Original Article

Assessment of burden of prediabetes and diabetes with oral glucose tolerance test in community-based settings of Bengaluru rural district

Gokul Sarveswaran, Vaitheeswaran Kulothungan, Sukanya Rangamani, Deepadarshan Huliyappa, Pruthvish Sreekantaiah

ICMR-National Centre for Disease Informatics and Research, Bengaluru, Karnataka, India

Abstract

Background and Objective(s): Diabetes is a major public health concern in India. The majority of studies done in rural population lack systematic methodology in estimating the prevalence of diabetes mellitus. Objectives of this study were to estimate the burden of prediabetes, type 2 diabetes mellitus and its associated risk factors among adults (18–69) years in rural Bengaluru, Karnataka. **Methods:** A cross-sectional study was conducted among adults aged 18–69 years in three villages of Devanahalli taluk of rural Bengaluru between May and October 2019. Behavioural and metabolic risk factors related to diabetes were assessed using WHO-STEPS instrument and IDSP-NCD risk factor tool. Fasting blood glucose and OGTT test were performed, and WHO diagnostic criteria were used to diagnose diabetes mellitus. **Results:** Prevalence of prediabetes and type 2 diabetes (T2DM) in rural Bengaluru was found to be 6.3% and 10.9%, respectively. Behavioural risk factors related to diabetes measured in the study population were current tobacco use (32.7%), current alcohol use (9.9%), physical inactivity (46.8%) and unhealthy diet (82.3%). Metabolic risk factors measured were obesity (7.5%), central obesity (46.4%), prediabetes (6.3%) and hypertension (24.3%). More than one-thirds of diabetes and three-fourths of hypertension individuals were newly diagnosed by the population-based screening. **Conclusion:** The burden of diabetes and its risk factors are high due to the health transition occurring in rural population of Bengaluru. Undiagnosed diabetes mellitus and hypertension in rural population as demonstrated by this study highlight the need to strengthen the population-based screening and diagnosis of T2DM and hypertension (HTN) under the national health programme.

Keywords: Diabetes mellitus, population-based screening, prediabetes, rural

Introduction

Non-communicable diseases (NCDs) contribute to nearly three-fourths of total deaths in the world, and 85% die prematurely in low- and middle-income countries (LMICs). NCDs were also the leading cause of morbidity globally in the year 2019. Among them, diabetes was the fifth leading cause of mortality and eight leading cause of disability.[1] Two-thirds of total deaths in India are caused by the four major NCDs (cardiovascular diseases, respiratory diseases, cancer and diabetes) with 3·1% of deaths due to diabetes alone, and among these 42·6% are premature deaths.[2]

With an overall prevalence of prediabetes (10.3%) and diabetes (7.3%), and varied prevalence of prediabetes (5.8% to 15.5%) and type 2 diabetes mellitus—T2DM (3.5% to 13%) in rural and urban areas across different states as

Address for correspondence: Dr. Sukanya Rangamani, National Centre for Disease Informatics and Research (Indian Council of Medical Research), II Floor of Nirmal Bhawan, ICMR Complex, Poojanhalli Road, Off NH-7, Adjacent to Trumpet Flyover of KIAL, Kannamangala Post, Bengaluru - 562 110, Karnataka, India.
E-mail: sukanya.r@icmr.gov.in

Received: 02-01-2024 **Revised:** 25-03-2024
Accepted: 08-04-2024 **Published:** 11-09-2024

Access this article online

Quick Response Code:

Website: http://journals.lww.com/JFMPC

DOI: 10.4103/jfmpc.jfmpc_9_24

How to cite this article: Sarveswaran G, Kulothungan V, Rangamani S, Huliyappa D, Sreekantaiah P. Assessment of burden of prediabetes and diabetes with oral glucose tolerance test in community-based settings of Bengaluru rural district. J Family Med Prim Care 2024;13:3806-14.

reported by the 'Indian Council of Medical Research-India Diabetes' (ICMR-INDIAB) study.[3]

