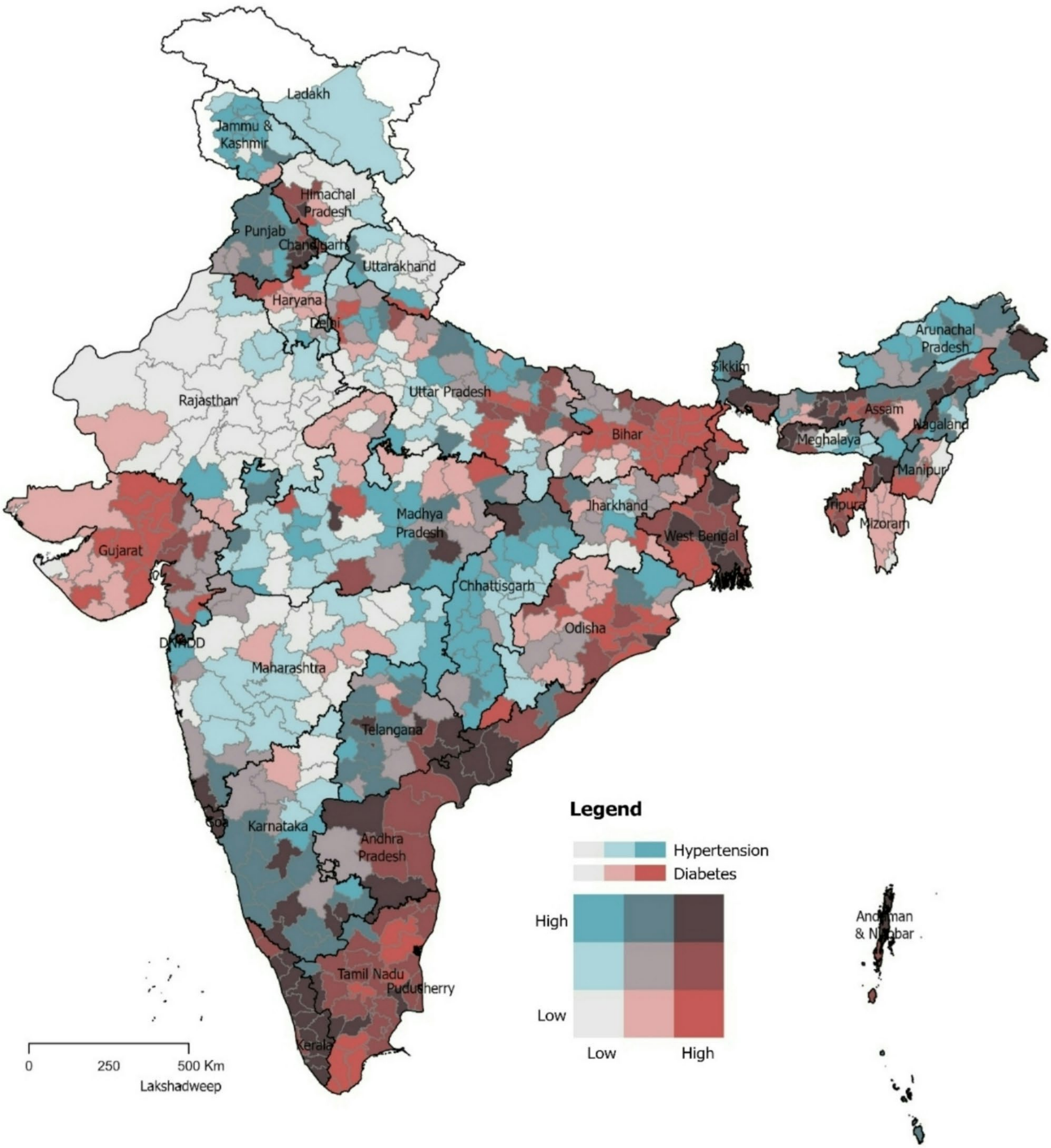

Fig. 4 Bivariate map showing the prevalence of hypertension and diabetes among women aged 30 and above, NFHS-5 (2019-21)

individuals with hypertension, Assam recorded the highest prevalence of diabetes among men (30%), while Bihar recorded the highest prevalence among women (27%) (Table 5).

Hotspots of the twin epidemic

Three significant hotspots were identified for men, while two significant hotspots were found for women in India regarding the prevalence of diabetes among hypertensive individuals (Figs. 5 and 6). The first hotspot, located in the southern part of the country, covered all districts of Kerala, Tamil Nadu, and Andhra Pradesh, along with

Table 3 Prevalence of diabetes among individuals aged 30 and above by socio-economic characteristics in the group of States as per the epidemiological transition level, India, 2019-21

Background Characteristics	Low ETL		Lower-middle ETL		Higher-middle ETL		High ETL		Total	
	%	95%CI	%	95%CI	%	95%CI	%	95%CI	%	95%CI
Men aged 30 and above										
Age-groups										
30–39	9.3	9.00-9.51	11.2	10.52–11.92	11.8	11.36–12.27	12.6	11.98–13.3	10.7	10.53–10.97
40–49	14.9	14.58–15.27	18.9	17.98–19.87	18.8	18.24–19.39	21.4	20.53–22.24	17.5	17.17–17.74
50–59	20.5	20.04–20.92	26.7	25.5-27.87	25.9	25.18–26.68	30.7	29.7–31.8	24.3	23.98–24.72
60–69	23.6	23.08–24.06	30.9	29.54–32.36	29.8	28.96–30.64	37.5	36.32–38.65	28.1	27.72–28.54
70+	25.6	24.88–26.23	33.5	31.61–35.45	29.5	28.44–30.61	36.3	34.84–37.74	29.1	28.52–29.6
Education										
Illiterate	16.5	16.17–16.83	21.9	20.72–23.03	21.1	20.5-21.73	24.2	23.06–25.4	19	18.68–19.27
Upto-8th	16	15.72–16.32	21.8	20.97–22.61	21.2	20.66–21.72	26.7	25.91–27.42	19.8	19.53–20.05
9th-above	17.8	17.46–18.06	20.6	19.83–21.3	20.3	19.85–20.77	25.3	24.67–25.93	20.1	19.83–20.3
Wealth quintile										
poorest	14.8	14.46–15.06	17.8	16.74–18.92	20	19.12–20.88	20.4	18.17–22.8	16.3	16-16.61
poorer	15.9	15.56–16.25	17.9	16.94–18.81	18.8	18.13–19.46	21.4	20.17–22.64	17.4	17.09–17.71
middle	16.8	16.42–17.26	21	20.01–22.04	19.5	18.96–20.12	24	23.07–24.95	19.2	18.9-19.54
richer	18.7	18.17–19.16	22.5	21.5-23.61	21.2	20.59–21.8	25.5	24.69–26.35	21.3	20.92–21.61
richest	20.3	19.78–20.89	23.7	22.62–24.89	23.5	22.84–24.28	28.6	27.81–29.37	23.7	23.28–24.04
Place of residence										
Urban	19	18.5-19.42	22.6	21.7-23.57	22.6	22.08–23.2	27.9	27.18–28.65	22.5	22.14–22.78
Rural	16.2	16.05–16.43	20.2	19.72–20.77	19.6	19.26–19.95	23.9	23.33–24.43	18.4	18.26–18.59
Total Men 30+	16.8	16.67–17.03	21.2	20.73–21.72	20.8	20.47–21.07	25.6	25.2–26.1	19.7	19.58–19.88
Women aged 30 and above										
Age-groups										
30–39	7	6.84–7.26	9.7	9.11–10.33	9.1	8.75–9.49	10.3	9.73–10.87	8.4	8.18–8.55
40–49	12.4	12.15–12.76	15.8	14.94–16.65	16.3	15.79–16.82	20	19.2-20.75	15.1	14.86–15.38
50–59	19.4	18.99–19.79	24	23-25.12	24.6	23.91–25.29	30.8	29.83–31.7	23.2	22.91–23.58
60–69	21.9	21.37–22.37	29.5	28.1-30.86	27.8	26.94–28.61	36.2	35.07–37.31	26.6	26.23–27.06
70+	22.6	21.96–23.35	29	27.26–30.8	27.8	26.74–28.92	33.8	32.41–35.18	26.9	26.31–27.41
Education										
Illiterate	14.8	14.61–15.03	20.4	19.76–21.16	19.6	19.23–20.04	25.1	24.3-25.84	17.5	17.3-17.68
Upto-8th	13.7	13.37–14.01	18.7	17.94–19.59	19.1	18.55–19.61	27	26.23–27.7	18.4	18.14–18.69
9th-above	13.3	12.88–13.66	16.6	15.73–17.43	15.4	14.82–15.89	20	19.4–20.6	15.9	15.59–16.16
Wealth quintile										
poorest	12.2	11.98–12.51	15.2	14.27–16.24	16.9	16.12–17.64	20.3	18.5-22.32	13.7	13.47-14
poorer	13.3	12.96–13.57	15.8	14.99–16.68	16.1	15.52–16.69	20.9	19.81–21.99	15	14.73–15.27
middle	14.9	14.53–15.29	18.2	17.29–19.12	17	16.53–17.58	22.3	21.45–23.15	17.1	16.8-17.39
richer	16.4	15.93–16.83	20.6	19.58–21.59	19.4	18.84–20.01	24.3	23.54–25.09	19.5	19.18–19.83
richest	17	16.51–17.52	21.4	20.37–22.44	20.9	20.23–21.55	25.5	24.77–26.15	20.8	20.47–21.17
Place of residence										
Urban	16.3	15.88–16.72	20.9	20.08–21.83	20.3	19.83–20.85	26.4	25.74–27.08	20.3	20.06–20.64
Rural	13.7	13.54–13.87	17.5	17.02–17.98	17	16.68–17.31	21.6	21.15–22.12	15.9	15.78–16.07
Total Women 30+	14.3	14.12–14.44	18.9	18.42–19.33	18.3	18.03–18.58	23.7	23.31–24.11	17.4	17.22–17.50

