Prevalence, awareness, treatment, and control of diabetes in India: a nationally representative survey of adults aged 45 years and older

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Summary

Background India is a country of 1·4 billion people that contributes to much of the global diabetes burden. Updated evidence on the state of the diabetes epidemic among middle-aged and older adults is imperative given that the risk of diabetes increases with age and that clinical and public health interventions can prevent diabetes complications. We aimed to estimate the prevalence, awareness, treatment, and control of diabetes in a nationally representative and state-representative sample of Indians aged 45 years and older.

Methods We conducted a cross-sectional, nationally representative survey of adults in India aged 45 years and older and their spouses from 2017 to 2019. Our sample included 57 810 individuals and their spouses from 36 states and union territories, reflecting a representative sample of India as a nation and of each state and union territory. Participants had available data on glycated haemoglobin (HbA_{1c}) measurement and non-missing information on diabetes diagnosis, household economic status, and BMI. Spouses younger than 45 years were excluded from the analysis. Our primary outcomes were diabetes prevalence and health service indicators recommended by WHO. Diabetes prevalence was defined as individuals self-reporting a previous diabetes diagnosis or having HbA_{1c} of 6·5% or higher. Available data did not allow the identification of type 1 versus type 2 diabetes. Diabetes health service indicators were based on four core metrics recommended by WHO: (1) proportion diagnosed out of all individuals with diabetes (awareness) and, out of individuals with diagnosed diabetes, (2) proportion with glycaemic control (measured HbA_{1c} <7·0%), (3) proportion with blood pressure control (measured blood pressure <140/90 mm Hg), and (4) proportion self-reporting use of lipid-lowering medications. Outcomes were assessed in the national sample; by state and union territory; and across individual-level characteristics of age, sex, rural versus urban area of residence, education, economic status, and BMI.

Findings Diabetes prevalence among adults aged 45 years and older in India was 19·8% (95% CI 19·4–20·2), which amounted to 50·4 million people (49·4–51·4). Prevalence among men and women was similar (men, 19·6% [95% CI 19·0–20·2] and women, 20·1% [19·5–20·6]). Urban diabetes prevalence (30·0% [95% CI 29·1–30·8]) was approximately twice as high as rural prevalence (15·0% [14·6–15·5]). States with higher levels of economic development tended to have greater age-standardised prevalence (standardised regression coefficient for gross domestic product per capita 0·65 [95% CI 0·45–0·85]). Overall, 60·1% (59·0–61·2) of individuals were aware of their diabetes. Of individuals with diagnosed diabetes, 45·7% (44·3–47·2) achieved glycaemic control, 58·9% (57·5–60·4) achieved blood pressure control, and 6·4% (5·8–7·2) were taking a lipid-lowering medication.

Interpretation Our findings emphasise the urgent need to scale up policies to better prevent, detect, manage, and control diabetes among middle-aged and older adults in India.

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Introduction

Globally, the number of adults with diabetes was about four times higher in 2014 than in 1980, making diabetes one of the world's most important public health challenges.[1] India is a country of 1·4 billion people that contributes much of the worldwide diabetes burden.[2] Approximately one of every seven adults with diabetes globally lives in India. Diabetes prevalence varies substantially across Indian states, many of which have a total number of adults with diabetes that is comparable to other large countries.[2]

The 2013 WHO Global Action Plan for the Prevention and Control of Noncommunicable Diseases set a worldwide goal of a 25% relative reduction in premature mortality from diabetes and other non-communicable diseases by the year 2025.[3] In response to limited progress towards achieving this goal for diabetes, WHO recently launched the Global Diabetes Compact—an

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Research in context

Evidence before this study

We searched PubMed on Feb 13, 2023, without language or date restrictions, using the search terms "India" and "diabetes" and ("population-based" or "representative") and ("prevalence" or "risk factors" or "outcomes" or "quality measures" or "performance measures" or "targets") in the title or abstract. We supplemented this search by reviewing the reference lists of relevant articles. We found several previous diabetes surveys that were conducted at the national level or among multistate samples of adults in India. We also identified state-level diabetes modelling estimates in India produced by the Global Burden of Diseases, Injuries, and Risk Factors Study. Taken together, these studies suggest rapid increases in diabetes prevalence in India in recent decades in states at higher levels of economic development. We also observed that previous studies had limitations in assessing diabetes prevalence and care that were probably driven by challenges in conducting large-scale survey research among large and diverse populations.

Added value of this study

Our study provides updated, nationally representative, and state-representative estimates of diabetes prevalence, awareness, treatment, and control using glycated haemoglobin (HbA_{1c}) concentrations among middle-aged and older adults in India. Using data collected between 2017 and 2019, we found that approximately one in five people aged 45 years and older had diabetes (50·4 million individuals), that variation across states was wide, and that urban diabetes prevalence was twice as high as rural prevalence. Approximately 40% of people with diabetes were unaware of their condition. Among those who were aware of their diabetes, depending on the definition of the target, 46–60% achieved glycaemic control, 28–59% achieved blood pressure control, and 6–7% were taking a lipid-lowering medication. We found a greater age-stratified and sex- stratified diabetes prevalence in India than observed in previous studies. Compared with a previous large national diabetes study between 2008 and 2020, the Longitudinal Aging Study in India suggests slightly higher achievement of glycaemic and blood pressure targets but lower achievement of lipid-lowering medication targets. Differences might be attributable to the year of data collection, sampling frame, or differences in diabetes definition and biomarkers.

Implications of all the available evidence

Our findings emphasise the urgent need to scale up policies to prevent, detect, manage, and control diabetes among middle-aged and older populations in India. These policies should target not only older Indians (aged >65 years) who have higher diabetes prevalence, but also middle-aged Indians (aged 45–64 years) who are in economically productive years of life. Diabetes affects approximately 20% of the middle-aged population in India, yet the ineffective disease control reported in our study for this group bodes poorly in terms of shortened life expectancy, risk of complications and disability from diabetes, and reduced economic output as these individuals age.

international policy initiative to improve diabetes outcomes by increasing access to quality diabetes care. A central component of the WHO Global Diabetes Compact is monitoring progress towards population-based targets for diabetes prevalence, awareness, access to care, and control.[4] The 2017 National Health Policy in India put forth similar targets.[5]

However, a key challenge in tracking progress towards diabetes targets at the population level is the scarce availability of representative data in many countries. In India, such data are challenging to generate given the country's large and diverse population. Previous diabetes surveys in India have had limitations including subnational scope,[6,7] no data regarding diabetes diagnoses,[8] extended data collection periods,[9] reliance on non-fasting capillary glucose measurements,[10] or focus on national-level rather than state-level estimates.[11] Updated evidence on the state of the diabetes epidemic among middle-aged and older adults is imperative given that the risk of diabetes rises with age and that clinical and public health interventions can prevent diabetes complications. In this study, we aimed to estimate the prevalence, awareness, treatment, and control of diabetes in a sample of Indians aged 45 years and older, representative of the nation and each state and union territory.