One-fourths (25%) of individuals with prediabetes will develop T2DM within 3–5 years and nearly 70% will develop T2DM within their lifetime.[4-6] Studies consistently indicate the alarming rise in the prevalence of prediabetes and T2DM, higher proportion with micro- or macrovascular complications due to late disease diagnosis, and that early diagnosis of T2DM prevented or delayed complications.[7-10] The 'National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke' (NPCDCS, recently renamed as National Programme for Prevention and Control of Non-communicable Diseases—NPNCD) was launched in 2010 by Ministry of Health, Government of India under the National Health Mission to address the T2DM burden through a public health approach of health promotion, early detection and management of T2DM and its complications across urban and rural India.[11]

Very few population-based studies have been conducted in rural parts of Karnataka to estimate the prevalence of risk factors of NCDs, prediabetes and T2DM in the state.[12-17] Bengaluru rural district comprises mainly of peri-urban areas with both agricultural and occupations linked to urban infrastructure development. Devanahalli taluk is a peri-urban area that has seen the conversion of agricultural areas to infrastructure developments of airports, industries, housing development, etc., in the last decade.[18]

As frontline caregivers, primary care providers and family physicians play a pivotal role in the early detection and management of T2DM within their communities. Understanding the burden of prediabetes and diabetes is paramount for effective screening and management strategies tailored to the needs of the local population. This study aimed to assess the prevalence of prediabetes and diabetes using the oral glucose tolerance test (OGTT) in community-based primary care settings in Bengaluru rural district.

Materials and Methods

The community-based cross-sectional study among all adults aged 18–69 years and residing in three villages of Devanahalli taluk, Bengaluru rural district of Karnataka from May to October 2019.

The sample size was estimated to be 1250 using Open Epi software,[19] based on the prevalence of T2DM in rural Karnataka as 9%,[3] relative precision of 20% and non-response of 20%. Three villages were selected through probability proportionate to size sampling method from the Census 2011 list of all villages of Devanahalli taluk. All eligible adults in these three villages were included.

The study involved mapping and listing all households, conducting interviews and anthropometric measurements for all adults 18–69 years with informed consent and OGTT for all adults. Intellectually disabled adults who were unable to respond to the questionnaire were excluded from the study, but were screened for blood glucose levels. FBG alone was recorded for self-reported diabetes individuals and pregnant women. The study was approved by the Institutional Ethics Committee.

Study procedure

Administrative permissions from the concerned health authorities of the public health system and their concurrence for referral of patients with T2DM for continued management were obtained. A detailed description of the field activities is available in an earlier publication.[20]

Field investigators obtained written informed consent and conducted interviews and anthropometric measurements among the participants by maintaining privacy and confidentiality. All eligible participants were provided appointment slips on specific days for attending the blood glucose screening camps, along with instructions (verbal and written) regarding the preparations for the fasting blood test and OGTT. OGTT was performed according to standard guidelines with 75 gms of anhydrous glucose mixed in 200 ml of potable water and consumed within 10 minutes. Capillary blood samples were taken for measuring the fasting and 2-hr blood glucose estimation. Time of consuming the glucose was recorded, and the participants were given instructions about the second blood test to be held after 2 hours. The field investigators mobilised the participants to complete the OGTT wherever needed. Patient reports were prepared with the findings, along with doctor's advice. All participants were given health education material pertaining to diabetes and prediabetes. The newly diagnosed cases of diabetes were referred to the nearest primary health centre (PHC) for further management. Figure 1 illustrates the process of data collection.

