



Research Article

Prevalence and Determinants of Undiagnosed Type 2 Diabetes and Prediabetes among Tribal Adults in Dadra and Nagar Haveli: A Community-Based Cross-Sectional Study

Darshan K. Mahyavanshi¹ and Mitali Patel^{2*}

¹Professor and Head, Department of Community Medicine, NAMO Medical Education and Research Institute (NAMOMERI), Silvassa, UT of Dadra and Nagar Haveli and Daman and Diu, India

²Associate Professor, Department of Community Medicine, NAMO Medical Education and Research Institute (NAMOMERI), Silvassa, UT of Dadra and Nagar Haveli and Daman and Diu, India

***Corresponding Author**

Mitali Patel
(dr.mitali05@gmail.com)

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Abstract: Background: Type 2 diabetes mellitus (T2DM) is rising rapidly in India, including among tribal populations traditionally considered to be at low risk. Undiagnosed diabetes and prediabetes represent missed opportunities for early intervention. Data from Dadra and Nagar Haveli (DNH), a predominantly tribal district, are lacking. We estimated the prevalence of undiagnosed T2DM and prediabetes and identified their determinants among tribal adults in DNH. **Methods:** In this community-based cross-sectional study, 640 Scheduled Tribe adults aged ≥ 18 years without known diabetes were selected by multistage sampling. A WHO STEPS-adapted questionnaire, standard anthropometry, blood pressure and fasting capillary glucose were obtained. Undiagnosed T2DM was defined as fasting glucose ≥ 126 mg/dL and prediabetes as 100–125 mg/dL (American Diabetes Association criteria). Multivariable logistic regression identified independent determinants. **Results:** The prevalence of undiagnosed T2DM was 9.7% (62/640; 95% CI 7.5–12.2) and of prediabetes 15.3% (98/640; 95% CI 12.6–18.3). Undiagnosed T2DM rose from 3.0% at 18–29 years to 17.6% at ≥ 60 years. Independent determinants of undiagnosed T2DM were age ≥ 40 years (adjusted odds ratio [aOR] 3.42; 95% CI 1.89–6.18), central obesity (aOR 2.67, 1.52–4.69), family history of diabetes (aOR 2.31; 1.18–4.52), physical inactivity (aOR 1.94; 1.11–3.39) and hypertension (aOR 1.88, 1.05–3.37). Prediabetes was independently associated with age ≥ 40 years, central obesity and low fruit and vegetable intake. Only 9.2% had had a blood-glucose test in the preceding 12 months; 72.5% had never been tested. **Conclusion:** One in four tribal adults in DNH has undetected dysglycaemia, largely linked to modifiable factors, amid very low screening coverage. Risk-stratified screening integrated with culturally tailored lifestyle interventions in primary care is urgently needed.

Keywords: Diabetes Mellitus, Type 2, Prediabetic State, Undiagnosed Diseases, Tribal Population, Indigenous Peoples, Mass Screening, Cross-Sectional Studies, India

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INTRODUCTION

Diabetes mellitus is one of the fastest-growing public-health challenges worldwide. The 11th edition of the International Diabetes Federation (IDF) Diabetes Atlas estimates that 589 million adults aged 20–79 years were living with diabetes in 2024, a figure projected to reach 853 million by 2050 [1,2]. India carries the second-largest burden globally, with an estimated 89.8 million affected adults in 2024.1 The nationally representative ICMR-INDIAB study reported a weighted prevalence of 11.4% for diabetes and 15.3% for prediabetes, with a clear shift of the epidemic from urban to rural areas and from affluent to less affluent groups [3,4].

A substantial proportion of people with diabetes are unaware of their condition. The IDF estimates that about 43% of Indian adults with diabetes are undiagnosed [1,5] and analysis of the fifth National Family Health Survey (NFHS-5) found that roughly one in four people with hyperglycaemia had never been diagnosed [6]. Undiagnosed T2DM progresses silently for years, so that many patients present only when microvascular or macrovascular complications have already developed [7]. Prediabetes is itself a high-risk state: up to 70% of affected individuals eventually progress to diabetes and it is associated with early nephropathy, retinopathy and cardiovascular risk [8]. Detection of both conditions is therefore central to prevention, because structured lifestyle modification reduced progression to diabetes by 58% in the US Diabetes Prevention Program and by about 29% in the Indian Diabetes Prevention Programme [9,10].