See Online for appendix 1

Methods

Study design and participants

We designed the Longitudinal Aging Study in India (LASI) as a nationally representative study to provide high-quality, comprehensive data on the health, social, and economic aspects of ageing in India. Details of LASI have been previously described.[12,13] Briefly, LASI enrolled adults aged 45 years and older and their spouses of all ages. Data were collected from 2017 to 2019 in all states except for Sikkim, where data were collected in 2021. The sample was selected using a multistage stratified area probability cluster design with the 2011 census as the sampling frame. The sample is representative of the nation as a whole and of each state and union territory. Henceforth, we use the term state to refer to both states and union territories.

The present analysis is restricted to 57 810 individuals with an available glycated haemoglobin (HbA_{1c}) measurement and non-missing information on diabetes diagnosis, household economic status, and BMI (appendix 1 p 3). Spouses younger than 45 years were excluded from this analysis as they are not representative of the population. The individual-level response rate for participation in the survey was 87·5%. Dried blood spot specimens were collected in 87·7% of individuals who were interviewed. We compared characteristics of included and excluded participants in our sample to check for sampling bias.

LASI obtained approval from the University of Southern California Institutional Review Board (UP-CG-14_00005), the Harvard University Institutional Review Board (CR-16715–10), and the International Institute for Population Sciences Institutional Review Board (Sr. 12/1054) and the Health Ministry's Screening Committee clearance from the Indian Council of Medical Research (F.No.T.21012/07/ 2012-NCD). Signed consent was obtained for the interviews, and additional signed consent was obtained before collection of blood.

Procedures

Participants were recruited in their homes by trained fieldworkers who had communicated with local leaders about the survey and advertised in local newspapers to heighten awareness and increase response rates (appendix 1 p 4).[13] All data including physical measurements and dried blood spot samples were collected during in-home interviews. The survey instrument included questions about demographics, work, health, health care, and family and social networks. Questions relevant to this study are shown in the appendix 1 (p 5). Biomarkers including anthropometric measurements, blood pressure assessments, and dried blood spot specimens were collected using a standardised protocol. Weight was assessed using a digital weight scale (Seca 803, Seca, Hamburg, Germany), and height was assessed using a stadiometer with levelling bubble. Blood pressure was assessed using an automatic device (Omron HEM 7121, Omron Healthcare, Kyoto, Japan); three blood pressure measurements were taken with 1-min intervals between consecutive measurements, and the mean of the final two measurements was used in this analysis.

We used a dried blood spot collection and HbA_{1c} measurement protocol previously validated against the gold standard venous collection method.[14] Capillary blood was collected after a fingerprick using Whatman 903 protein saver filter paper. Dried blood spot cards were dried for at least 4 h or overnight, packed in a Ziploc bag with desiccants, and sent to the Indian Council of Medical Research–National AIDS Research Institute in Pune, India, within 10 days of collection for storage and testing.[13] Samples were stored below –20°C until the time of testing. From blood spots, punches of 3·2 mm in diameter were used to measure HbA_{1c} concentrations using the Cobas Integra 400 Plus Biochemistry analyser (Roche Diagnostics, Basel, Switzerland). Because clinical HbA_{1c} cutoff points for diagnosis and control for diabetes are based on whole blood and not dried blood spot values, we constructed a calibration equation converting dried blood spot HbA_{1c} concentrations to whole blood equivalent values used in this analysis. This calibration equation was based on the average of repeated measurements of 24 paired dried blood spot and whole blood samples pooled from de-identified clinical specimens from Seattle, WA, USA.[15] Further details of the dried blood spot HbA_{1c} measurement procedures are provided in appendix 1 (pp 6–10).

Outcomes

Our primary outcomes were diabetes prevalence and health service indicators for the diagnosis, treatment, and control of diabetes. To assess diabetes prevalence, we defined diabetes as individuals self-reporting a previous diabetes diagnosis made by a health professional or having HbA_{1c} concentrations of 6·5% or higher.[16,17] Available data in LASI do not allow the identification of type 1 versus type 2 diabetes. The primary outcomes were assessed in all participants with available data.

Diabetes health service indicators were based on four core metrics recommended in the WHO Global Diabetes Compact.[4] These metrics align with the WHO package of essential non-communicable disease interventions and are consistent with national diabetes guidelines in India.[17] The metrics include awareness—ie, the proportion of individuals self-reporting a diabetes diagnosis by a health professional out of all individuals found to have diabetes (diagnosed or undiagnosed)—and proportion of individuals with diagnosed diabetes with glycaemic control (defined as measured HbA_{1c} <7·0%), blood pressure control (defined as measured blood pressure <140/90 mm Hg), and self-reporting use of lipid-lowering medications. In a complementary analysis, we conceptualised diabetes health service indicators using a glycaemic cascade of care[18] approach in which we assessed the proportion of all individuals (diagnosed or undiagnosed) with diabetes who were previously diagnosed (or aware), were receiving treatment with any glucose-lowering medication, and had achieved glycaemic control (HbA_{1c} <7·0%). Further details of outcome definitions are provided in the appendix 1 (p 11).

Statistical analysis

We constructed weights, first accounting for unequal selection probabilities from the sampling design and then correcting for differential non-response rates.[13] We estimated the survey-weighted proportion of individuals achieving each outcome. Both crude and age-standardised estimates using the WHO standard population are presented. We assessed the population implication of our results by multiplying crude proportions by the number of adults aged 45 years and older living in India and in each Indian state according to the 2011 census.