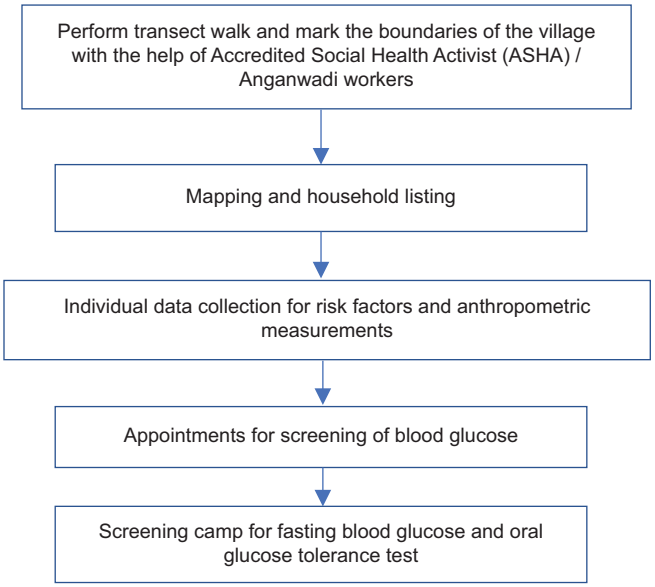

Figure 1: Process of data collection

Operational definitions

The participants who are 'known case of diabetes mellitus or FBG ≥126 mg/dl and/or 2-hour blood glucose (2-hr BG) ≥220 mg/dl' were defined as having diabetes mellitus.[21] Capillary and venous plasma glucose levels remain identical in the fasting state. Conversion factor of 10% was applied to 2-hr BG values to make them equivalent to venous plasma glucose levels as per WHO guidelines.[22]

Prediabetes was defined as 'the presence of either impaired fasting glucose (IFG) with (FBG between ≥110 mg/dl and <126 mg/dl; and 2-hr BG <160 mg/dl) or impaired glucose tolerance (IGT) (FBG <110 mg/dl and 2-hr BG between ≥160 mg/dl but <220 mg/dl)'.[21]

Raised blood pressure was defined as 'known case of hypertension or systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg'.[3]

Behavioural risk factors on alcohol, tobacco, physical activity and diet were classified based on 'WHO-STEPs questionnaire[23] and Integrated Disease Surveillance Project (IDSP)-NCD risk factor survey'.[24] Body mass index (BMI) and waist circumference were classified based on WHO cut-off for Southeast Asian population and Asia-Pacific guidelines.[25,26]

Study variables

Independent variables were socio-demographic characteristics, family history of diabetes mellitus, behavioural and metabolic risk factors. Outcome variable was presence of prediabetes (diagnosed by OGTT) and diabetes mellitus (self-reported and newly diagnosed).

Statistical analysis

Data was collected in forms and entered through software application developed by ICMR-NCDIR. Continuous variables were presented as mean and standard deviation (SD). Categorical variables such as gender, behavioural and metabolic risk factors were expressed in proportions. Prevalence of diabetes mellitus and prediabetes among adults were expressed in proportions with 95% confidence interval (CI). Chi-square test was used to determine the association between socio-demographic, behavioural risk factors with diabetes mellitus and prediabetes. Univariate logistic regression analysis was performed to determine the strength of association and expressed as unadjusted odds ratio (uOR). Multivariate logistic regression was performed to identify the determinants of prediabetes and T2DM, expressed in adjusted odds ratio (aOR) with 95% CI. Variables having *P* value < 0.20 in univariate analysis were considered for multivariate analysis. All analysis was carried out using SPSS software (version 27.0).

Results

There were 615 households listed, 555 households with 1789 adults in age group 18–69 years were enumerated with complete details on socio-demographic information, and 1502 were available to participate in the study. Among the eligible population (n = 1502), 1234 (82.2%) had completed questionnaires, anthropometric and biochemical measurements.

Table 1 describes the prevalence of diabetes (10.9%; 95% CI: 9.2-12.7), prediabetes (6.3%; 95% CI: 5.1-7.8) and hypertension (24.3%; 95% CI: 22.0-26.8). One-thirds (35%) of all diabetes individuals were newly diagnosed by OGTT. Ratio of self-reported hypertension to total hypertension was 0.22: 1.

The mean (SD) age of the participants was 39.7 ± 13.4 years; 55.1% were females; 172 (14.5%) belonged to upper socio-economic class ('modified B G Prasad's scale, January 2019'); and 21.2% had family history of diabetes mellitus [Table 2]. Increase in age and male gender were associated with the presence of prediabetes and diabetes.

The association of behavioural and metabolic risk factors with prediabetes and diabetes among the study participants was described in Table 3. The majority of study participants (82.3%) reported inadequate intake of fruits and vegetables in accordance with WHO recommendations of five servings or 400 gms of fruits and vegetables daily and 46.8% reported inadequate physical activity (less than 75 minutes of vigorous-intensity or 150 minutes of moderate-intensity physical activity per week). One-thirds (32.7%) were current tobacco users with mean (SD) age recorded for starting any form of tobacco and were 23.1 years. Risk factors of generalized obesity (uOR-1.99) and central obesity (uOR-1.90) were significantly associated with the presence of prediabetes. Physical inactivity (uOR-1.57), ever tobacco use (uOR-1.46), ever alcohol use (uOR-1.99), generalized obesity (uOR-2.68), central obesity (uOR-2.99) and raised blood pressure (uOR-2.51) were significantly associated with diabetes mellitus.