India has the world's largest tribal population. According to the 2011 Census, Scheduled Tribes (STs) number about 104 million people, constituting 8.6% of the national population, with nearly 90% living in rural areas [11,12]. Historically, high levels of occupational physical activity, traditional plant-based diets and low body mass were thought to protect tribal communities against metabolic disease. This profile is changing rapidly. Market integration, displacement from forest livelihoods, mechanisation, increased consumption of refined cereals, sugar and edible oils and high tobacco and alcohol use are driving an epidemiological transition in many tribal areas [13,14]. A systematic review of tribal studies documented wide variation in diabetes and prediabetes prevalence across communities, with higher rates in groups

undergoing urbanisation and acculturation [15] and a more recent meta-analysis estimated a pooled prevalence of 4.9%, lower than in the general population but rising over time [16]. Globally, Indigenous populations in most settings now experience diabetes rates exceeding general-population estimates [17]. Contemporary Indian tribal studies also show high and largely undetected hypertension [18] and diabetes prevalence close to that of neighbouring non-tribal populations in some regions [19].

These National Figures conceal considerable heterogeneity. Tribal groups differ in genetics, diet, livelihoods and access to health services and the Expert Committee on Tribal Health highlighted the absence of reliable, community-specific data on Non-Communicable Diseases (NCDs) as a major barrier to planning [13]. Dadra and Nagar Haveli (DNH), a district of the Union Territory of Dadra and Nagar Haveli and Daman and Diu, lie between Gujarat and Maharashtra. Its population of 343,709 is predominantly tribal, with the Varli (Warli), Kokna, Dhodia and Dubla (Halpati) communities forming the principal groups [11,20]. Rapid industrialisation around Silvassa over the past three decades has transformed employment and diet in the district, yet systematic community-level glycaemic screening is not routine and published estimates of undiagnosed diabetes among its tribal residents are, to our knowledge, lacking.

Reliable local estimates of undiagnosed T2DM and prediabetes, together with their sociodemographic and behavioural correlates, are required to target screening under the National Programme for Prevention and Control of Non-Communicable Diseases (NP-NCD) and to design culturally appropriate prevention [21]. We therefore conducted a community-based cross-sectional study to estimate the prevalence of undiagnosed T2DM and prediabetes among tribal adults in DNH and to identify their independent determinants.

Objectives

- To estimate the prevalence of undiagnosed T2DM and prediabetes among Scheduled Tribe adults aged ≥ 18 years in Dadra and Nagar Haveli
- To describe the age- and sex-specific distribution of undiagnosed T2DM and prediabetes
- To identify sociodemographic, anthropometric, clinical and behavioural determinants of undiagnosed T2DM and prediabetes
- To assess previous blood-glucose screening in the study population

MATERIALS AND METHODS

Study Design, Setting and Period

A community-based cross-sectional study was conducted in tribal-dominated villages of Dadra and Nagar Haveli between April 2025 to June 2026. DNH covers 491 km² with 72 villages and more than 40% forest cover; its tribal residents are engaged mainly in agriculture, agricultural and industrial wage labour and forest-based livelihoods [20]. Primary care in the study area is delivered through primary health centres, sub-centres now functioning as Ayushman Arogya Mandirs (formerly Health and Wellness Centres) and the district hospital at Silvassa. The study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [22].

Study Population and Eligibility

Adults aged ≥ 18 years belonging to a Scheduled Tribe and usually resident in the selected village for at least six months were eligible. Individuals with a previous diagnosis of diabetes by a health professional or on glucose-lowering medication were excluded, because the study aimed to measure undiagnosed dysglycaemia. Pregnant women, individuals with acute illness on the day of the survey, those unable to communicate or who had not fasted and those who declined consent were also excluded.

Sample Size

Sample size was calculated with the formula $n = Z^2p(1 - p)/d^2$, assuming an expected prevalence of undiagnosed diabetes (p) of 8% based on rural and tribal Indian studies, 4,15 a 95% confidence level ($Z = 1.96$) and an absolute precision (d) of 2.75%. This gave 374; after applying a design effect of 1.5 for cluster sampling and allowing for 10% non-response, the required sample was 617, rounded to 620. A total of 640 participants were enrolled.

Sampling Procedure

A multistage sampling design was used. In the first stage, villages (primary sampling units) were selected from the list of tribal-majority villages of DNH by probability proportional to size, using Census 2011 population figures. In the second stage, a household list was prepared or updated in each selected village and households were selected by systematic random sampling with a random start. In the third stage, one eligible adult per household was selected at random using a Kish grid. When the selected individual was unavailable, up to two repeat visits were made before recording non-response; households were not substituted.