To investigate the state-level patterns in the outcomes, we constructed a choropleth map of India and plotted results by each state's per-capita gross domestic product (GDP).[19] To investigate individual-level patterns in the outcomes, we estimated each outcome across characteristics of age in years (45–49, 50–54, 55–59, 60–64, 65–69, 70–74, and ≥75), sex (male *vs* female; self-reported by participants during the survey), area of residence (urban *vs* rural), education (no education, less than secondary education, and secondary education or higher), household economic status (tertiles), and BMI categories for Asian Indians (underweight, BMI <18·0 kg/m²; normal weight, BMI 18·0–22·9 kg/m²; overweight, BMI 23·0–24·9 kg/m²; obese, BMI ≥25·0 kg/m²).[17] Household economic status was defined using per-capita consumption as this is the preferred measure of living standard derived from surveys in low-income and middle-income countries.[20] Per-capita consumption was estimated using responses to a detailed set of questions on household expenditures, with missing responses imputed using the predictive mean matching method. We also constructed multivariable logistic regression models using the aforementioned characteristics.

	Sample characteristics		Diabetes prevalence	
	Number of participants	Proportion (95% CI)*	Number of participants	Proportion (95% CI)*†
Overall	57 810	100	11 956	19·8% (19·4–20·2)
Age, years				
45–49	11 820	20·2% (19·8–20·7)	1768	14·7% (13·8–15·6)
50–54	9731	19·1% (18·7–19·6)	1883	18·8% (17·8–19·7)
55–59	8974	17·8% (17·3–18·2)	1949	20·5% (19·5–21·5)
60–64	9005	14·0% (13·7–14·3)	2096	22·4% (21·4–23·5)
65–69	7798	12·7% (12·3–13·0)	1862	22·7% (21·6–23·8)
70–74	4984	7·8% (7·5–8·1)	1217	23·4% (22·0–24·9)
≥75	5498	8·5% (8·2–8·7)	1181	21·2% (19·9–22·6)
Sex				
Female	30 965	46·6% (46·1–47·1)	6340	20·1% (19·5–20·6)
Male	26 845	53·4% (52·9–53·9)	5616	19·6% (19·0–20·2)
Area of residence				
Rural	38 076	67·9% (67·4–68·4)	5923	15·0% (14·6–15·5)
Urban	19 734	32·1% (31·6–32·6)	6033	30·0% (29·1–30·8)
Education				
None	27 181	52·3% (51·8–52·8)	4215	15·1% (14·6–15·7)
Less than secondary	20 016	28·9% (28·4–29·3)	4506	22·2% (21·5–23·0)
Secondary or higher	10 613	18·8% (18·4–19·3)	3235	29·2% (28·0–30·3)
Economic status‡				
Low	19 270	36·0% (35·4–36·5)	2951	14·9% (14·3–15·6)
Middle	19 278	33·4% (32·9–33·9)	3953	19·7% (19·0–20·5)
High	19 262	30·6% (30·2–31·1)	5052	25·7% (24·9–26·5)
BMI, kg/m²				
<18 (underweight)	8470	16·4% (16·0–16·8)	626	7·3% (6·6–8·0)
18·0–22·9 (healthy)	23 523	41·8% (41·3–42·3)	3296	13·5% (12·9–14·0)
23·0–24·9 (overweight)	8801	14·7% (14·3–15·0)	2189	24·7% (23·5–25·8)
≥25 (obese)	17 016	27·1% (26·7–27·6)	5845	34·6% (33·7–35·5)

Diabetes was defined among individuals self-reporting a previous diabetes diagnosis or those with glycated haemoglobin of 6·5% or higher. *Values are estimated using survey weights. †This column refers to the crude diabetes prevalence; age-standardised diabetes prevalence is presented in appendix 1 (p 13). ‡The cutoff points for economic status tertials are measured by yearly household per-capita consumption in nominal rupees: (1) 0–26 954; (2) 26 955–47 523; and (3) 47 524–5 033 478.

Table 1: **Sample characteristics and diabetes prevalence of adults aged 45 years and older in India**

We conducted a sensitivity analysis using an alternative HbA_{1c} calibration equation derived from a subsample of 117 LASI respondents with paired dried blood spot samples and venous samples (appendix 1 pp 6–10). This sensitivity analysis was performed because the conversion of dried blood spot sample HbA_{1c} to whole blood equivalents in the main analysis was not done using blood samples from India. Results from this HbA_{1c} calibration were reported as a sensitivity analysis rather than as the main analysis for several reasons. The values in the main analysis also reflected the HbA_{1c} calibration that was most likely to be accurate as it directly compared the University of Washington and LASI laboratories using assays run simultaneously with quality control and field samples. Conversely, the HbA_{1c} calibration using 117 LASI respondents was performed after LASI wave 1 was completed and required a two-step process, as detailed in appendix 1 (pp 6–10).

In additional sensitivity analyses, we used alternative definitions of diabetes prevalence (self-reported use of glucose-lowering medication or HbA_{1c} ≥6·5%) and WHO Global Diabetes Compact metrics of glycaemic control (HbA_{1c} <8·0%), blood pressure control (<130/80 mm Hg), and use of lipid-lowering medications. For lipid-lowering medications, we adapted national lipid guidelines to define a narrower eligibility criteria among individuals at high risk with diabetes who had either pre-existing cardiovascular disease or at least two of the following risk factors: age 40 years or older (all individuals in our sample), first-degree family history of cardiovascular disease, BMI of 25 kg/m² or higher, current smoking, or high blood pressure (defined as use of an antihypertensive medication or blood pressure ≥140/90 mm Hg).[17]

Analyses were done with Stata (version 16.1).

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Characteristics of the study sample are presented in table 1 and details of the excluded sample (13·2% of individuals) are presented in appendix 1 (p 12). Compared to the included sample, excluded individuals tended to be older, be male, live in urban areas, be more educated, have higher household economic status, and be less likely to be obese. Among the 57 810 individuals included in the study sample, using survey weights that accounted for non-response, 53·4% (95% CI 52·9–53·9) were men and 46·6% (46·1–47·1) were women, 67·9% (67·4–68·4) lived in a rural area, and 52·3% (51·8–52·8) had no formal education. The prevalence of individuals who were overweight was 14·7% (95% CI 14·3–15·0) and obese was 27·1% (26·7–27·6).