most parts of Karnataka except for the upper region of the state, and a few southern districts in Telangana. The second hotspot comprised all districts of West Bengal, Bihar, and Jharkhand excluding the western districts of these states. Moreover, the northeastern states of Sikkim, as well as the western parts of Assam and Meghalaya, along with the southern part of Tripura, constituted the second hotspot for the prevalence of diabetes among hypertensive men and women. The third hotspot for men included the western districts of Gujarat.

In the case of the prevalence of hypertension among the diabetic population for both men and women, three significant hotspots were identified (Figs. 7 and 8). The first hotspot, similar to that observed for diabetes among hypertensive individuals included the southern states of India with the addition of more districts from Telangana.

Table 4 Prevalence of hypertension among individuals aged 30 & above who have diabetes, by socio-economic characteristics in the group of States as per the epidemiological transition level, India, 2019-21

Background Characteristics	Low ETL		Lower-middle ETL		Higher-middle ETL		High ETL		Total	
	%	95%CI	%	95%CI	%	95%CI	%	95%CI	%	95%CI
Men aged 30 and above										
Age-groups										
30–39	26.5	25.27–27.87	23.3	20.75–26.02	28.3	26.46–30.18	35.1	32.47–37.83	28.2	27.18–29.19
40–49	34.2	33.05–35.45	34.8	32.23–37.47	38.7	37.03–40.35	44	41.73–46.21	37.5	36.65–38.43
50–59	40.6	39.45–41.83	38.4	35.96–40.97	44.8	43.08–46.47	50.5	48.53–52.51	43.8	42.93–44.69
60–69	44.8	43.64–46.03	45.6	42.8-48.34	53	51.3-54.71	59	56.99–60.89	50.5	49.61–51.37
70+	49.9	48.34–51.4	49.8	46.15–53.4	57.5	55.35–59.72	62.9	60.49–65.32	55.1	53.95–56.16
Education										
Illiterate	36.1	35.01–37.12	35.1	32.29–38.01	40.6	38.94–42.2	50	47.24–52.73	39.1	38.25–39.97
Upto-8th	38	37.05–39.04	36.3	34.28–38.36	43.9	42.47–45.3	52	50.4-53.69	42.8	42.03–43.5
9th-above	42.4	41.47–43.32	41	39.08–43.01	45.9	44.64–47.18	51.3	49.84–52.69	45.3	44.64–45.97
Wealth quintile										
poorest	32.2	31.16–33.21	33.8	30.65–37.12	31.8	29.55–34.24	44.7	38.58–50.93	32.5	31.56–33.52
poorer	35.7	34.57–36.86	33.1	30.57–35.83	36.4	34.54–38.34	43.6	40.37–46.81	36.5	35.56–37.46
middle	38.5	37.18–39.82	36.2	33.71–38.83	41.6	39.96–43.25	46.6	44.39–48.84	41	40.11–41.96
richer	44.3	42.83–45.73	38.7	36.17–41.28	47.6	46-49.26	50.7	48.81–52.54	46.6	45.67–47.51
richest	49.5	48.01–51.08	42.9	40.19–45.58	52.9	51.12–54.66	56.7	55.09–58.29	52	51.12–52.97
Place of residence										
Urban	46.3	44.93–47.63	40.2	37.89–42.46	50.1	48.65–51.47	52.6	51.06–54.17	48.8	47.95–49.57
Rural	37	36.39–37.61	36.8	35.37–38.18	39.7	38.77–40.7	50.3	49-51.58	39.8	39.32–40.29
Total Men 30+	39.3	38.76–39.91	38.3	36.99–39.54	44.1	43.23–44.88	51.4	50.4–52.4	43.1	42.67–43.53
Women aged 30 and above										
Age-groups										
30–39	19.9	18.67–21.18	16.7	14.53–19.08	21.3	19.62–23.14	20.5	18.27–22.9	20.3	19.39–21.24
40–49	31.3	30.06–32.49	30.1	27.55–32.87	37.3	35.61–38.99	35.3	33.29–37.36	34.3	33.41–35.2
50–59	41.5	40.32–42.59	42.1	39.6-44.69	49.4	47.79–51.06	49	47.16–50.8	45.9	45.06–46.72
60–69	50.7	49.41–52.01	50.5	47.65–53.38	60.4	58.64–62.21	63.3	61.46–65.16	56.9	55.98–57.81
70+	54.2	52.46–55.97	55	51.26–58.62	62.4	60.15–64.69	71.5	69.27–73.66	61.1	59.88–62.22
Education										
Illiterate	39.8	39.02–40.54	39.9	38.03–41.83	49.3	48.18–50.5	53	51.28–54.76	44.7	44.09–45.29
Upto-8th	40.2	38.92–41.41	38.6	36.24–41.03	45.3	43.73–46.83	52.1	50.44–53.67	45.1	44.24–45.9
9th-above	36.7	35.2-38.29	39.1	36.4-41.93	41.5	39.69–43.41	43.6	41.96–45.28	40.7	39.77–41.69
Wealth quintile										
poorest	33.5	32.46–34.63	34.7	31.38–38.09	38.1	35.69–40.58	44.3	39.32–49.39	35.4	34.41–36.45
poorer	36.4	35.18–37.59	34	31.25–36.8	41.4	39.42–43.36	43.6	40.7-46.45	38.8	37.86–39.81
middle	39.2	37.86–40.58	36.1	33.46–38.75	44.3	42.64–46.01	44.8	42.65–46.92	42.1	41.21–43.08
richer	44.1	42.61–45.63	40.1	37.42–42.8	49.1	47.44–50.81	49.2	47.38–51.04	47.1	46.13–48.01
richest	47.1	45.43–48.69	44.4	41.75–47.16	51.7	49.86–53.44	54.4	52.83–56.01	50.6	49.7-51.59
Place of residence										
Urban	45.1	43.66–46.47	43.4	41.09–45.74	51.2	49.76–52.57	50.4	48.94–51.92	48.9	48.06–49.67
Rural	37.5	36.84–38.12	36	34.6-37.51	42.5	41.49–43.51	48.6	47.33–49.83	40.9	40.39–41.38
Total Women 30+	39.4	38.8-39.99	39.3	37.99–40.61	46.3	45.44–47.12	49.5	48.51–50.44	43.9	43.48–44.36

The second hotspot was located in the northern states of India, including the districts of Ladakh, Jammu & Kashmir, Himachal Pradesh, Chandigarh, as well as the upper regions of Uttarakhand and Rajasthan. The third hotspot was identified in the northeastern states of Arunachal Pradesh, Nagaland, the eastern part of Assam and the northern part of Manipur.