Data Collection

Data were collected by trained field investigators (medical interns and postgraduate residents of Community Medicine under supervision of the investigators, using a structured questionnaire adapted from the WHO STEP wise approach to NCD risk-factor surveillance [23]. The questionnaire was translated into Gujarati and/or local dialect, back-translated and pre-tested tribal adults outside the study villages. It covered sociodemographic characteristics (age, sex, tribe, education, occupation, marital status and socioeconomic status assessed with the Modified B.G. Prasad scale, updated for the survey year), behavioural factors (tobacco use, alcohol use, physical activity using the Global Physical Activity Questionnaire and number of servings of fruit and vegetables per day), family history of diabetes in first-degree relatives and history of previous blood-glucose testing.

Anthropometry

Height was measured to the nearest 0.1 cm with a portable stadiometer, with participants barefoot and head in the Frankfort plane. Weight was measured to the nearest 0.1 kg on a calibrated digital scale with participants in light clothing. Waist circumference was measured to the nearest 0.1 cm with a non-stretchable tape at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest, at the end of normal expiration [23].

Blood Pressure

After at least five minutes of seated rest, blood pressure was measured on the right arm with a validated automated digital device using an appropriately sized cuff. Two readings were taken three minutes apart and their mean was used; a third reading was taken if the first two differed by more than 10 mmHg.

Blood Glucose

Participants were instructed on the previous evening to fast overnight for at least 8 hours. Fasting status was confirmed on the morning of the survey and fasting capillary glucose was measured by finger-prick using a plasma-calibrated glucometer. Glucometers were checked daily with manufacturer control solutions and strips from a single lot were used where possible. Capillary glucose measurement is an established and practical method in large Indian field surveys and shows acceptable agreement with venous plasma glucose [24,25].

Operational Definitions

Operational definitions used in the analysis are summarised in Table 1. Glycaemic categories followed the American Diabetes Association (ADA) fasting glucose criteria; the diabetes threshold (≥ 126 mg/dL) is identical to that of the WHO [26–28]. Asian-specific cut-offs were used for BMI and waist circumference [29–31].

Statistical Analysis

Data were double-entered in Microsoft Excel / EpiData and analysed using software and version, e.g. IBM SPSS Statistics v26/Stata [17]. Continuous variables are presented as mean $\pm$ standard deviation and categorical variables as frequency and percentage. Prevalence estimates are presented with exact (Clopper–Pearson) binomial 95% confidence intervals. Differences between sexes were assessed with the independent-samples t-test for continuous variables and the chi-square test for proportions.

Determinants of undiagnosed T2DM and of prediabetes were examined separately, each compared with normoglycaemic participants. Variables with $p < 0.20$ in univariable analysis, together with age and sex as a priori confounders, were entered into multivariable binary logistic regression models. Results are expressed as crude and adjusted odds ratios (OR, aOR) with 95% CIs. Multicollinearity was assessed with variance inflation factors and model fit with the Hosmer–Lemeshow test. A two-sided $p < 0.05$ was considered statistically significant.

Table 1: Operational Definitions Used in the Study

Variable	Definition
Undiagnosed T2DM	Fasting capillary glucose ≥ 126 mg/dL (≥ 7.0 mmol/L) in a person with no previous diagnosis of diabetes [26,27]
Prediabetes (impaired fasting glucose)	Fasting capillary glucose 100–125 mg/dL (5.6–6.9 mmol/L) ²⁷
Normoglycaemia	Fasting capillary glucose < 100 mg/dL
Central obesity	Waist circumference ≥ 90 cm in men and ≥ 80 cm in women ^{30,31}
General overweight / obesity	BMI 23.0–24.9 kg/m ² / ≥ 25.0 kg/m ² (Asian cut-offs) ^{29,30}
Hypertension	Systolic ≥ 140 and/or diastolic ≥ 90 mmHg, or current antihypertensive treatment ³²
Physical inactivity	< 150 minutes of moderate-intensity (or equivalent) physical activity per week ³³
Low fruit and vegetable intake	< 5 servings of fruit and/or vegetables per day ²³
Current tobacco / alcohol use	Use of any smoked or smokeless tobacco / any alcohol in the past 30 days ²³
Family history of diabetes	Diabetes in at least one first-degree relative (parent or sibling)