One-fifth of households (22.1%) reported one or more diabetes individuals in their family [Figure 2].

Table 1: Prevalence of diabetes, prediabetes and hypertension among adults aged 18–69 years and residing in Bengaluru rural district, *n*=1234

Prevalence	Frequency, *n* (%)	95% Confidence interval
Diabetes	134 (10.9)	9.2-12.7
Self-reported	87 (7.1)	5.8-8.6
Newly diagnosed^	47 (3.8)	2.9-5.0
Prediabetes&	78 (6.3)	5.1-7.8
Impaired fasting glucose†	26 (2.1)	1.4-3.1
Impaired glucose tolerance‡	52 (4.2)	3.2-5.5
Hypertension/Raised blood pressure	300 (24.3)	22.0-26.8
Known hypertensive*	55 (4.3)	3.4-5.8
Newly diagnosed#	245 (20.0)	17.7-22.2

^Fasting blood glucose ≥126 mg/dl or 2-hour post-glucose load ≥220 mg/dl. †Fasting blood glucose 110–126 mg/dl and 2-hour post-glucose load <160 mg/dl. ‡Fasting blood glucose <110 mg/dl and 2-hour post-glucose load ≥160 mg/dl but <220 mg/dl. &Presence of impaired fasting glucose and/or impaired glucose tolerance. *Self-reported hypertension and/or on anti-hypertensive agents. #Measured using systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg and/

Table 2: Socio-demographic characteristics of the study participants aged 18–69 years and residing in Bengaluru rural district, *n*=1234

Socio-demographic characteristics	Frequency, *n* (%)				*p* value			
	Normal (I)	Prediabetes† (II)	Diabetes^ (III)	Total	(I)*(II)	(I)*(III)	(II)*(III)	Total
Age category (in years)								
18–29	314 (30.7)	6 (7.7)	3 (2.2)	323 (26.2)	<0.0001	<0.0001	0.005	<0.0001
30–44	373 (36.5)	33 (42.3)	36 (26.9)	442 (35.8)				
≥45	335 (32.8)	39 (50.0)	95 (70.9)	469 (38.0)				
Gender								
Male	452 (44.2)	26 (33.3)	76 (56.7)	554 (44.9)	0.061	0.006	0.001	0.003
Female	570 (55.8)	52 (66.7)	58 (43.3)	680 (55.1)				
Education (in class)								
No formal education	187 (18.3)	25 (32.1)	40 (29.9)	252 (20.4)	0.005	<0.0001	0.458	<0.0001
Primary (1–5)	115 (11.3)	9 (11.5)	23 (17.2)	147 (11.9)				
Middle (6–8)	133 (13.0)	14 (17.9)	14 (10.4)	161 (13.0)				
Secondary (9–10)	281 (27.5)	19 (24.4)	39 (29.1)	339 (27.5)				
Higher secondary and above	306 (29.9)	11 (14.1)	18 (13.4)	335 (27.1)				
Occupation								
Employed	606 (59.3)	46 (59.0)	91 (67.9)	743 (60.2)	0.088	0.001	0.063	0.001
Student	90 (8.8)	1 (1.3)	0 (0.0)	91 (7.4)				
Homemaker	280 (27.4)	29 (37.2)	34 (25.4)	343 (27.8)				
Retired/unemployed or able to work	16 (1.6)	1 (1.3)	0 (0)	17 (1.4)				
Unemployed or unable to work	23 (2.3)	0 (0.0)	7 (5.2)	30 (2.4)				
No response	7 (0.7)	1 (1.3)	2 (1.5)	10 (0.8)				
Marital status								
Never married	191 (18.7)	6 (7.7)	4 (3.0)	201 (16.3)	0.023	<0.0001	0.37	0.000
Currently married	780 (76.3)	64 (82.1)	117 (87.3)	961 (77.9)				
Widowed/Separated/Divorced	49 (4.8)	8 (10.3)	12 (9.0)	69 (5.6)				
No response	2 (0.2)	0 (0.0)	1 (0.7)	3 (0.2)				
Religion								
Hindu	976 (95.5)	74 (94.9)	127 (94.8)	1177 (95.4)	0.592	0.55	0.504	0.64
Christian	28 (2.7)	4 (5.1)	4 (3.0)	36 (2.9)				
Muslim	16 (1.6)	0 (0.0)	2 (1.5)	18 (1.5)				
Others	2 (0.2)	0 (0.0)	1 (0.7)	3 (0.24)				
Socio-economic class (in rupees)*								
Lower-class V (≤₹1050)	235 (23.8)	17 (23.9)	37 (29.1)	289 (24.3)	0.711	0.365	0.869	0.621
Lower middle-class IV (₹1051-2101)	155 (15.7)	11 (15.5)	23 (18.1)	189 (15.9)				
Middle-class III (₹2102-3503)	239 (24.2)	22 (31.0)	32 (25.2)	293 (24.7)				
Upper middle-class II (₹3504-7007)	212 (21.4)	12 (16.9)	20 (15.7)	244 (20.6)				
Upper-class I (≥₹7008)	148 (15.0)	9 (12.7)	15 (11.8)	172 (14.5)				
Presence of family history of diabetes mellitus	200 (19.6)	21 (26.9)	41 (30.6)	262 (21.2)	0.118	0.003	0.571	0.006