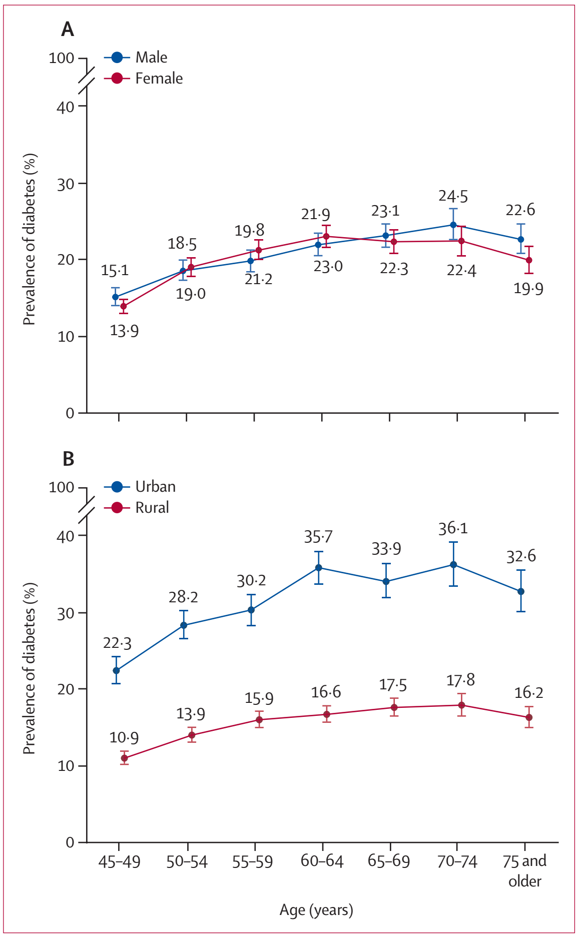

Figure 1: **Age-specific prevalence of diabetes among adults aged 45 years and older in India by sex (A) and area of residence (B)**
Diabetes was defined among individuals self-reporting a previous diabetes diagnosis or those with glycated haemoglobin concentrations of 6·5% or higher. Values are estimated using survey weights. The vertical error bars represent 95% CIs.

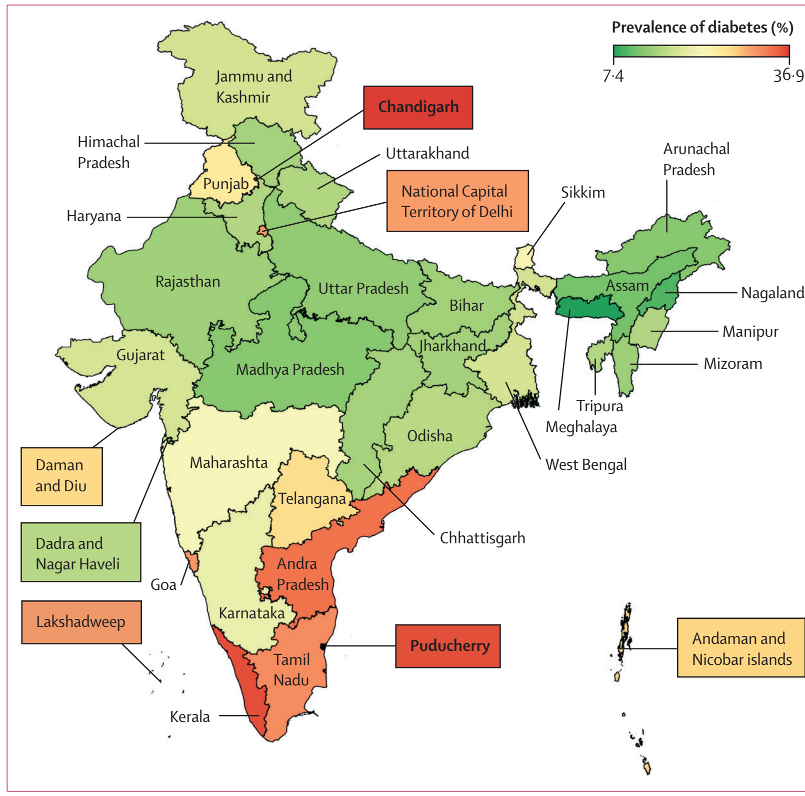

Figure 2: **Age-standardised prevalence of diabetes among adults aged 45 years and older in the states of India**
Diabetes was defined among individuals self-reporting a previous diabetes diagnosis or those with glycated haemoglobin concentrations of 6·5% or higher. Further details are presented in appendix 1 (p 16). India state boundaries provided by DataMeet Community Maps; this project is made available under Creative Commons Attribution 4.0.

National diabetes prevalence among adults aged 45 years and older in India was 19·8% (95% CI 19·4–20·2). This amounts to a national total of 50·4 (49·4–51·4) million people aged 45 years and older with diabetes. Diabetes prevalence among men and women was similar overall (19·6% [95% CI 19·0–20·2] and 20·1% [19·5–20·6], respectively) and across sex-stratified age groups (figure 1A). The urban diabetes prevalence (30·0% [95% CI 29·1–30·8]) was approximately twice as high as rural prevalence (15·0% [14·6–15·5]; figure 1B). In the population who were overweight, diabetes prevalence was 24·7% (95% CI 23·5–25·8), and in the population with obesity, prevalence was 34·6% (33·7–35·5). Age-standardised diabetes prevalence estimates stratified by individual sociodemographic and clinical characteristics are presented in appendix 1 (p 13). In the multivariable regressions, older age, urban residence, higher educational attainment and economic status, and higher categories of body mass index were associated with increased odds of diabetes (appendix 1 p 14).

For more on **DataMeet Community Maps** see http://projects.datameet.org/maps/

Age-standardised diabetes prevalence across states is presented in figure 2 and appendix 1 (pp 15–16). Within-country differences were large. States in southern India tended to have greater age-standardised prevalence, and states in central India and northeastern India tended to have lower age-standardised diabetes prevalence (regional classifications are presented in appendix 1 pp 17–18). The association between state-level per-capita GDP and age-standardised diabetes prevalence appeared to be positive (R^2=0·42, standardised regression coefficient=0·65 [95% CI 0·45–0·85]; appendix 1 p 19). The states with the highest age-standardised diabetes prevalence among adults aged 45 years or older were Chandigarh (36·9% [95% CI 33·2–40·8]), Kerala (36·0% [33·7–38·5]), and Puducherry (36·0% [33·0–39·1]). The states with the greatest total number of adults aged 45 years or older with diabetes were Tamil Nadu (6·1 million people [95% CI 5·7–6·4]), Maharashtra (5·8 million people [5·4–6·3]), and Uttar Pradesh (4·7 million people [4·3–5·2]). State-level diabetes prevalence by sex and area of residence are provided in appendix 1 (pp 20–22).