Highlighted definitions were not specified in the original draft and should be confirmed against the study protocol

Ethical Considerations

The study protocol was approved by the Institutional Ethics Committee of NAMO Medical Education and Research Institute, Silvassa and was conducted in accordance with the ICMR National Ethical Guidelines for Biomedical and Health Research Involving Human Participants and the Declaration of Helsinki [34,35]. Written informed consent (or thumb impression witnessed by an impartial literate witness for participants unable to read) was obtained in the local language. Permission was obtained from the district health authorities and village leaders. Participants with fasting glucose ≥ 100 mg/dL or elevated blood pressure were counselled and referred to the nearest primary health centre or the district hospital for confirmatory testing and management. Data were anonymised before analysis and stored securely.

RESULTS

Characteristics of Participants

Of 681 eligible adults approached, 640 completed the interview, anthropometry and fasting glucose test (response rate 94%). The mean age was 39.8 ± 13.6 years and did not differ significantly between men and women (40.6 ± 13.9 vs 39.1 ± 13.3 years; $p = 0.16$); 334 (52.2%) were women (Table 2). Most participants had no formal or only primary education (71.6%) and worked in agriculture or wage labour (64.5%). Central obesity was present in 182 participants (28.4%) and was more frequent in women (31.7% vs 24.8%). Hypertension was present in 22.7%. Current tobacco and alcohol use were considerably more common in men, whereas physical inactivity was more common in women (34.4% vs 26.1%; $p = 0.03$).

Prevalence of Undiagnosed T2DM and Prediabetes

Overall, 62 participants had undiagnosed T2DM (9.7%; 95% CI 7.5–12.2) and 98 had prediabetes (15.3%; 95% CI 12.6–18.3). Thus 160 participants (25.0%; 95% CI 21.7–28.5), one in four, had previously unrecognised abnormal fasting glucose (Figure 1). The prevalence of undiagnosed T2DM was similar in men and women (10.1% vs 9.3%; $p = 0.82$), as was the prevalence of prediabetes (14.7% vs 15.9%; $p = 0.77$).

Both conditions showed a pronounced age gradient (Table 3, Figure 2). Undiagnosed T2DM increased almost six-fold, from 3.0% among those aged 18–29 years to 17.6% among those aged ≥ 60 years and exceeded 10% in every age group from 40 years onwards. Prediabetes increased from 8.8% at 18–29 years to a peak of 21.7% at 50–59 years and plateaued at 20.1% in those aged ≥ 60 years. Sex differences within age groups were small and not statistically significant after adjustment for age.

Table 2: Sociodemographic, Clinical and Behavioural Characteristics of Participants, by Sex (N = 640)

Characteristic	Male (n = 306)	Female (n = 334)	Total (N = 640)	p-value
Age, years, mean $\pm$ SD	40.6 $\pm$ 13.9	39.1 $\pm$ 13.3	39.8 $\pm$ 13.6	0.16
No formal / primary education	209 (68.3)	249 (74.6)	458 (71.6)	0.10
Agriculture / wage labour	218 (71.2)	195 (58.4)	413 (64.5)	<0.001
Central obesity	76 (24.8)	106 (31.7)	182 (28.4)	0.07
Hypertension	78 (25.5)	67 (20.1)	145 (22.7)	0.12
Family history of diabetes	35 (11.4)	44 (13.2)	79 (12.3)	0.58
Current tobacco use	131 (42.8)	62 (18.6)	193 (30.2)	<0.001
Current alcohol use	97 (31.7)	23 (6.9)	120 (18.8)	<0.001
Physically inactive	80 (26.1)	115 (34.4)	195 (30.5)	0.03

Values are n (%) unless otherwise stated. Counts were back-calculated from the reported percentages and should be checked against the dataset. p-values: independent-samples t-test (age) and chi-square test (proportions). SD, standard deviation

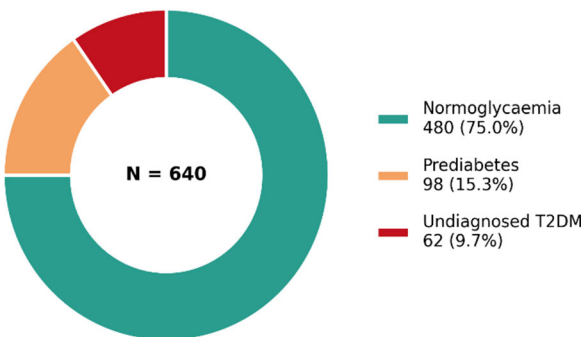


Figure 1: Distribution of Glycaemic Status Among Tribal Adults Without Previously Diagnosed Diabetes (N = 640)