*Modified B G Prasad's scale, January 2019. †Fasting blood glucose 110–126 mg/dl and/or 2-hour post-glucose load ≥160 mg/dl but <220 mg/dl. ^Self-reported as diabetes or fasting blood glucose ≥126 mg/dl or 2-hour post-glucose load ≥220 mg/dl

Table 4 describes the univariate and multivariate analysis of risk factors for diabetes mellitus and prediabetes among study participants. Increasing age group (aOR-6.48 for 30-44 years, aOR-20.18 for ≥45 years), males (aOR-1.65), family history of diabetes mellitus (aOR-1.89) and insufficient physical activity (aOR-1.73) were associated with the presence of diabetes after adjusting for education, tobacco and alcohol use, generalized obesity, central obesity and raised blood pressure. Increasing age (aOR-3.92 for 30–44 years, aOR-5.02 for ≥45 years) was associated with the occurrence of prediabetes after adjustments for other socio-demographic, behavioural and metabolic risk factors.

Discussion

The prevalence of diabetes mellitus in selected villages of Bengaluru rural district was 10.9% (95% CI: 9.2-12.7) as compared to 5.6% in the ICMR-INDIAB study (2017), 6.9% in National Non-Communicable Disease Monitoring Survey (NNMS)(2017–18), 6.8% in women and 7.6% in men of National Family Health Survey-5 (NFHS-5, 2019–21).[3,27,28] Other community-based cross-sectional studies done in rural parts of Karnataka and Tamil Nadu have reported prevalence of diabetes mellitus ranging from 7% to 19%.[12,16] Lower prevalence of prediabetes [6.3% (95% CI: 5.1–7.8)] was found in this study

Table 3: Behavioural and metabolic risk factors characteristics of the study participants aged 18–69 years and residing in Bengaluru rural district, *n*=1234