Adjusted risk ratio (ARRs)

At the national level, individuals aged 30 and above with diabetes revealed an increased risk of hypertension, with the adjusted risk at 39% (ARR: 1.39, 95% CI: 1.38–1.40) and 41% (ARR: 1.41, 95% CI: 1.39–1.42), respectively for men and women. Among men, the lowest ARR for hypertension among those with diabetes was observed in the lower-middle ETLs, while the highest ARR was

Table 5 Prevalence of diabetes among individuals aged 30 & above who have hypertension, by socio-economic characteristics in the group of States as per the epidemiological transition level, India, 2019-21

Background Characteristics	Low ETL		Lower-middle ETL		Higher-middle ETL		High ETL		Total	
	%	95%CI	%	95%CI	%	95%CI	%	95%CI	%	95%CI
Men aged 30 and above										
Age-groups										
30–39	14.2	13.44–14.94	15	13.32–16.8	17.7	16.48–18.93	19.3	17.7-21.04	16.3	15.69–16.94
40–49	20.8	20.02–21.6	25.7	23.71–27.74	26	24.82–27.24	28	26.42–29.68	24.2	23.63–24.88
50–59	26.5	25.62–27.33	32.5	30.41–34.62	32.3	31.05–33.63	36.3	34.56–38.03	30.8	30.11–31.45
60–69	29	28.1-29.83	35.5	33.28–37.86	36.1	34.76–37.45	43.7	42-45.34	34.5	33.82–35.19
70+	30.3	29.23–31.44	36.7	33.81–39.71	34.1	32.5-35.77	40.9	38.95–42.96	34	33.18–34.87
Education										
Illiterate	22.3	21.61–23.04	28.2	25.85–30.6	27.1	25.93–28.32	29.4	27.52–31.36	25.1	24.54–25.76
Upto-8th	22.5	21.9-23.21	28.4	26.82–30.11	30	28.96–31.08	35.2	33.87–36.5	28	27.46–28.53
9th-above	26.4	25.78–27.08	29.4	27.89–30.86	29.8	28.93–30.76	35.3	34.15–36.49	29.5	29.05–30.02
Wealth quintile										
poorest	19.8	19.15–20.51	23.5	21.19–25.98	26.3	24.33–28.29	27.7	23.5-32.35	21.8	21.12–22.51
poorer	22.5	21.75–23.32	23.2	21.39–25.18	25.3	23.96–26.75	27.4	25.13–29.86	24	23.33–24.67
middle	23.5	22.58–24.36	27	25.06–28.97	27.3	26.1-28.46	31.9	30.15–33.69	26.6	25.99–27.32
richer	26.6	25.66–27.63	30.8	28.76–32.9	30.3	29.08–31.45	34.2	32.65–35.68	30	29.34–30.69
richest	29.7	28.67–30.81	33.2	31.03–35.44	33.3	32.08–34.6	38.1	36.83–39.39	33.5	32.8-34.16
Place of residence										
Urban	28	27.12–28.98	32	30.14–33.9	32.9	31.8-33.93	37.4	36.15–38.69	32.4	31.77-33
Rural	22.7	22.33–23.16	26.6	25.55–27.68	26.7	26-27.36	32	30.97–32.97	25.6	25.27–25.95
Total Men 30+	24.1	23.7-24.48	28.8	27.85–29.85	29.3	28.7–29.9	34.4	33.62–35.22	28.1	27.75–28.37
Women aged 30 and above										
Age-groups										
30–39	11.4	10.65–12.16	13.7	11.94–15.7	15.5	14.19–16.83	16.8	14.92–18.78	13.7	13.05–14.34
40–49	17.9	17.12–18.62	21.3	19.44–23.35	23.2	22.08–24.35	27.4	25.84–29.1	21.6	21.03–22.24
50–59	24.8	24.09–25.62	29.5	27.63–31.54	30.5	29.35–31.69	37.3	35.75–38.79	29.4	28.81–30.02
60–69	27.3	26.46–28.14	33.1	30.94–35.23	33.5	32.33–34.78	42	40.43–43.58	32.7	32.04–33.34
70+	26.3	25.21–27.36	31.6	29.1-34.18	30.9	29.41–32.39	38.1	36.35–39.98	30.8	30.02–31.6
Education										
Illiterate	21.4	20.97–21.9	26.5	25.14–27.88	27	26.26–27.79	31.5	30.17–32.78	24.8	24.41–25.19
Upto-8th	22.7	21.93–23.54	27.2	25.42–28.98	29.2	28.06–30.27	38	36.72–39.27	29	28.38–29.57
9th-above	23.4	22.39–24.54	27.8	25.67–29.98	27.3	25.99–28.65	34.1	32.72–35.48	28	27.3-28.73
Wealth quintile										
poorest	18.1	17.46–18.74	20.7	18.62-23	22.8	21.17–24.42	27.1	23.58–30.87	19.9	19.25–20.52
poorer	20	19.28–20.75	21.5	19.66–23.44	23.8	22.53–25.08	29.4	27.15–31.74	22.4	21.75–23.01
middle	22.3	21.42–23.16	24.3	22.47–26.29	25.4	24.28–26.49	31.4	29.81–33.14	25.2	24.61–25.87
richer	25.5	24.55–26.56	29.1	27.06–31.23	30	28.79–31.13	35.8	34.35–37.29	29.9	29.19–30.53
richest	26.9	25.79–27.94	32.2	30.08–34.34	32.5	31.18–33.75	38.1	36.82–39.3	32.3	31.65–33.02
Place of residence										
Urban	26.1	25.22–27.09	31.7	29.93–33.59	32	30.96–33.01	38.2	36.96–39.41	31.7	31.13–32.33
Rural	20.7	20.3-21.09	23.6	22.6-24.66	24.7	24.01–25.31	31.9	30.96–32.87	23.8	23.51–24.15
Total Women 30+	22	21.64–22.4	27	26.02–27.97	27.7	27.14–28.29	34.7	33.96–35.5	26.6	26.33–26.93

recorded in the higher-middle ETLs. Conversely, for women, the risk of hypertension followed a similar trend. Similarly, at the national level, the risk of diabetes among men who were hypertensive was 51% (ARR: 1.51, 95% CI 1.49–1.52), while among women, it was 55% (ARR: 1.55, 95% CI 1.53–1.57). The lowest risk of diabetes among men and women who were hypertensive was observed in lower-middle ETLs, while the highest ARR was observed in the higher-middle ETLs (Table 6, 7).

Discussion

To the best of our knowledge, this study is the first to provide empirical estimates of the prevalence and coexistence of diabetes and hypertension using nationally representative, individual-level biomarker data on blood

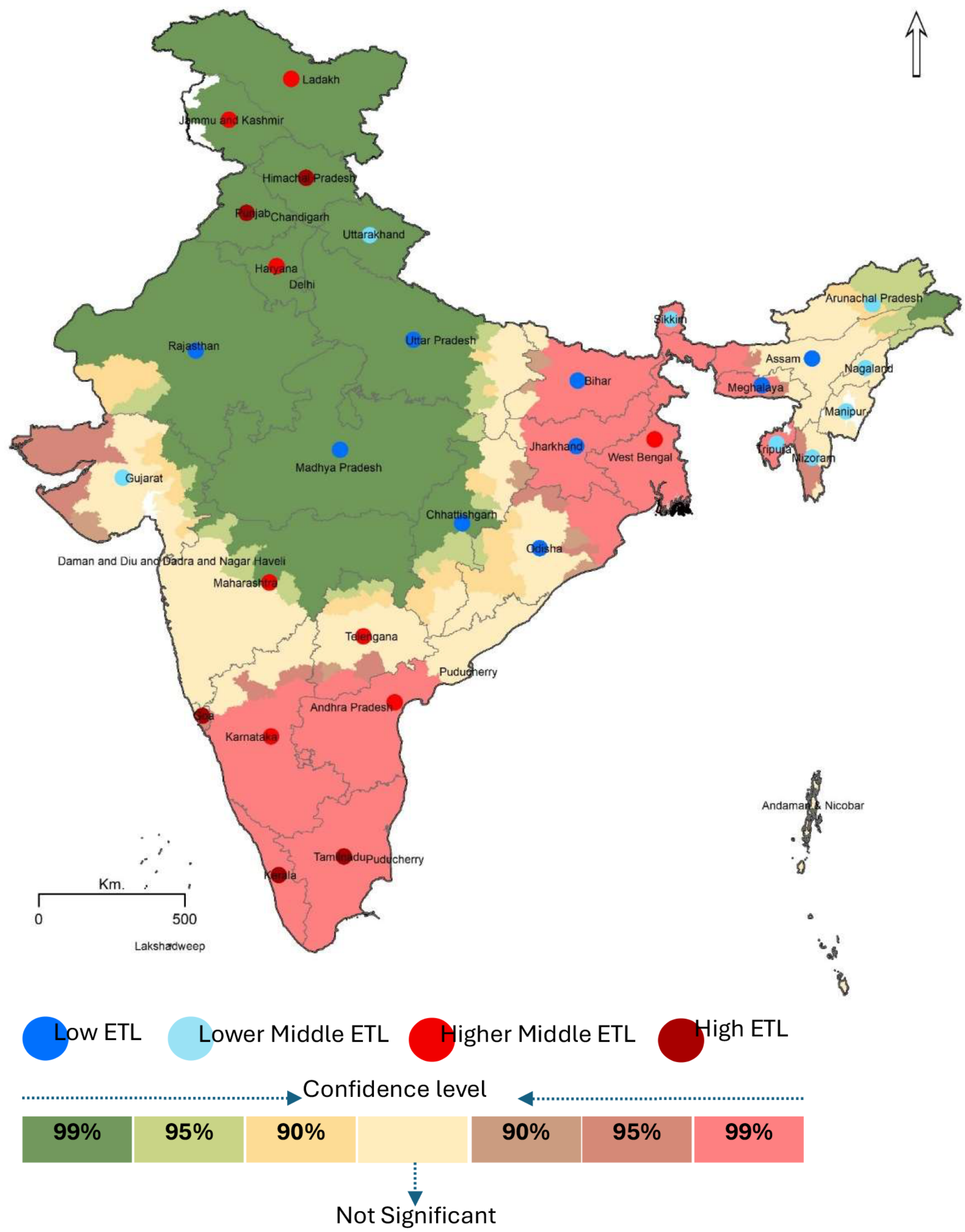

Fig. 5 Hot spots and cold spots of diabetes among men aged 30 and above who had hypertension, India, NFHS-5 (2029-21)