The crude proportion of adults aged 45 years and older achieving WHO-recommended diabetes metrics

	Proportion of all participants with diabetes who were diagnosed with diabetes (95% CI)	Participants with diagnosed diabetes		
		Proportion with HbA_{1c} <7·0% (95% CI)*	Proportion with blood pressure <140/90 mm Hg (95% CI)*	Proportion on lipid-lowering medication (95% CI)*
Overall	60·1% (59·0–61·2)	45·7% (44·3–47·2)	58·9% (57·5–60·4)	6·4% (5·8–7·2)
Age, years				
45–49	49·5% (46·2–52·8)	42·6% (38·0–47·3)	63·6% (59·0–68·1)	6·0% (4·1–8·6)
50–54	56·7% (53·8–59·5)	38·9% (35·3–42·7)	62·8% (59·1–66·4)	7·1% (5·5–9·1)
55–59	60·7% (58·0–63·5)	43·1% (39·6–46·7)	60·5% (57·0–64·0)	6·1% (4·6–8·0)
60–64	63·5% (60·9–66·0)	43·6% (40·3–46·9)	59·5% (56·2–62·7)	6·6% (5·2–8·3)
65–69	66·0% (63·2–68·6)	48·0% (44·5–51·5)	54·9% (51·4–58·4)	4·9% (3·7–6·5)
70–74	66·6% (63·2–69·9)	53·0% (48·8–57·2)	58·4% (54·2–62·5)	8·3% (6·4–10·8)
≥75	61·4% (57·8–64·8)	59·8% (55·3–64·1)	48·8% (44·4–53·4)	6·8% (4·9–9·3)
Sex				
Male	60·2% (58·5–61·8)	45·1% (42·9–47·2)	58·8% (56·7–60·9)	6·5% (5·6–7·6)
Female	60·1% (58·5–61·6)	46·5% (44·5–48·5)	59·1% (57·1–61·0)	6·3% (5·5–7·3)
Area of residence				
Rural	54·9% (53·3–56·5)	48·9% (46·7–51·0)	59·3% (57·2–61·4)	5·1% (4·3–6·1)
Urban	65·7% (64·0–67·2)	43·0% (41·0–45·0)	58·6% (56·6–60·6)	7·6% (6·6–8·7)
Education				
None	54·0% (52·1–55·8)	50·0% (47·4–52·5)	58·9% (56·3–61·4)	2·9% (2·2–3·9)
Less than secondary	62·2% (60·3–64·0)	44·7% (42·4–47·1)	57·8% (55·5–60·1)	7·9% (6·8–9·2)
Secondary or higher	66·6% (64·4–68·7)	41·9% (39·3–44·6)	60·2% (57·6–62·9)	8·9% (7·5–10·5)
Economic status†				
Low	51·1% (48·8–53·4)	51·5% (48·3–54·6)	60·2% (57·1–63·3)	3·0% (2·1–4·2)
Middle	59·5% (57·5–61·4)	43·6% (41·1–46·2)	58·0% (55·5–60·5)	6·0% (4·9–7·3)
High	66·8% (65·0–68·5)	44·3% (42·1–46·5)	58·9% (56·8–61·1)	8·6% (7·5–9·8)
BMI, kg/m²				
<18 (underweight)	49·7% (44·9–54·4)	71·3% (65·0–77·0)	68·6% (62·1–74·4)	1·5% (0·6–4·1)
18·0–22·9 (healthy)	59·3% (57·1–61·4)	53·1% (50·3–55·9)	61·5% (58·7–64·2)	4·3% (3·4–5·5)
23·0–24·9 (overweight)	61·9% (59·2–64·5)	42·8% (39·5–46·2)	58·9% (55·6–62·2)	6·7% (5·2–8·6)
≥25 (obese)	61·3% (59·6–62·9)	40·0% (37·9–42·0)	56·5% (54·3–58·5)	8·1% (7·1–9·2)

Diabetes was defined among individuals self-reporting a previous diabetes diagnosis or those with HbA_{1c} concentrations of 6·5% or higher. WHO-recommended diabetes metrics include (1) proportion diagnosed out of all individuals with diabetes, and, out of individuals with diagnosed diabetes, (2) proportion with glycaemic control (measured HbA_{1c} <7·0%), (3) proportion with blood pressure control (measured blood pressure <140/90 mm Hg), and (4) proportion self-reporting use of lipid-lowering medications. HbA_{1c}=glycated haemoglobin. *Values are estimated using survey weights. †The cutoff points for economic status tertials are measured by yearly household per-capita consumption in nominal rupees: (1) 0–26 954; (2) 26 955–47 523; and (3) 47 524–5 033 478.

***Table 2:* Crude proportion of adults aged 45 years and older achieving WHO-recommended diabetes metrics**

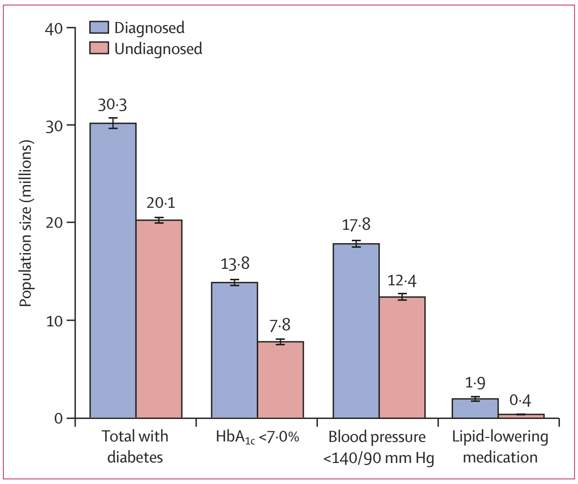

***Figure 3:* Estimated total population aged 45 years and older achieving WHO-recommended diabetes metrics**
Diagnosed diabetes was defined among individuals self-reporting a previous diabetes diagnosis irrespective of haemoglobin concentrations. Undiagnosed diabetes was defined among individuals not self-reporting a previous diabetes diagnosis yet having HbA_{1c} concentrations of 6·5% or higher. WHO-recommended diabetes metrics include (1) proportion diagnosed out of all individuals with diabetes, and, out of individuals with diagnosed diabetes, (2) proportion with glycaemic control (measured HbA_{1c} <7·0%), (3) proportion with blood pressure control (measured blood pressure <140/90 mm Hg), and (4) proportion self-reporting use of lipid-lowering medications. The vertical error bars represent 95% CIs. HbA_{1c}=glycated haemoglobin.

is presented in table 2 (age-standardised results are presented in appendix 1 p 23). Overall, 60·1% (95% CI 59·0–61·2) of individuals were aware of their diabetes. Approximately 50% of individuals who were aware of their diabetes had been diagnosed in the past 5 years and about 75% in the past 10 years (appendix 1 p 24). At the population level among individuals in India aged 45 years and older, 30·3 million people (95% CI 29·7–30·8) had diagnosed diabetes and 20·1 million people (19·5–20·7) had undiagnosed diabetes (figure 3).