Behavioural and metabolic risk factor characteristics	Frequency, *n* (%)				*p* value			
	Normal (I)	Prediabetes (II)	Diabetes (III)	Total	(I)*(II)	(I)*(III)	(II)*(III)	Total
Diet characteristics								
Intake of fruits and vegetables in the diet								
Adequate	181 (17.7)	14 (17.9)	24 (17.9)	219 (17.7)	0.958	0.955	0.994	0.997
Inadequate	841 (82.3)	64 (82.1)	110 (82.1)	1015 (82.3)				
Physical activity characteristics								
Adequate‡	560 (54.8)	39 (50.0)	58 (43.3)	657 (53.2)	0.412	0.012	0.344	0.036
Inadequate	462 (45.2)	39 (50.0)	76 (56.7)	577 (46.8)				
Practice of yoga and meditation								
Practice yoga and/or meditation	30 (2.9)	3 (3.8)	9 (6.7)	42 (3.4)	0.649	0.023	0.383	0.074
Tobacco use characteristics								
Current tobacco user	327 (32.0)	21 (26.9)	55 (41.0)	403 (32.7)	0.064	0.107	0.055	0.035
Past tobacco user	38 (3.7)	7 (9.0)	5 (3.7)	50 (4.1)				
Current tobacco use characteristics								
Smoke	40 (3.9)	2 (2.6)	12 (9.0)	54 (4.4)	0.734	0.034	0.129	0.103
Smokeless	275 (26.9)	19 (24.4)	41 (30.6)	335 (27.1)				
Both	7 (0.7)	0 (0)	1 (0.7)	8 (0.6)				
Mean age of start using any form tobacco	23.0±10.4	21.4±11.3	23.8±10.7	23.1±10.4	0.729	0.857	0.597	0.625
Alcohol use characteristics								
Current alcohol use	95 (9.3)	4 (5.1)	23 (17.2)	122 (9.9)	0.203	0.009	0.04	0.011
Past alcohol use	35 (3.4)	5 (6.4)	7 (5.2)	47 (3.8)				
Alcohol use in the last 30 days								
Alcohol use in the last 7 days	941 (92.1)	75 (96.2)	117 (87.3)	1133 (91.8)	0.408	0.177	0.101	0.220
Heavy drinking#	19 (1.9)	1 (1.3)	4 (3.0)	24 (1.9)				
Light drinking†	62 (6.1)	2 (2.6)	13 (9.7)	77 (6.2)				
Body mass index – BMI (kg/m^2)*								
Underweight (<18.50)	158 (15.6)	9 (11.5)	4 (3.1)	171 (14.0)	0.048	<0.0001	0.121	<0.0001
Normal (18.50–22.99)	334 (32.9)	16 (20.5)	28 (21.9)	378 (30.9)				
Overweight (23.00–24.99)	179 (17.6)	18 (23.1)	32 (25.0)	229 (18.7)				
Obese (≥25.00)	345 (34.0)	35 (44.9)	64 (50.0)	444 (36.3)				
Body mass index – BMI (kg/m^2)&								
Underweight (<18.50)	158 (15.6)	9 (11.5)	4 (3.1)	171 (14.0)	0.199	<0.0001	0.103	<0.0001
Normal (18.50–24.99)	513 (50.5)	34 (43.6)	60 (46.9)	607 (49.7)				
Overweight (25.00–29.99)	275 (27.1)	26 (33.3)	51 (39.8)	352 (28.8)				
Obese (≥30.00)	70 (6.9)	9 (11.5)	13 (10.2)	92 (7.5)				
Central obesity$	431 (42.5)	45 (58.4)	90 (69.8)	566 (46.4)	0.006	<0.0001	0.098	<0.0001
Raised blood pressure (mm/hg)								
Known hypertensive	28 (2.8)	4 (5.1)	23 (17.6)	55 (4.5)	0.225	<0.0001	0.029	<0.0001
Newly diagnosed‡	194 (19.1)	19 (24.4)	32 (24.4)	245 (20.0)				

‡150 minutes of moderate-intensity physical activity or 75 minutes of vigorous-intensity physical activity per week. #Five or more standard drinks on one occasion. †less than five standard drinks on one occasion. *Based on Asia-Pacific guidelines. & Based on WHO South-Asian cut-off. $measured by waist circumference, ≥90 cm for men and ≥80 cm for women. ‡measured by systolic blood pressure ≥140 mm/Hg and/or diastolic blood pressure ≥90 mm/Hg

as compared to 10.2% in rural Karnataka[3] and 9.5% in rural Tamil Nadu.[29]

The variation in prevalence of diabetes mellitus and prediabetes with other studies could be attributed to the different time periods of study and health transition phase of different rural communities (time for conversion of prediabetes cases into diabetes) and methods and diagnostic criteria for T2DM and prediabetes. OGTT used to diagnose diabetes mellitus is known to yield reliable and true prevalence of diabetes mellitus in communities. Other possible reasons include adaptations to urban lifestyle over time prevailing in the selected villages that were nestled within the airport developmental zone of Bengaluru.[18] Increased access to junk foods, low levels of physical activity, urban occupational patterns and high levels of tobacco and alcohol use in these villages could have contributed to higher prevalence of diabetes mellitus.