pressure and blood glucose from the fifth round of the NFHS in India. We present a sex-stratified analysis of the twin epidemics at the population level across Indian states, categorised by ETL state group [37]. A sex-disaggregated approach was adopted, recognising that the risk factors for hypertension and diabetes differ between men and women due to variations in socioeconomic status, behavioural patterns, and biological factors [22].

Our study revealed that among individuals aged 30 years and above, the mean age of individuals with hypertension was 54 years for men and 55 years for women, while the mean age for diabetes was 54 years for both sexes. These findings are consistent with those reported by Varghese et al. [40] for hypertension (based on participants aged 18–98 years) and by Uma et al. [41]for diabetes (among individuals aged 41 years and above). Our findings showed a clear age gradient in the prevalence of hypertension and diabetes, with affected individuals being, on average, nearly a decade older than those without these conditions. This finding highlights the progressive nature of both diseases and the heightened risk of onset with advancing age. Furthermore, the

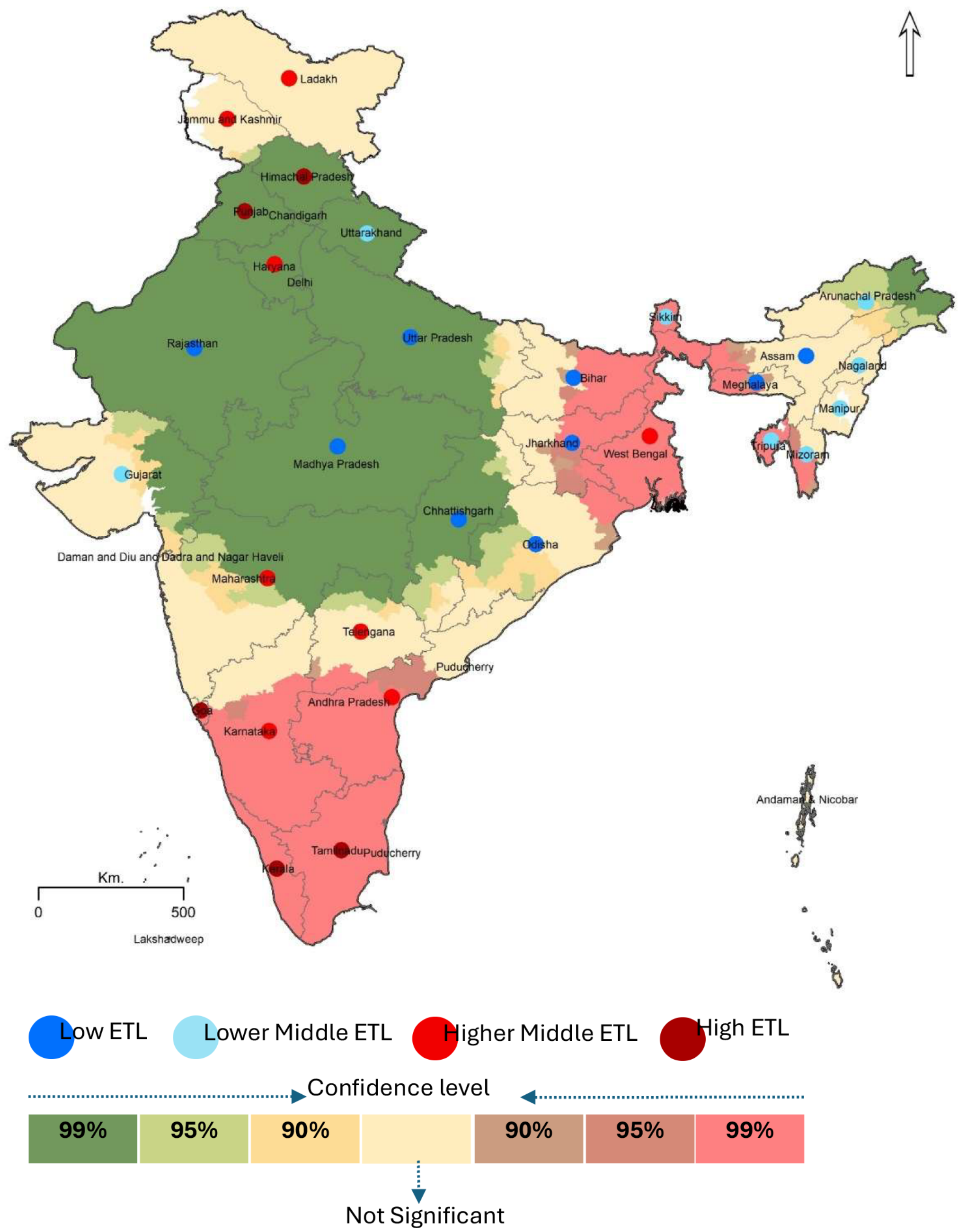

Fig. 6 Hot spots and cold spots of diabetes among women aged 30 and above who had hypertension, India, NFHS-5 (2029-21)

close alignment between mean and median ages indicates minimal skewness in the age distribution, suggesting that the burden is broadly distributed across older adults and not disproportionately driven by a small number of very elderly cases. The analysis revealed that the overall age-standardized prevalence of hypertension in India was particularly higher compared to the prevalence of diabetes at the population level. Similar patterns were observed in other low and middle-income countries such as Bangladesh [34], Nepal [42], Pakistan [43] and Sri Lanka [44]. Further, the prevalence of hypertension and diabetes was higher in urban areas as compared to rural areas and shows a gradually increase with age, level of education, and rising income across the groups of ETL states. The increasing trend of both risk factors across the selected socioeconomic and demographic gradient has been observed in several studies on the socioeconomic gradient scale, for example, research indicated that diabetes and hypertension were somewhat common in India [23, 29, 45]. According to a WHO-ICMR Indian NCD risk factor surveillance research, the highest prevalence of diabetes and hypertension was found in urban regions,