Of individuals with previously diagnosed diabetes, 45·7% (95% CI 44·3–47·2) achieved glycaemic control, 58·9% (57·5–60·4) achieved blood pressure control, and 6·4% (5·8–7·2) were taking a lipid-lowering medication. Of all individuals with diagnosed or undiagnosed diabetes, 49·4% (95% CI 48·3–50·6) were taking a glucose-lowering medication and 43·0% (41·8–44·1) achieved glycaemic control (appendix 1 pp 25–26). At the state level, a weak positive association appeared between per-capita GDP and awareness (R^2=0·32, standardised regression coefficient, 0·57 [95% CI 0·34–0·80]). Per-capita GDP accounted for less of the statistical variation for glycaemic control (R^2=0·02), blood pressure control (R^2=<0·01), and use of a lipid-lowering medication (R^2=0·03; figure 4; appendix 1 pp 27–32). In the multivariable regressions, older age, urban residence, greater educational attainment, and higher household economic status were associated with greater odds of awareness, but these patterns were less marked for the other health service indicators (appendix 1 pp 33–36).

The results of the sensitivity analysis using the alternative, post-hoc HbA_{1c} validation and calibration study among a subsample of LASI respondents showed a higher diabetes prevalence (23·7% [95% CI 23·3–24·2]) and estimated number of people aged 45 years or older in India with diabetes (60·3 million [59·3–61·6]; appendix 1 pp 37–42). If diabetes were alternatively defined by self-reported use of

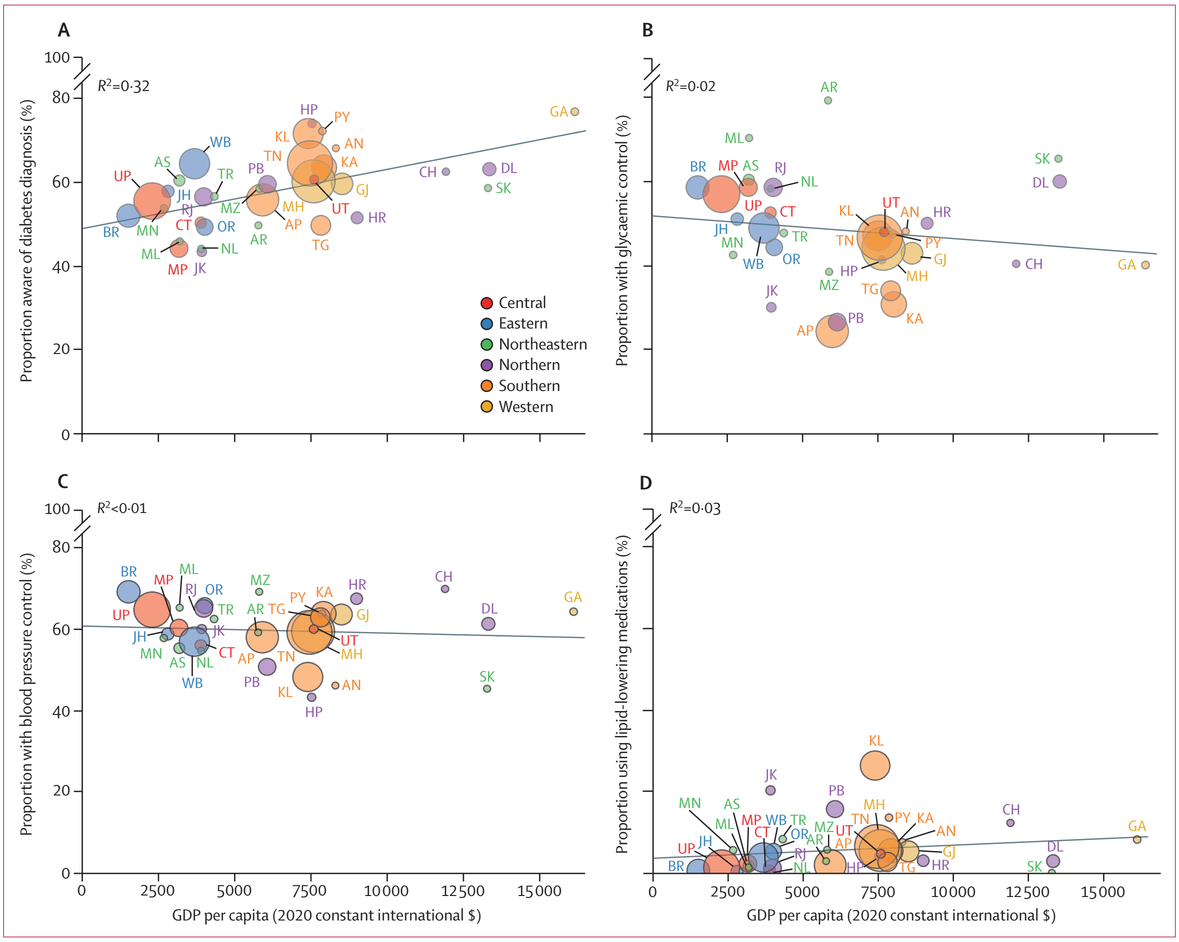

Figure 4: **Age-standardised proportion of adults aged 45 years and older achieving WHO-recommended diabetes metrics in the states of India by state per-capita GDP for diabetes awareness (A), glycaemic control (B), blood pressure control (C), and lipid-lowering medication use (D)**