Determinants of Undiagnosed T2DM

The prevalence of undiagnosed T2DM was highest among participants with central obesity (18.4%), a family history of diabetes (16.8%) and hypertension (15.6%), roughly 1.6 to 1.9 times the overall prevalence (Figure 3). In univariable analysis, undiagnosed T2DM was significantly associated with age ≥ 40 years, central obesity, physical inactivity, family history of diabetes and hypertension, while low fruit and vegetable intake showed a borderline association (crude OR 1.67; 95% CI 0.98–2.85). In the multivariable model, age ≥ 40 years (aOR 3.42; 95% CI 1.89–6.18), central obesity (aOR 2.67; 1.52–4.69), family history of diabetes (aOR 2.31; 1.18–4.52), physical inactivity (aOR 1.94; 1.11–3.39) and hypertension (aOR 1.88; 1.05–3.37) remained independently associated (Table 4). Low fruit and vegetable intake and current alcohol use were not independently associated.

Determinants of Prediabetes

Prediabetes was independently associated with age ≥ 40 years (aOR 2.18; 95% CI 1.36–3.49), central obesity (aOR 1.92; 1.21–3.05) and low fruit and vegetable intake (aOR 1.61; 1.02–2.54). Physical inactivity showed a borderline association that did not reach statistical significance and sex and tobacco use were not independently associated after adjustment.

Previous Blood-Glucose Screening

Prior screening was strikingly low (Figure 4). Only 59 participants (9.2%) reported a blood-glucose test within the previous 12 months and 117 (18.3%) had been tested more than 12 months earlier, while 464 (72.5%) had never had their blood glucose checked. Screening coverage in the preceding year was slightly higher among older adults and those with hypertension but remained below 20% even in these higher-risk subgroups.

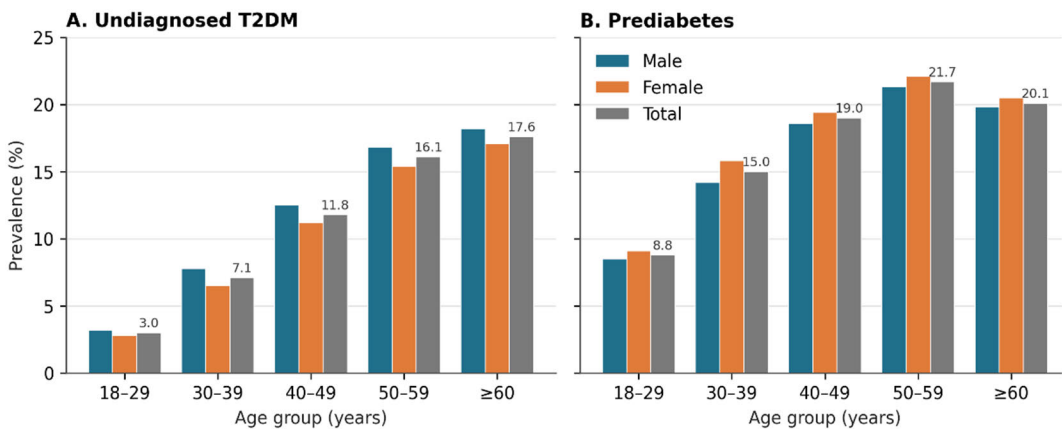


Figure 2: Age- and Sex-Specific Prevalence of (A) Undiagnosed Type 2 Diabetes and (B) Prediabetes. Data Labels Show the Total Prevalence for Each Age Group