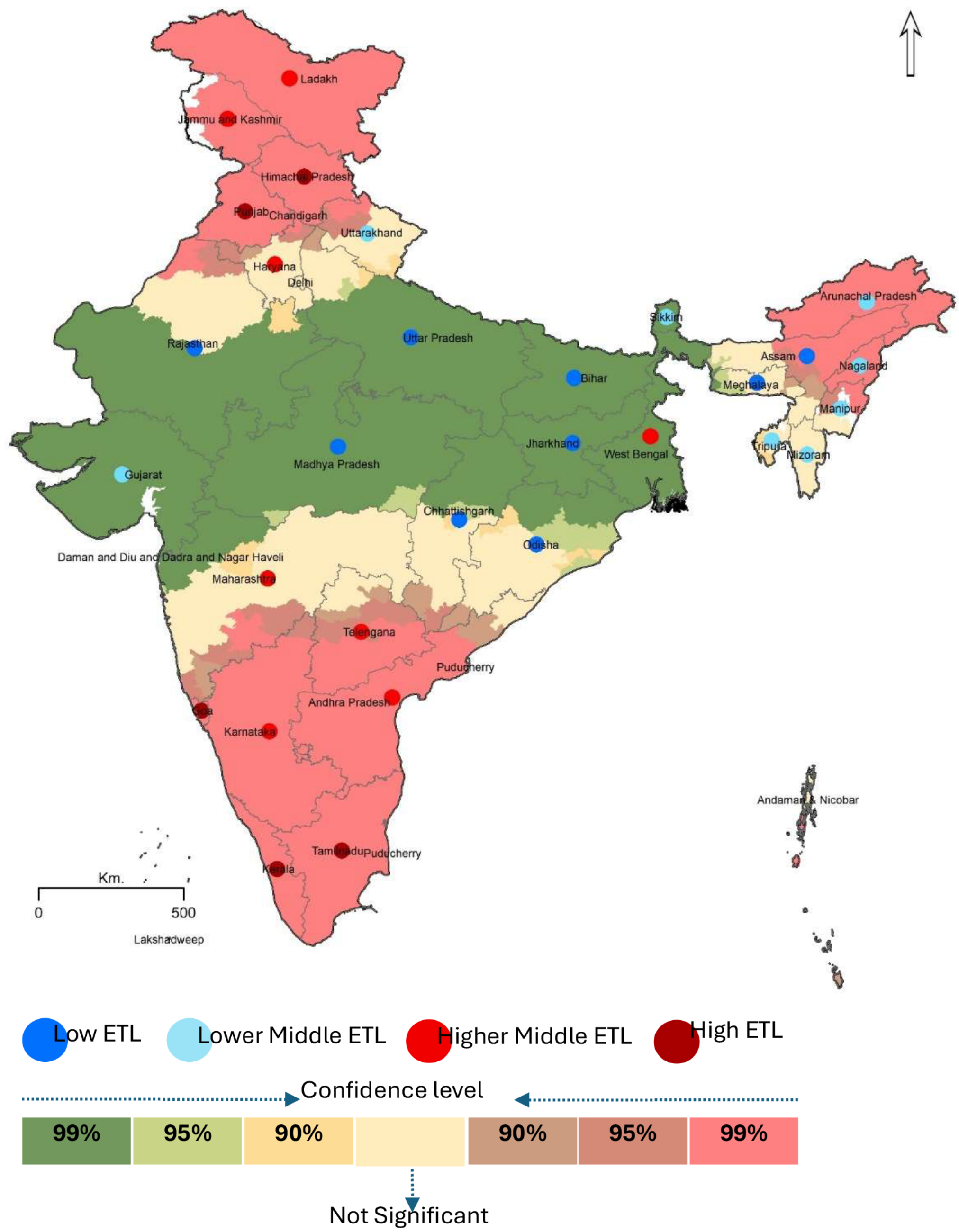

Fig. 7 Hot spots and cold spots of hypertension among men aged 30 and above who had diabetes, India, NFHS-5 (2029-21)

followed by peri-urban/slum areas, which had an intermediate prevalence, and rural areas, which had the lowest prevalence [46]. The results also support the findings of the India State-Level Disease Burden Initiative [37], which found that NCD prevalence increased significantly in India between 1990 and 2016, with states with advanced epidemiological transition bearing a disproportionately higher burden.

Regional variations in the prevalence of hypertension, diabetes and their coexistence reveal a distinct pattern, with the lowest prevalence observed in regions classified as the lowest ETLs and the highest prevalence in regions categorized as the highest ETLs. The hotspot analysis further reveals significant regional disparities, with the southern region emerging as a prominent hotspot for the prevalence of both hypertension among the diabetic population and diabetes among the hypertensive population. These states exhibit a high prevalence of both hypertension and diabetes, which aligns with findings from previous studies [23, 35, 47]. Moreover, these states are characterized by high levels of smoking and alcohol consumption [48] as well as a transition from communicable

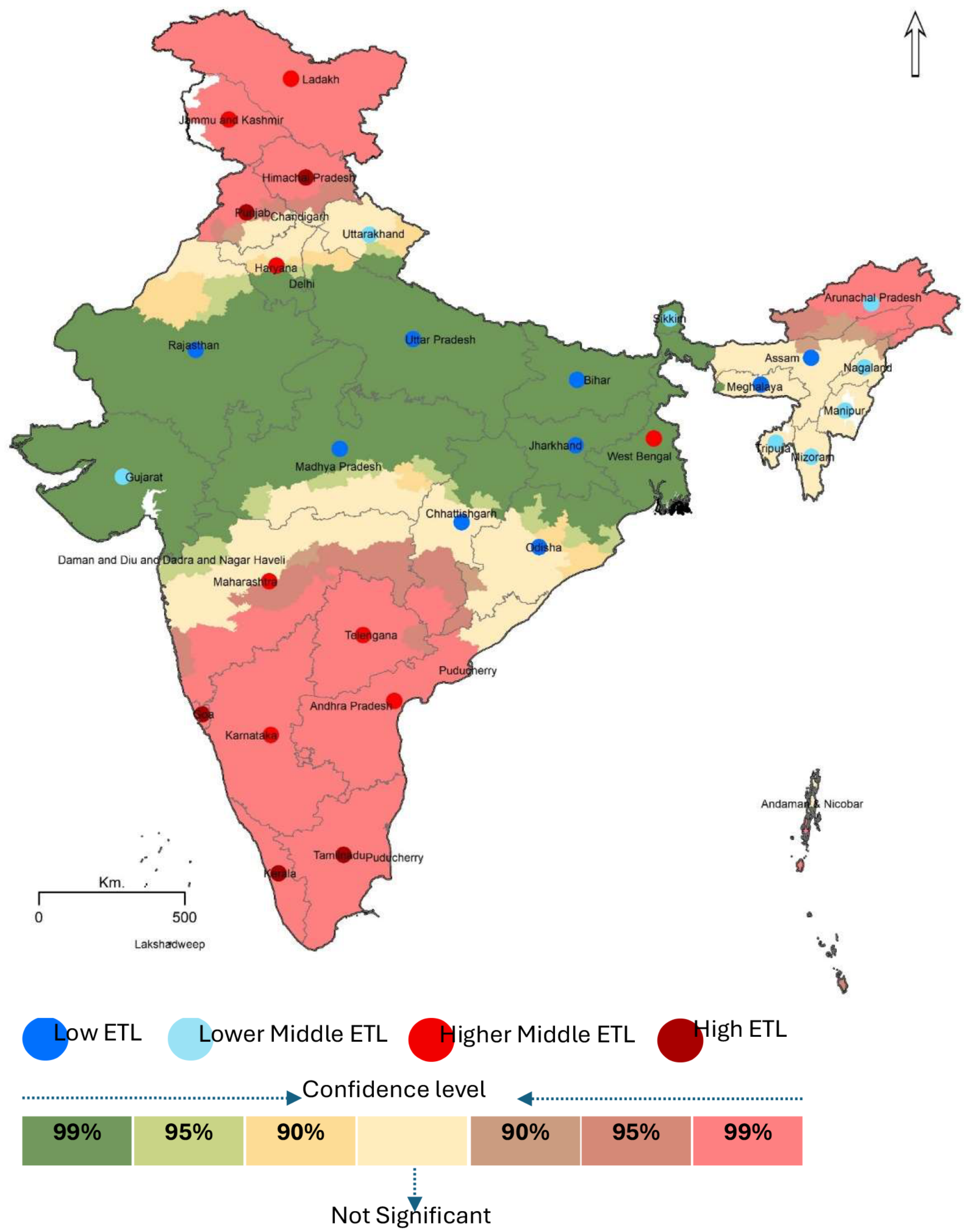

Fig. 8 Hot spots and cold spots of hypertension among women aged 30 and above who had diabetes, India, NFHS-5 (2029-21)

diseases to NCDs [37], which could be major contributing factors to their high prevalence of hypertension and diabetes. Another contributing factor to the high prevalence of diabetes is persistent high temperature [49, 50], which negatively affects the glucose metabolism through suppressing the brown adipose tissue activity [51]. The second hotspot for the prevalence of diabetes among the hypertensive population was primarily concentrated in the districts of West Bengal, Jharkhand, and Bihar, findings that are supported by a study conducted in major populous states of India by Joshi et al. [23]. Furthermore, two hotspots for hypertension among individuals with diabetes were identified in the states/UTs of Ladakh, Jammu & Kashmir, Himachal Pradesh, and Punjab from the northern region, and Arunachal Pradesh, Nagaland and Assam from the northeastern region of the country. The considerable prevalence of alcohol consumption [39, 48] in northern states such as Ladakh, Jammu & Kashmir, Punjab and Himachal Pradesh, coupled with high levels of smoking and smokeless tobacco could be the major reason for the high prevalence of hypertension in these hotspots. Another contributing factor to the high

Table 6 Adjusted risk-ratio for hypertension among individuals aged 30 & above who have diabetes by group of States as per the epidemiological transition level, India, 2019-21