WHO-recommended diabetes metrics include (1) proportion diagnosed out of all individuals with diabetes, and, out of individuals with diagnosed diabetes, (2) proportion with glycaemic control (measured HbA_{1c} <7·0%), (3) proportion with blood pressure control (measured blood pressure <140/90 mm Hg), and (4) proportion self-reporting use of lipid-lowering medications. The size of each marker is weighted in proportion to the total number of people with diabetes in the state (appendix 1 p 16). The colours refer to the regions of India as defined by the Government of India's Zonal Councils (appendix 1 pp 17–18). The diagonal line depicts an unweighted ordinary least squares regression. Standardised regression coefficients were as follows: (A) awareness: 0·57 (95% CI 0·34 to 0·80); (B) HbA_{1c} <7·0%: –0·16 (95% CI –0·49 to 0·18); (C) blood pressure <140/90 mm Hg: – 0·09 (95% CI –0·43 to 0·25); and (D) lipid-lowering medication: 0·19 (95% CI –0·14 to 0·52). AN=Andaman and Nicobar Islands. AP=Andhra Pradesh. AR=Arunachal Pradesh. AS=Assam. BR=Bihar. CH=Chandigarh. CT=Chhattisgarh. DL=National Capital Territory of Delhi. GA=Goa. GDP=gross domestic product. GJ=Gujarat. HbA_{1c}=glycated haemoglobin. HP=Himachal Pradesh. HR=Haryana. JH=Jharkhand. JK=Jammu and Kashmir. KA=Karnataka. KL=Kerala. MH=Maharashtra. ML=Meghalaya. MN=Manipur. MP=Madhya Pradesh. MZ=Mizoram. NL=Nagaland. OR=Odisha. PB=Punjab. PY=Puducherry. RJ=Rajasthan. SK=Sikkim. TG=Telangana. TN=Tamil Nadu. TR=Tripura. UP=Uttar Pradesh. UT=Uttarakhand. WB=West Bengal.

glucose-lowering medication or HbA_{1c} of at least 6·5%, the diabetes prevalence would be 18·5% (95% CI 18·1–18·9; appendix 1 p 43). Using alternative definitions for the WHO-recommended metrics, of individuals with diagnosed diabetes, among invididuals at high risk, the crude proportion achieving glycaemic control of HbA_{1c} less than 8·0% was 59·7% (95% CI 58·2–61·1), 28·0% (26·7–29·4) for those achieving blood pressure control of less than 130/80 mm Hg, and 7·3% (6·5–8·1) for those using a lipid-lowering medication (appendix 1 pp 44–45). Arunachal Pradesh was the only state in India where more than 80% of individuals with diagnosed diabetes achieved glycaemic control of HbA_{1c} less than 8·0% (appendix 1 p 46).

Discussion

Our study provides updated, nationally representative and state-representative data of diabetes prevalence, awareness, treatment, and control using HbA_{1c} concentrations among middle-aged and older adults in India. Using data collected in India between 2017 and 2019, we found that approximately one in five people aged 45 years and older had diabetes (50·4 million individuals). Diabetes prevalence was similar by sex and was approximately double in urban than in rural areas. Diabetes prevalence was higher in states with greater levels of economic development, and in the highest-prevalence states, a third or more of individuals had diabetes. Approximately 40% of people with diabetes were unaware of their condition. Among those who were aware of their diabetes, depending on the definition of the target, 46–60% achieved glycaemic control, 28–59% achieved blood pressure control, and 6–7% were taking a lipid-lowering medication.

Our study showed greater age-stratified and sex-stratified diabetes prevalence in India than observed in most previous studies that used population data from multiple states or meta-analytical methods. Differences might be attributable to the year of data collection, sampling frame, or differences in diabetes definition and biomarkers. The Indian Council of Medical Research–India Diabetes (ICMR–INDIAB) survey assessed diabetes prevalence using capillary fasting glucose and oral glucose tolerance tests in a sample of 15 states between 2008 and 2013.[6] A recent study using data from the 2019–21 National Family Health Survey-5 (NFHS-5), which was representative of Indians aged 18 years or older at the district level, showed much lower diabetes prevalence and higher achievement of diabetes care targets than did the present study.[10] However, 99% of glucose measurements in NFHS-5 were non-fasting. The 2017–18 National Non-communicable Disease Monitoring Survey (NNMS) reported regional diabetes prevalence of 21·8% among adults aged 50–69 years in India—results which were generally consistent with our findings.[11] Finally, models from the Global Burden of Disease Study suggest large increases in diabetes prevalence in India between 1990 and 2016.[2] In the context of ongoing economic development and epidemiological transition in India, our results might reflect a continuation of this upward trend.

Our study also provides updated, high-quality evidence on the patterns of diabetes within India. The variation in diabetes prevalence across states reinforces the notion that India's states are "nations within a nation" with different trajectories of diabetes burdens, partly reflecting different levels of economic development.[2,21] Across individuals, we found strong associations between diabetes and individual-level characteristics of urban residence, higher education, and proxy measures of better economic status. Although these associations have been previously reported,[6,8,22] our recent data support the notion that India continues to be at a stage in the nutrition transition characterised by greatest diabetes prevalence among higher socioeconomic groups.[23] The finding of greater diabetes prevalence in older age groups is important given that India's population is rapidly ageing. These demographic shifts suggest that, in the coming years, the total number of middle-aged and older adults with diabetes will increase even if the rise in age-specific diabetes prevalence can be halted.

In 2021, the WHO Global Diabetes Compact released worldwide targets for 2030 that at least 80% of people with diabetes are diagnosed, and out of those with a diagnosis, at least 80% achieve glycaemic control (HbA_{1c} <8·0%), 80% achieve blood pressure control (<140/90 mm Hg), and 60% use a statin.[4] Compared with ICMR–INDIAB national data collected between 2008 and 2020, LASI suggests slightly higher achievement of glycaemic (45·7% *vs* 36·3%) and blood pressure targets (58·9% *vs* 48·8%) but lower achievement of lipid-lowering medication targets (6·4% *vs* 16·4%).[9] Only one state in LASI achieved any of the four recommended targets in the WHO Global Diabetes Compact.[4] Arunachal Pradesh achieved the target for HbA_{1c} concentration less than 8·0% among those with diagnosed diabetes. The fact that fewer than one in ten people with diagnosed diabetes reported using lipid-lowering medications such as statins is also noteworthy. Low use of these medications has been reported in ICMR–INDIAB and national surveys from other low-income and middle-income countries.[24] Our findings suggest that considerable progress must be made towards these national targets to achieve them in the proposed timeline.