The prevalence of hypertension in three villages was 24.3%, and ratio of self-reported to newly diagnosed hypertension was 0.22:1 which suggests a higher proportion (nearly 80%) of undiagnosed hypertension in the community. Previous study done in Karnataka had reported the prevalence of hypertension as 17.3%, and only 30% were aware of their hypertension status.[30] As hypertension is an established modifiable risk factor for cardiovascular diseases, public prevention strategies addressing increased awareness, early

Table 4: Association of socio-demographic, behavioural and metabolic risk factors with type 2 diabetes mellitus and prediabetes among the study participants aged 18–69 years and residing in Bengaluru rural district, *n*=1234

Socio-demographic characteristics	Prediabetes				Diabetes			
	Unadjusted odds ratio (95% CI)	*P*	Adjusted odds ratio (95% CI)	*P*	Unadjusted odds ratio (95% CI)	*P*	Adjusted odds ratio (95% CI)	*P*
Age (in years)								
18–29	1.00		1.00		1.00		1.00	
30–44	4.63 (1.91-11.19)	0.001	3.92 (1.59-9.61)	0.003	9.45 (2.89-30.99)	<0.0001	6.48 (1.93-21.68)	0.002
≥45	6.09 (2.54-14.59)	<0.0001	5.02 (1.98-12.74)	0.001	27.09 (8.50-86.34)	<0.0001	20.18 (6.13-66.49)	<0.0001
Gender								
Female	1.00		1.00		1.00		1.00	
Male	0.63 (0.39-1.03)	0.063	0.65 (0.39-1.09)	0.104	1.70 (1.19-2.45)	0.004	1.65 (1.03-2.64)	0.036
Education								
Literate	1.00		1.00		1.00		1.00	
Illiterate	2.12 (1.28-3.48)	0.004	1.51 (0.85-2.68)	0.163	1.78 (1.19-2.66)	0.005	1.30 (0.79-2.15)	0.297
Family history of diabetes mellitus								
No	1.00		1.00		1.00		1.00	
Yes	1.51 (0.89-2.56)	0.120	1.43 (0.83-2.49)	0.200	1.75 (1.18-2.60)	0.005	1.89 (1.20-2.95)	0.006
Physical activity			Excluded for multivariate analysis					
Sufficient	1.00			1.00		1.00		
Insufficient	1.12 (0.76-1.92)	0.413		1.57 (1.09-2.25)	0.015	1.73 (1.16-2.57)	0.007	
Intake of fruits and vegetables						Excluded for multivariate analysis		
Sufficient	1.00			1.00				
Insufficient	0.98 (0.54-1.79)	0.958		0.99 (0.62-1.58)	0.958			
Ever tobacco use								
No	1.00			1.00		1.00		
Yes	1.01 (0.62-1.63)	0.974		1.46 (1.01-2.09)	0.041	0.92 (0.59-1.45)	0.731	
Ever alcohol use								
No	1.00			1.00		1.00		
Yes	0.89 (0.44-1.84)	0.762		1.99 (1.28-3.12)	0.002	1.22 (0.68-2.19)	0.512	
Central obesity								
No	1.00		1.00		1.00		1.00	
Yes	1.90 (1.19-3.05)	<0.0001	1.16 (0.63-2.15)	0.633	2.99 (2.01-4.43)	<0.0001	1.71 (1.01-2.90)	0.047
Overweight (BMI ≥25.00 kg/m^2)								
No	1.00		1.00		1.00		1.00	
Yes	1.99 (1.22-3.25)	0.006	1.77 (0.92-3.41)	0.086	2.68 (1.77-4.08)	<0.0001	1.65 (0.95-2.89)	0.079
Raised blood pressure (mm/hg)								
No	1.00		1.00		1.00		1.00	
Yes	1.49 (0.90-2.49)	0.120	1.04 (0.61-1.79)	0.881	2.51 (1.73-3.65)	<0.0001	1.34 (0.89-2.03)	0.166

identification and appropriate management (therapeutic and lifestyle modifications) would help in reduction of morbidity and mortality due to hypertension.