ETL- States Groups	Men aged 30 & above		Women aged 30 & above	
	ARR	95%CI	ARR	95%CI
Low ETL group	1.39	1.37–1.41	1.40	1.38–1.43
Lower-middle ETL	1.31	1.28–1.34	1.33	1.30–1.36
Higher-middle ETL group	1.43	1.41–1.45	1.43	1.41–1.45
High ETL group	1.35	1.32–1.37	1.38	1.35–1.41
India	1.39	1.38–1.40	1.41	1.39–1.42

Note: All estimates are significant and adjusted with age, education, religion, social groups, wealth quintiles and place of residence

Table 7 Adjusted risk-ratio for diabetes among individuals aged 30 & above who have hypertension by group of States as per the epidemiological transition level, India, 2019-21

ETL- States Groups	Men aged 30 & above		Women aged 30 & above	
	ARR	95%CI	ARR	95%CI
Low ETL group	1.49	1.46–1.52	1.53	1.50–1.56
Lower-middle ETL	1.40	1.36–1.44	1.42	1.38–1.47
Higher-middle ETL group	1.58	1.54–1.61	1.62	1.58–1.66
High ETL group	1.47	1.43–1.52	1.53	1.48–1.57
India	1.51	1.49–1.52	1.55	1.53–1.57

Note: All estimates are significant and adjusted with age, education, religion, social groups, wealth quintiles and place of residence

prevalence of hypertension could be the elevated topography in states/UTs such as Ladakh, Jammu & Kashmir, Himachal Pradesh, and Arunachal Pradesh, as reported in a study conducted in high-altitude regions [52].

A notable strength of this study lies in its ability to provide detailed disaggregated data on the prevalence of hypertension and diabetes by state- and individual-level sociodemographic characteristics. This enables a nuanced understanding of the twin epidemics in their co-existing forms, at a granular level. The higher prevalence of diabetes and hypertension in urban areas and among higher socioeconomic groups may be attributed to lifestyle-related risk factors such as unhealthy diets, physical inactivity, and increased stress levels [21, 53]. Urban populations also tend to have better access to screening and diagnosis, contributing to higher detection rates [24]. Conversely, underdiagnosis in rural and lower-income populations may lead to an underestimation of the true prevalence [53].

Hypertension and diabetes are both components of metabolic syndrome and frequently coexist. This could be attributed to shared risk factors or the damaging effects of elevated blood sugar levels on cells within the cardiovascular system [10, 23, 33, 54]. Our findings also indicate that at the national level, 43% of diabetic men and 44% of diabetic women were hypertensive. According to a study done to determine the prevalence of hypertension in patients with type 2 diabetes who had just received a diagnosis, 39% of the patients had hypertension at the time of their diabetes diagnosis [46]. About 60% of 5427 patients with a diagnosis of diabetes also had concomitant hypertension, according to the Screening India's Twin Epidemic research (SITE), which looked at the incidence of both conditions in the seven most populated Indian states. According to estimates of the prevalence of hypertension in people with diabetes mellitus, which range from 40 to 80%, hypertension is more common in these persons than in the general population, according to another study [23]. These findings may be attributed to high blood glucose levels, which can result in widespread damage to tissues and organs, including those crucial for maintaining healthy blood pressure. For instance, damage to blood vessels and kidneys can lead to an increase in blood pressure [54].

Similarly, the prevalence of diabetes among hypertensive populations showed that 28% of men and 27% of women had diabetes at the time of the survey. The prevalence of diabetes was similar to that reported in a cross-sectional study on hypertensive outpatients in China [55]. Again, the observations of the SITE study conducted in seven Indian states reported that out of 7212 study patients with hypertension, diabetes coexisted in 44.7%. Additionally, in a large prospective cohort study by Lip et al., involving 12,550 adults, the onset of type 2 diabetes was nearly 2.5 times more likely in patients with hypertension than in their normotensive counterparts [56]. Another study conducted in China found that high prevalence of diabetes mellitus accounted for 24% among outpatients with hypertension [55]. This finding could be attributed to individuals with high blood pressure typically having insulin resistance, which increases their risk of diabetes. Our results further corroborate the strong and convincing evidence that a high prevalence of diabetes can raise the risk of hypertension and vice versa. This result is in line with a previous study that found that people with diabetes mellitus have a higher risk of developing hypertension, with the incidence of hypertension in DM patients being twice as high as in people of the same age without DM [57]. A study on blood pressure control in diabetes from an Indian perspective found that individuals with diabetes are 1.5 to 2 times more likely to develop hypertension compared to those without diabetes. Likewise, approximately one-third of individuals with hypertension go on to develop diabetes over time [45]. In a different areas of research people in the Karnataka area of Mysore, it was found that people with hypertension had a far higher chance of getting diabetes than people with normotension [17]. Additionally, it was discovered that women were more likely than males to have both diabetes and hypertension in both situations, the risk of hypertension among people with diabetes and the risk of diabetes among people with hypertension. The total prevalence of diabetes mellitus among hypertensive patients was 32.0%, with rates of 29.6% for men and 33.5% for women, according to a cross-sectional study done on patients in southwest China between the ages of 40 and 79 [58]. Diabetes mellitus at baseline was a significant predictor of incident hypertension, regardless of sex, age, body mass index, and family history of diabetes mellitus, according to another study [20] that used the cohort data to examine the co-prediction and time trajectories for hypertension and diabetes. On the other hand, incidence diabetes mellitus was independently predicted by baseline hypertension [20].

According to epidemiological research, diabetes and hypertension have similar risk factors and linked pathophysiological pathways, creating a network that could potentially result in a vicious cycle [57]. Consequently, diabetes mellitus and hypertension are prone to comorbidity and are essential elements of the metabolic syndrome [59]. When diabetes and hypertension coexist, the risk is raised, and the start of vascular problems is accelerated. The risk of cardiovascular disease is increased by 75% when diabetes and hypertension coexist, which further raises total rates of morbidity and death [60]. Additionally, individuals with hypertension who also have diabetes mellitus have a more than twofold increased risk of stroke; in contrast, patients with HTN and DM who have lower blood pressure (BP) have a 44% lower risk of stroke. According to a different study, individuals with diabetes have greater baseline heart rates, more isolated systolic hypertension, and less nocturnal blood pressure lowering because of autonomic neuropathy [57]. Because the goal blood pressure (BP) is usually low and the response to treatment is frequently insufficient, managing BP in these individuals is a considerable problem [61]. Therefore, it is imperative to improve diabetes mellitus screening among hypertensive patients, especially among younger patients or those with lower incomes in certain geographic areas. Treating the twinned diseases as a separate priority category due to heightened risk of complications. Annual screening for complications to prevent adverse events. Further research could point to the need for a more effective drug regimen to control both the diseases together than each separately and the role played by the twinned diseases in adverse events and preventive interventions to mitigate the risk.

The strength of the study lies in its uniform operational definition of hypertension and diabetes in large and nationally representative sample. By investigating the interplay between hypertension and diabetes across states based on the ETLs, the study provides valuable, context-specific insights for future decision-making aimed at addressing the dual burden of diabetes and hypertension as a unified entity. However, the study has few limitations. First, hypertensive subjects were defined as those with an average of three blood pressure readings on one occasion, while raised blood pressure readings on at least two occasions are usually necessary for a clinical diagnosis of hypertension [62]. Second, it is not advised to diagnose diabetes in clinical settings using a single capillary blood glucose measurement. However, this method has been demonstrated to have enough sensitivity and specificity for diagnosing diabetes in population-based research, which is why the WHO's STEP-wise Approach to NCD Risk Factor Surveillance suggests it for monitoring diabetes prevalence [62]. Third, the study could not distinguish between type 1 and type 2 diabetes. Fourth, the study was unable to consider information on waist-hip ratio and body mass index as this data was only available for women aged 15–49 years and men aged 15–54 years in the NFHS-5 dataset [21]. Finally, hypertension and diabetes can also result from the side effects of certain medications, these factors were not addressed in this study.

Conclusions

The observed age gradients in hypertension and diabetes prevalence highlight the urgent need for early detection, especially among individuals approaching midlife. Public health interventions should integrate age-specific strategies, such as prioritised CBAC (Community-Based Assessment Checklist) screenings for individuals over 30, to pre-empt disease onset and mitigate long-term complications. Combining and analyzing the differences between diabetes and hypertension in each state according to the ETL offers important, context-specific evidence for developing future decision-making plans to deal with the dual burden of diabetes and hypertension as a single condition. To determine the prevalence of twin epidemics, analyzing the success of earlier efforts, and directing the creation of focused strategies, this study offers a reliable instrument. With an emphasis on early intervention based on the most recent research, we highlight the importance of population-specific interventions and policies in order to avert serious problems. Services for prevention, screening, and treatment must be adapted to the unique requirements of various locations and situations, taking into account the common risk factors and pathways that lead to the development of both diabetes and hypertension. Future research should explore the shared risk factors, disease progression pathways, and regional disparities in the coexistence of hypertension and diabetes to inform the development of integrated, context-specific interventions at the primary care level. Longitudinal studies are essential to assess the long-term effectiveness of early intervention models and to refine prevention, screening, and treatment strategies in response to India's rapidly evolving epidemiological landscape.