Our study has limitations. First, the LASI sample is restricted to adults aged 45 years and older and their spouses of all ages, and we further excluded spouses younger than 45 years from this analysis. Nevertheless, this sampling range targets middle-aged and older individuals who have the greatest risk of developing diabetes and experiencing diabetes-related complications. Second, our data do not allow us to distinguish between type 1 and type 2 diabetes. Third, we did not collect details on exact medications used, so we cannot report the proportion of statin use among individuals using lipid-lowering medications or the specific agents used among individuals taking glucose-lowering medications. Additionally, the question on use of cholesterol-lowering medications was only asked of participants who reported a diagnosis of high cholesterol, so we therefore might have underestimated use of these medications. Fourth, while our sample had low overall missingness, some subgroups with greater diabetes prevalence tended to be slightly less likely to consent to blood collection. We addressed this issue by correcting sampling weights for differential non-response, but it is possible that diabetes prevalence might be slightly underestimated or overestimated.

Our use of HbA_{1c} concentrations was both a strength and a limitation of our study. Due to high assay costs, population-based surveys in India and other low-income and middle-income countries infrequently incorporate HbA_{1c} measurements.[1] HbA_{1c} has good test characteristics when accounting for repeat testing, as recommended in clinical practice.[25] Use of HbA_{1c} minimises bias that can occur in the reporting of individuals' fasting status—an important consideration in the use of fasting glucose in population surveys. HbA_{1c} is the preferred biomarker for monitoring glycaemic control in people with diabetes, a key objective of our study, and it has a stronger association with cardiovascular disease and death than does fasting glucose.[26] Population diabetes prevalence using HbA_{1c} criterion might be higher than prevalence using fasting glucose in south Asia.[27] This finding might be due to an effect on HbA_{1c} from common health conditions such as anaemia or haemoglobinopathies such as thalassaemia.[28] Alternatively, it might reflect that individuals with elevated HbA_{1c} are a distinct subgroup compared with those with elevations in fasting or postprandial glucose.[29] One study of younger Indians (aged 21–23 years) showed that iron-deficiency anaemia probably contributed to an overestimation of the prevalence of prediabetes but not diabetes using HbA_{1c} compared with postprandial glucose criteria.[30] This finding could be explained by anaemia-induced shifts in the HbA_{1c} distribution at lower levels.[31] We measured HbA_{1c} concentrations from dried blood spot samples rather than venous samples, which is the gold-standard collection method. We then calibrated dried blood spot sample HbA_{1c} to whole blood equivalent values that could be compared with other large international ageing studies. In most previous studies, including our validation study,[14] HbA_{1c} from dried blood spot samples with whole blood conversion had excellent comparability with venous results.[32–35] One study showed that collection conditions including humidity affected the precision of dried blood spot sample HbA_{1c} measurements, although recalibrated values were unbiased.[36] Finally, our sensitivity analysis using a dried blood spot sample HbA_{1c} validation and calibration study among 117 LASI respondents showed similar results to our main analysis, which used a correction equation based on repeat testing of 24 blood samples from the USA.

These findings emphasise the need to scale up policies to prevent, manage, and control diabetes in India. These policies should target not only older Indians (aged >65 years) who have a higher diabetes prevalence, but also middle-aged Indians (aged 45–64 years) who are in economically productive years of life. Diabetes affects approximately 20% of the middle-aged population in India, yet the ineffective disease control reported in our study for this group bodes poorly in terms of shortened life expectancy, risk of disability, and reduced economic output as these individuals age.

The National Multisectoral Action Plan for Prevention and Control of Common Non-communicable Diseases (2017–22) in India focuses on four strategic actions of multisectoral coordination: health promotion and health system strengthening, monitoring, and evaluation.[37] This ambitious plan aims to reduce diabetes mortality by 25% and to stop the increase in diabetes prevalence by 2025. The Indian health system is decentralised, and thus an implication of our study is the need to tailor the policy responses proposed in this plan to each Indian state while also ensuring coordination mechanisms across states.

As both a nationally representative and state-representative survey of diabetes prevalence and care, our survey also reinforces the need for periodic population-based surveys to assess progress towards national and global diabetes targets. The NNMS is designed for this purpose, although its sampling methodology precludes state-level estimates or inferences among adults aged 70 years or older.[11] Our survey was conducted in the years immediately preceding and during the COVID-19 pandemic, which has disrupted access to health care and healthy lifestyle patterns of adults with chronic diseases including diabetes in India.[38] Future studies are needed to understand the population-level impact of COVID-19 on prevalence and care of diabetes in India.

In conclusion, approximately one in five people aged 45 years and older in India has diabetes (50·4 million individuals). However, only half of these people are aware of their condition and even fewer achieve targets for glycaemic control, blood pressure control, and use of lipid-lowering medications. Our findings emphasise the urgent need to scale up policies to better prevent, detect, manage, and control diabetes among middle-aged and older adults in India.

Contributors

DF and JL conceptualised the study. HG curated the data. DF and HG formally analysed the data. DEB, JL, and TVS acquired funding. PH and EMC conducted the methodology for dried blood spot analyses. SP and AS undertook project administration of dried blood spot analyses. DF and HG were responsible for creating the figures and writing the original draft. JL, HG, PH, MKA, SP, KML, EMC, TVS, and DEB wrote, reviewed, and edited the manuscript. JL and HG accessed and verified the underlying data. All authors confirm they had access to all the data in the study and accept responsibility for the decision to submit for publication.

Equitable partnership declaration

The authors of this paper have submitted an equitable partnership declaration (appendix 2). This statement allows researchers to describe how their work engages with researchers, communities, and environments in the countries of study. This statement is part of *The Lancet Global Health*'s broader goal to decolonise global health.

See **Online** for appendix 2

Declaration of interests

We declare no competing interests.

Data sharing

LASI data used in this study, with the exception of dried blood spot sample biomarkers, are publicly available on the websites of the Gateway to Global Aging Data and International Institute for Population Sciences. Academic researchers can access dried blook spot biomarker data after review and approval. To access data, users must register, provide an email address, and sign a data use agreement.

For more on the **Gateway to Global Aging Data** see https://g2aging.org/

For more on the **International Institute for Population Sciences** see https://www.iipsindia.ac.in/content/LASI-data

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