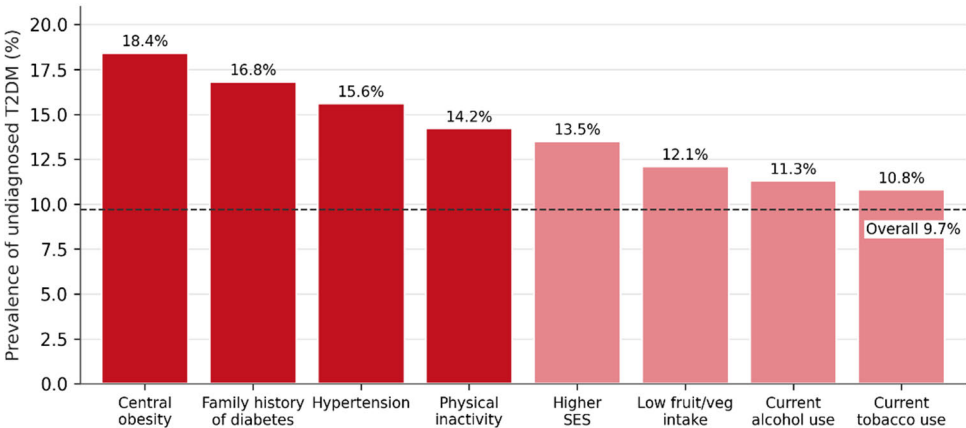


Figure 3: Prevalence of Undiagnosed Type 2 Diabetes Among Participants with Selected Risk Factors. Dark Bars Indicate Factors Independently Associated with Undiagnosed T2DM in Multivariable Analysis; the Dashed Line Indicates the Overall Prevalence (9.7%). SES, Socioeconomic Status

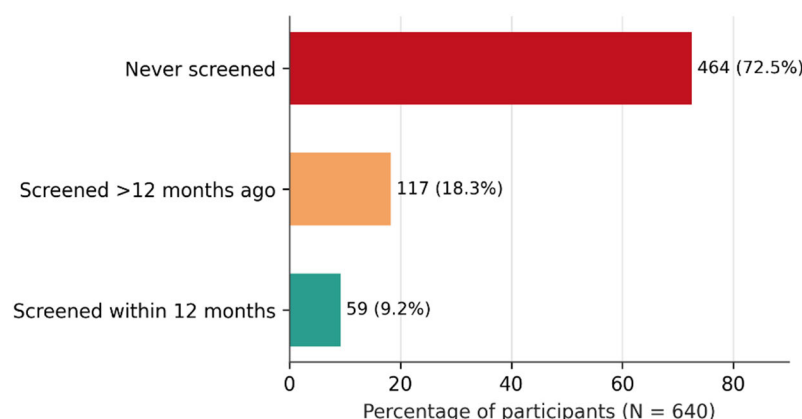


Figure 4: History of Previous Blood-Glucose Testing Among Participants (N = 640)

Table 3: Age- and Sex-Specific Prevalence (%) of Undiagnosed T2DM and Prediabetes

Age group (years)	T2DM Male	T2DM Female	T2DM Total	Pre-DM Male	Pre-DM Female	Pre-DM Total
18–29	3.2	2.8	3.0	8.5	9.1	8.8
30–39	7.8	6.5	7.1	14.2	15.8	15.0
40–49	12.5	11.2	11.8	18.6	19.4	19.0
50–59	16.8	15.4	16.1	21.3	22.1	21.7
≥60	18.2	17.1	17.6	19.8	20.5	20.1
Overall	10.1	9.3	9.7	14.7	15.9	15.3

T2DM, undiagnosed type 2 diabetes mellitus; Pre-DM, prediabetes

Table 4: Univariable and Multivariable Logistic Regression Analysis of Determinants of Undiagnosed T2DM

Variable (reference)	Crude OR	95% CI	Adjusted OR	95% CI
Age ≥40 years (<40 years)	3.85	2.21–6.71	3.42	1.89–6.18
Central obesity (no)	3.12	1.84–5.29	2.67	1.52–4.69
Family history of diabetes (no)	2.64	1.41–4.94	2.31	1.18–4.52
Physical inactivity (no)	2.28	1.35–3.86	1.94	1.11–3.39
Hypertension (no)	2.41	1.40–4.15	1.88	1.05–3.37
Low fruit/vegetable intake (no)	1.67	0.98–2.85	1.42	0.81–2.49
Current alcohol use (no)	1.53	0.84–2.78	1.29	0.68–2.45

OR, odds ratio; CI, confidence interval. Adjusted ORs are from a multivariable binary logistic regression model including all variables shown, together with sex. Bold values indicate statistical significance ($p < 0.05$)

DISCUSSION

Principal Findings

This community-based study provides, to our knowledge, the first systematic estimate of undiagnosed T2DM and prediabetes among tribal adults in Dadra and Nagar Haveli. Among adults with no previous diagnosis, almost one in ten had diabetes and a further 15% had prediabetes, so that a quarter of the tribal adult population harboured unrecognised dysglycaemia. The burden increased steeply with age and clustered with central obesity, physical inactivity, family history and hypertension, whereas screening coverage was minimal. Together these findings indicate that the metabolic transition is well advanced in this tribal population and that the health system is currently detecting only a small fraction of it.