India must prioritise diabetes and hypertension as critical national public health challenges. As principal drivers of cardiovascular disease, their escalating burden-transcending socioeconomic and geographic boundaries-necessitates sustained action. With India accounting for a substantial share of the global prevalence, nuanced understanding of the distribution and coexistence of these conditions is critical to inform targeted prevention, early detection, and long-term control strategies. Strengthening primary healthcare systems remains critical to mitigate their far-reaching health and economic consequences. Progress towards SDG Target 3.4-reducing premature mortality from non-communicable diseases by one-third by 2030-will depend on India's capacity to confront these twin epidemics within the context of its rapid epidemiological transition.

Supplementary Information

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Supplementary Material 1

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Author contributions

NKS and SKS jointly conceptualized and designed the study and are co-first authors. SKS and RB were responsible for data extraction, statistical analysis, and interpretation, while NKS conducted the geospatial analysis. RPSG, PJ, RRP, PC, and NY performed the literature review and contributed to drafting the initial manuscript. RB, PJ, PC, and NKS critically revised the manuscript. PJ, NS, and RS provided valuable intellectual inputs. All authors approved the final manuscript, and NKS had primary responsibility for the final content.

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Data availability

Data utilized in this study is publicly available from DHS upon request and filing the registration. DHS data are available on https://dhsprogram.com/data/available-datasets.cfm.

Declarations

Ethics approval and consent to participate

Ethical approval for this study was not needed. The study used only anonymised data from secondary sources. All methods were carried out following relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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References

1. Global Health Metrics. (2019) non-communicable-diseases. Lancet 396. https://www.thelancet.com/pb-assets/Lancet/gbd/summaries/diseases/non-communicable-diseases.pdf
2. Shu J, Jin W. Prioritizing non-communicable diseases in the post-pandemic era based on a comprehensive analysis of the GBD 2019 from 1990 to 2019. Sci Rep. 2023. https://doi.org/10.1038/s41598-023-40595-7.
3. WHO. (2024) Noncommunicable diseases. https://www.who.int/health-topics/noncommunicable-diseases#tab=tab_1. Accessed 1 Apr 2025.
4. Mamgai A, Halder P, Behera A, Goel K, Pal S, Amudhamozhi KS, Sharma D, Kiran T. Cardiovascular risk assessment using non-laboratory based WHO CVD risk prediction chart with respect to hypertension status among older Indian adults: insights from nationally representative survey. Front Public Health. 2024. https://doi.org/10.3389/fpubh.2024.1407918.
5. Halder P, Jeer G, Nongkynrih B. Risk assessment of type 2 diabetes mellitus using Indian diabetes risk score among females aged 30 years and above in urban Delhi. Indian J Med Sci. 2023;75:136–43.
6. Singh Thakur J, Nangia R, Singh S. Progress and challenges in achieving noncommunicable diseases targets for the sustainable development goals. FASEB Bioadv. 2021;3:563–8.
7. Zhou B, Perel P, Mensah GA, Ezzati M. Global epidemiology, health burden and effective interventions for elevated blood pressure and hypertension. Nat Rev Cardiol. 2021;18:785–802.
8. Francis A, Harhay MN, Ong ACM, et al. Chronic kidney disease and the global public health agenda: an international consensus. Nat Rev Nephrol. 2024;20:473–85.
9. Ulasi II, Awobusuyi O, Nayak S et al. (2022) Chronic kidney disease burden in Low-Resource settings: regional perspectives. Semin Nephrol. https://doi.org/10.1016/j.semnephrol.2023.151336
10. Zhou B, Carrillo-Larco RM, Danaei G, et al. Worldwide trends in hypertension prevalence and progress in treatment and control from 1990 to 2019: a pooled analysis of 1201 population-representative studies with 104 million participants. Lancet. 2021;398:957–80.
11. Prabhakaran D, Jeemon P, Roy A. Cardiovascular diseases in India: current epidemiology and future directions. Circulation. 2016;133:1605–20.
12. Ong KL, Stafford LK, McLaughlin SA, et al. Global, regional, and National burden of diabetes from 1990 to 2021, with projections of prevalence to 2050: a systematic analysis for the global burden of disease study 2021. Lancet. 2023;402:203–34.
13. IDF Diabetes Atlas 10th Edition. (2021) International Diabetes Federation. https://idf.org/about-diabetes/diabetes-facts-figures/. Accessed 2 Apr 2025.
14. Hossain MJ, Al-Mamun M, Islam MR. Diabetes mellitus, the fastest growing global public health concern: early detection should be focused. Health Sci Rep. 2024. https://doi.org/10.1002/hsr2.2004.
15. International Diabetes Federation. (2021) IDF Diabetes Atlas 10th edition. https://diabetesatlas.org/resources/idf-diabetes-atlas-2025/
16. Barrera FJ, Shekhar S, Wurth R, et al. Prevalence of diabetes and hypertension and their associated risks for poor outcomes in Covid-19 patients. J Endocr Soc. 2020. https://doi.org/10.1210/jendso/bvaa102.
17. Huang XB, Tang WW, Liu Y, Hu R, Ouyang LY, Liu J, Li XJ, Yi YJ, Wang TD, Zhao SP. Prevalence of diabetes and unrecognized diabetes in hypertensive patients aged 40 to 79 years in Southwest China. PLoS ONE. 2017. https://doi.org/10.1371/journal.pone.0170250.
18. Tiptaradol S, Aekplakorn W. Prevalence, awareness, treatment and control of coexistence of diabetes and hypertension in Thai population. Int J Hypertens. 2012. https://doi.org/10.1155/2012/386453.
19. Abdelbagi O, Musa IR, Musa SM, ALtigani SA, Adam I. Prevalence and associated factors of hypertension among adults with diabetes mellitus in Northern Sudan: a cross-sectional study. BMC Cardiovasc Disord. 2021. https://doi.org/10.1186/s12872-021-01983-x.