Comparison with Other Studies

Selected Indian estimates are compared in Table 5. Because our study excluded people with known diabetes, the 9.7% prevalence represents only the undetected fraction of the burden; total prevalence in the community would be higher. Even so, this figure exceeds the pooled total diabetes prevalence of 4.9% reported for Indian tribal populations [16] and is several-fold higher than the 1.3% reported among tribal adults in Kashmir [36]. It is also higher than the approximately 4–5% of Indian adults with undiagnosed diabetes implied by IDF estimates (age-standardised prevalence 10.5%, of whom about 43% are undiagnosed) [1] and approaches the total national prevalence of 11.4% reported by ICMR-INDIAB [3]. Our prediabetes prevalence (15.3%) is identical to the national ICMR-INDIAB estimate and to that among tribal adults in the Javadhu hills of Tamil Nadu, where 62% of diabetes cases were newly detected on screening [3,19]. The west-Indian location of DNH, adjacent to industrialising districts of Gujarat and Maharashtra, may partly explain why its tribal residents resemble the general population more closely than more remote tribal groups. Differences in diagnostic methods (fasting capillary glucose, OGTT or HbA1c), age structure and the inclusion or exclusion of known cases limit direct comparison.

Interpretation of Determinants

- **Age:** The steep age gradient mirrors national data and the natural history of progressive beta-cell dysfunction and insulin resistance [3,7]. That undiagnosed diabetes exceeded 10% from the fifth decade onwards supports the NP-NCD strategy of population-based screening from 30 years of age and argues for particular attention to adults aged ≥ 40 years [21]
- **Central Obesity:** Central obesity was the strongest modifiable determinant of both undiagnosed T2DM and prediabetes, even though average body size in the population was modest. Asian Indians accumulate visceral and ectopic fat and develop insulin resistance, at lower BMI and waist circumference than Europeans – the “thin-fat” phenotype described by Yajnik and Yudkin [30,37]. Waist circumference, a simple and inexpensive measurement, therefore identifies high-risk tribal adults more effectively than BMI and should be part of routine screening
- **Physical Inactivity and Diet:** Nearly one-third of participants and over one-third of women, were physically inactive – a striking finding for a population traditionally dependent on manual agricultural work. The shift from farming and forest livelihoods to industrial and service employment and the replacement of traditional coarse grains with polished rice, refined wheat and processed foods probably underlie both the inactivity and the association of low fruit and vegetable intake with prediabetes [13,14]. These are precisely the behaviours targeted by lifestyle-intervention trials that have prevented diabetes in Indian adults [10]
- **Family History and Hypertension:** A family history of diabetes more than doubled the odds of undiagnosed T2DM, reflecting both shared genetic susceptibility and shared household environments. Its reporting, however, depends on relatives having been diagnosed, so in a population with low screening coverage the true familial aggregation is probably underestimated. The association with hypertension reflects the common insulin-resistant, obesity-related pathway and is particularly relevant because hypertension is itself frequent and under-detected in Indian tribal populations [18,38]. Adults with hypertension attending primary care represent a readily identifiable group for opportunistic glucose testing
- **Tobacco and Alcohol:** Despite high tobacco use among men, neither tobacco nor alcohol use was independently associated with dysglycaemia. This may reflect the cross-sectional design, crude exposure categories, or confounding by lower body weight among users and does not diminish the importance of addressing these behaviours for cardiovascular prevention

The Screening Gap and Implications for Practice

Perhaps the most actionable finding is the minimal prior screening: more than 70% of participants had never been tested and fewer than one in ten had been tested in the past year. This contrasts with the aims of NP-NCD, under which all adults aged ≥ 30 years should undergo population-based screening for diabetes, hypertension and common cancers through Ayushman Arogya Mandirs [21]. Barriers commonly reported in tribal areas include distance to facilities, loss of daily wages, limited awareness, reliance on traditional healers and shortage of staff [13]. Our data suggest that a risk-stratified approach – prioritising adults aged ≥ 40 years and those with central obesity, hypertension or a family history of diabetes, for example using simple risk tools such as the Indian Diabetes Risk Score [39], or the Community Based Assessment Checklist used under NP-NCD21 – would capture most undiagnosed cases efficiently. Screening must be accompanied by confirmatory testing, a reliable supply of essential medicines and culturally tailored lifestyle counselling delivered by community health officers and ASHAs in local languages; otherwise, detection will not translate into better outcomes.

Strengths and Limitations

Strengths of this study include its community-based design with probability sampling, a high response rate, an adequate sample size, standardised anthropometric and blood-pressure measurements, objective glucose measurement and multivariable analysis of determinants in a previously unstudied tribal population. Several limitations should be considered:

- Glycaemic status was based on a single fasting capillary glucose measurement. Clinical diagnosis requires confirmation by repeat testing, venous plasma glucose, OGTT or HbA1c [27] and capillary values may differ modestly from venous plasma [25]. A single measurement may misclassify some individuals and our estimates should be regarded as screening prevalence

Table 5: Comparison of the present findings with selected Indian studies

Study, setting	Population	Glycaemic measure	Diabetes (%)	Prediabetes (%)
Present study, DNH	ST adults ≥ 18 y without known diabetes; n = 640	Fasting capillary glucose	9.7 (undiagnosed)	15.3
ICMR-INDIAB-17, 31 states/UTs3	General population ≥ 20 y; n = 113 043	OGTT (capillary)	11.4 (total)	15.3
Shriraam <i>et al.</i> , Tamil Nadu [19]	Tribal adults, Javadhu hills; n = 502	Capillary glucose	7.4 (total; 62% newly diagnosed)	15.3
Ganie <i>et al.</i> , Kashmir [36]	Tribal adults; n = 6808	HbA1c	1.3 (total)	11.6
Hazarika & Babu, meta-analysis [16]	Indian tribal studies (pooled)	Various	4.9 (pooled)	-

DNH, Dadra and Nagar Haveli; ST, Scheduled Tribe; OGTT, oral glucose tolerance test; HbA1c, glycated haemoglobin

- Reliance on fasting glucose alone does not detect individuals with isolated impaired glucose tolerance or isolated post-load hyperglycaemia, which are common in Asian Indians; the true burden of dysglycaemia is therefore likely to be underestimated [4]
- Prediabetes was defined by the ADA threshold (100–125 mg/dL). Under the WHO threshold for impaired fasting glucose (110–125 mg/dL), prevalence would be lower [26]
- Confidence intervals were not adjusted for the cluster sampling design and may therefore be somewhat narrower than design-based intervals
- Because people with known diabetes were excluded, total diabetes prevalence and the proportion of cases that are undiagnosed could not be estimated
- The cross-sectional design precludes causal inference and self-reported behaviours (physical activity, diet, tobacco and alcohol use, family history) are subject to recall and social-desirability bias
- Results were not disaggregated by individual tribe and findings may not be generalisable to tribal communities in other regions of India

Future Research

Future work should include total (known plus undiagnosed) prevalence with confirmation by HbA1c or OGTT, tribe-specific analyses, longitudinal follow-up of the prediabetic cohort to quantify progression and pragmatic evaluation of community-based screening-and-lifestyle interventions delivered through Ayushman Arogya Mandirs.

CONCLUSION

Undiagnosed T2DM and prediabetes affect about one in four tribal adults in Dadra and Nagar Haveli. Older age, central obesity, physical inactivity, family history of diabetes and hypertension are the key determinants, most of which are modifiable or readily identifiable at the primary-care level. The very low coverage of blood-glucose screening reveals a large unmet need. Integrating risk-stratified opportunistic and community-based glycaemic screening with culturally appropriate lifestyle counselling into existing primary health-care platforms is urgently warranted.

Recommendations

- Implement systematic population-based screening for diabetes and prediabetes, as envisaged under NP-NCD, at all primary health centres and Ayushman Arogya Mandirs serving tribal communities in DNH, supplemented by village-level screening camps
- Prioritise adults aged ≥ 40 years and those with central obesity, hypertension or a family history of diabetes for early testing and include waist-circumference measurement in routine screening
- Couple screening with brief, culturally tailored counselling on physical activity, traditional diets rich in millets, pulses, fruit and vegetables and weight management, delivered in local languages by community health officers and ASHAs
- Strengthen referral pathways and ensure the availability of confirmatory tests (venous plasma glucose or HbA1c) and essential medicines at the primary-care level
- Institute periodic population-based surveillance of NCD risk factors in tribal areas of DNH to monitor trends and evaluate the impact of screening programmes

Declarations

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- **Data Availability:** The de-identified dataset is available from the corresponding author on reasonable request

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