20. Wang Z, Yang T, Fu H. Prevalence of diabetes and hypertension and their interaction effects on cardio-cerebrovascular diseases: a cross-sectional study. BMC Public Health. 2021;21:1224.
21. Sengupta R, Bajpai R, Shukla SK, Singh N, Singh N. Sedentary work and expanding waistlines: a cross-sectional study on occupational roles and abdominal obesity in India. BMC Public Health. 2025. https://doi.org/10.1186/s12889-025-21956-5.
22. Sujata TR. Unequal burden of equal risk factors of diabetes between different gender in India: a cross-sectional analysis. Sci Rep. 2021. https://doi.org/10.1038/s41598-021-02012-9.
23. Joshi SR, Saboo B, Vadivale M, et al. Prevalence of diagnosed and undiagnosed diabetes and hypertension in India-results from the screening India's twin epidemic (SITE) study. Diabetes Technol Ther. 2012;14:8–15.
24. Mohan V, Mathur P, Deepa R, et al. Urban rural differences in prevalence of self-reported diabetes in India-The WHO-ICMR Indian NCD risk factor surveillance. Diabetes Res Clin Pract. 2008;80:159–68.
25. Kaur P, Kunwar A, Sharma M, et al. The India hypertension control Initiative–early outcomes in 26 districts across five States of India, 2018–2020. J Hum Hypertens. 2023;37:560–7.
26. International Institute for Population Sciences (IIPS); ICF NFHS (NFHS-5), 2019–2021: I. (2021) VOLUME I. Mumbai. https://dhsprogram.com/pubs/pdf/FR375/FR375.pdf
27. Ministry of health & family welfare National programme for prevention and control of Non-Communicable diseases operational Guidelines. National Programme for Prevention and Control of Non-Communicable Diseases. 2023. https://mohfw.gov.in/sites/default/files/NP-NCD%20Operational%20Guidelines.pdf
28. Shukla SK, John P, Khemani S, Nair AS, Singh N, Sadanandan R. Assessing the financial burden of Multimorbidity among patients aged 30 and above in India. BMC Health Service Research. 2025;25:86. https://doi.org/10.1186/s12913-025-12206-w
29. Geldsetzer P, Manne-Goehler J, Theilmann M, Davies JI, Awasthi A, Vollmer S, Jaacks LM, Bärnighausen T, Atun R. Diabetes and hypertension in India a nationally representative study of 1.3 million adults. JAMA Intern Med. 2018;178:363–72.
30. World Health Organization. (2023) Hypertension. https://www.who.int/news-room/fact-sheets/detail/hypertension#:~:text=Hypertension
31. Maiti S, Akhtar S, Upadhyay AK, Mohanty SK. Socioeconomic inequality in awareness, treatment and control of diabetes among adults in India: Evidence from National Family Health Survey of India (NFHS), 2019–2021. Scientific reports. 2023 Feb 20;13(1):2971. https://doi.org/10.1038/s41598-023-29978-y
32. Ferrannini E, Cushman WC. Diabetes and hypertension: the bad companions. Lancet. 2012;380:601–10. https://doi.org/10.1016/S0140-6736(12)60987-8
33. Sun D, Zhou T, Heianza Y, Li X, Fan M, Fonseca VA, Qi L. Type 2 diabetes and hypertension: A study on bidirectional causality. Circulation Research. 2019;124:930–7. https://doi.org/10.1161/CIRCRESAHA.118.314487
34. Kundu S, Rahman MA, Kabir H, Al Banna MH, Hagan JE, Srem-Sai M, Wang L. Diabetes, hypertension, and comorbidity among Bangladeshi adults: associated factors and Socio-Economic inequalities. J Cardiovasc Dev Dis. 2023. https://doi.org/10.3390/jcdd10010007.
35. Vennu V, Abdulrahman TA, Bindawas SM. The prevalence of overweight, obesity, hypertension, and diabetes in India: analysis of the 2015–2016 National family health survey. Int J Environ Res Public Health. 2019. https://doi.org/10.3390/ijerph16203987.
36. Jobe M, Mactaggart I, Bell S, et al. Prevalence of hypertension, diabetes, obesity, Multimorbidity, and related risk factors among adult Gambians: a cross-sectional nationwide study. Lancet Glob Health. 2024;12:e55–65.
37. Dandona L, Dandona R, Kumar GA, et al. Nations within a nation: variations in epidemiological transition across the States of India, 1990–2016 in the global burden of disease study. Lancet. 2017;390:2437–60.
38. Norton EC, Miller MM, Kleinman LC. Computing adjusted risk ratios and risk differences in Stata. The Stata Journal. 2013 Sep;13(3):492-509. https://doi.org/10.1177/1536867X1301300304
39. Balasubramani K, Paulson W, Chellappan S, Ramachandran R, Behera SK, Balabaskaran Nina P. Epidemiology, hot spots, and sociodemographic risk factors of alcohol consumption in Indian men and women: analysis of National family health Survey-4 (2015-16), a nationally representative Cross-Sectional study. Front Public Health. 2021. https://doi.org/10.3389/fpubh.2021.617311.
40. Varghese JS, Venkateshmurthy NS, Sudharsanan N, et al. Hypertension diagnosis, treatment, and control in India. JAMA Netw Open. 2023;6:E2339098.
41. Uma NM, Parmar MC, Shah S, Dindod SM. Study of prevalence of hypertension and its various risk factor in type 2 diabetes mellitus patients. Int J Adv Med. 2019;6:1069.
42. Sitaula D, Shrestha N, Timalsina S, Pokharel B, Sapkota S, Acharya S, Thapa R, Dhakal A, Dhakal S. Knowledge, attitude and practice regarding diabetes and hypertension among school students of Nepal: A rural vs. urban study. PLoS ONE. 2022. https://doi.org/10.1371/journal.pone.0270186.
43. Elahi A, Ali AA, Khan AH, Samad Z, Shahab H, Aziz N, Almas A. Challenges of managing hypertension in Pakistan - a review. Clin Hypertens. 2023. https://doi.org/10.1186/s40885-023-00245-6.
44. Rannan-Eliya RP, Wijemunige N, Perera P et al. (2022) Prevalence and associations of hypertension in Sri Lankan adults: estimates from the SLHAS 2018–19 survey using JNC7 and ACC/AHA 2017 guidelines. Glob Heart. https://doi.org/10.5334/gh.1135
45. Viswanathan V, Smina TP. Blood pressure control in diabetes—the Indian perspective. J Hum Hypertens. 2019;33:588–93.
46. Mohan V, Seedat YK, Pradeepa R. The rising burden of diabetes and hypertension in Southeast Asian and African regions: need for effective strategies for prevention and control in primary health care settings. Int J Hypertens. 2013. https://doi.org/10.1155/2013/409083.
47. Jacob AM, Muruganathan A, Datta M, Viswanathan V. Prevalence of hypertension among urban poor with and without diabetes-a study from South India. J Assoc Physicians India. 2019 Nov 1;67(11):41–5.
48. Singh PK, Singh N, Jain P, et al. Mapping the triple burden of smoking, smokeless tobacco and alcohol consumption among adults in 28,521 communities across 640 districts of India: A sex-stratified multilevel cross-sectional study. Health Place. 2021. https://doi.org/10.1016/j.healthplace.2021.102565.
49. Seposo XT, Dang TN, Honda Y. How does ambient air temperature affect diabetes mortality in tropical cities? Int J Environ Res Public Health. 2017. https://doi.org/10.3390/ijerph14040385.
50. Schwartz J. Who is sensitive to extremes of temperature? A case-only analysis. Epidemiology. 2005;16:67–72. https://doi.org/10.1097/01.ede.0000147114.25957.71
51. Blauw LL, Aziz A, Tannemaat MR, Blauw CA, De Craen AJ, Pijl H, Rensen PCN. (2017) Diabetes incidence and glucose intolerance prevalence increase with higher outdoor temperature. 5:317.
52. Norboo T, Stobdan T, Tsering N, et al. Prevalence of hypertension at high altitude: Cross-sectional survey in Ladakh, Northern India 2007–2011. BMJ Open. 2015. https://doi.org/10.1136/bmjopen-2014-007026.
53. Wetzel S, Geldsetzer P, Mani SS, Gupta A, Singh K, Ali MK, Prabhakaran D, Tandon N, Sudharsanan N. (2023) Changing socioeconomic and geographic gradients in cardiovascular disease risk factors among Indians aged 15–49 years–evidence from nationally representative household surveys. The Lancet Regional Health - Southeast Asia. https://doi.org/10.1016/j.lansea.2023.100188
54. Schutta MH. Diabetes and hypertension: epidemiology of the relationship and pathophysiology of factors associated with these comorbid conditions. Journal of the cardiometabolic syndrome. 2007 Feb;2(2):124–30. https://doi.org/10.1111/j.1559-4564.2007.06368.x
55. Liu J, Zhao D, Liu J, Qi Y, Sun J, Wang W. Prevalence of diabetes mellitus in outpatients with essential hypertension in China: A cross-sectional study. BMJ Open. 2013. https://doi.org/10.1136/bmjopen-2013-003798.
56. Lip S, Jeemon P, Mccallum L, Dominiczak AF, Mcinnes GT, Padmanabhan S. Contrasting mortality risks among subgroups of treated hypertensive patients developing new-onset diabetes. Eur Heart J. 2016;37:968–74.
57. Chokshi NP, Grossman E, Messerli FH. Blood pressure and diabetes: vicious twins education in heart. Heart. 2013;99:577–85. https://doi.org/10.1136/heartjnl-2012-302029
58. Tsimihodimos V, Gonzalez-Villalpando C, Meigs JB, Ferrannini E. Hypertension and diabetes mellitus coprediction and time trajectories. Hypertension. 2018;71:422–8.
59. Sowers JR, Epstein M, Frohlich ED. Diabetes, hypertension, and cardiovascular disease: an update. Hypertension. 2001 Apr;37(4):1053–9. https://doi.org/10.1161/01.hyp.37.4.1053
60. Brown MJ, Castaigne A, de Leeuw PW, Mancia G, Palmer CR, Rosenthal T, Ruilope LM. Influence of diabetes and type of hypertension on response to antihypertensive treatment. Hypertension. 2000 May;35(5):1038–42. https://doi.org/10.1161/01.hyp.35.5.1038
61. Rao Guthi V, Sujith Kumar DS, Kumar S, Kondagunta N, Raj S, Goel S, Ojah P. (2023) Hypertension treatment cascade among men and women of reproductive age group in India: analysis of National family health Survey-5

(2019–2021). The Lancet Regional Health - Southeast Asia. https://doi.org/10.1016/j.lansea.2023.100271
62. Riley L, Guthold R, Cowan M, Savin S, Bhatti L, Armstrong T, Bonita R. The world health organization STEPwise approach to noncommunicable disease risk-factor surveillance: methods, challenges, and opportunities. Am J Public Health. 2016;106:74–8.