The prevalence of current tobacco and alcohol use was 32.7% and 9.9% respectively in this study. The NNMS survey had reported similar prevalence (36.8%) of current tobacco use among rural adults.[27] The 'Global Adult Tobacco Survey-2' (GATS-2, 2016–17) had reported lower prevalence of current tobacco use (22.8%) in Karnataka.[31] The NFHS-5 had reported 42.9% of rural men and 4.9% of woman who use any kind of tobacco.[28] Higher prevalence of alcohol use was reported in NNMS (16.7%),[27] NFHS-5 (26%),[28] and 'magnitude of substance use in India' (14.6%)[32] as compared to this study. Recent literature highlights the increasing rising tobacco and alcohol use in India in rural population and among young adults.[33,34] Alcohol use was higher among prediabetes and diabetes groups in this study when compared to normal individuals. Role of alcohol on glucose and carbohydrate metabolism with increasing insulin resistance is a matter of concern to be addressed in the management of T2DM.

Community-based studies in rural areas and NNMS (98.7%) had reported that more than 80% of adults were consuming reduced amounts of fruits and vegetables a finding consistent with this study.[27,35] Factors that determine their intake include lack of awareness, rice-based meals and limited availability of fruits and vegetables within the villages. Nearly half (46.8%) of

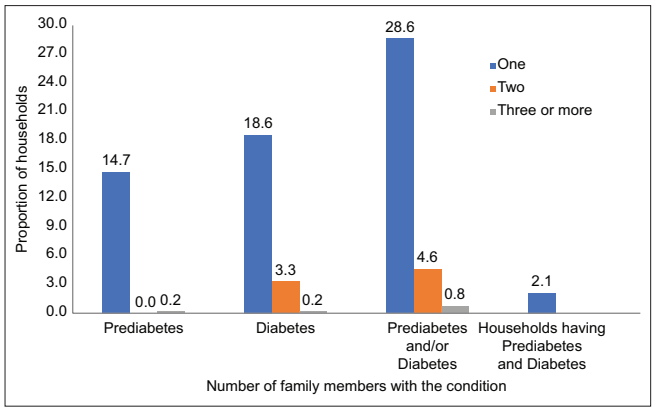

Figure 2: Proportion of households with prediabetes and diabetes

the participants had reported inadequate physical activity that is comparable with other epidemiological studies done in rural areas (42.3%) and the recently completed NNMS (48.6%).[27,35]

The prevalence of obesity (BMI ≥25 Kg/m^2) was found to be 46.2%. NNMS had reported the prevalence of overweight/obesity among rural adults as 21.7%.[27] The NFHS-5 had reported the levels of overweight/obesity to be 30.2% in Karnataka.[28] The higher prevalence of obesity within the selected villages may be attributed to the lifestyle changes due to changing pattern of occupations and levels of physical activity in these villages.

Determinants of T2DM prevalence were increasing age, male sex, lower levels of physical activity and presence of family history of diabetes mellitus after adjustments for other socio-demographic, behavioural and metabolic risk factors. Central obesity, overweight and raised blood pressure were associated with T2DM in univariate analysis but this association was nullified in multivariate analysis. This could be due to the confounding effect of physical activity coupled with central obesity and raised blood pressure. Similar community-based studies had reported that abdominal obesity, generalized obesity, tobacco and alcohol use were significant determinants for T2DM.[3,28,35-37] Family history of diabetes mellitus was significantly associated with diabetes mellitus indicating the genetic susceptibility prevailing across generations.

Prediabetes was significantly associated with increased age after adjustments for other socio-demographic, behavioural and metabolic risk factors. Physical inactivity and family history of diabetes mellitus were significantly associated with prediabetes in other studies.[3] Low prevalence of prediabetes in the study population limited the analysis in detecting any associations with risk factors and prediabetes.

Strengths and limitations

This study employed the OGTT as the diagnostic method for diabetes mellitus within a community-based setting. This approach is notable as it represents a more accurate assessment of the true prevalence of prediabetes and T2DM compared to glycated haemoglobin (HbA1C) or random blood glucose levels or FBG levels.[38] Further, the demonstration of OGTT in a community rural setting is significant in terms of the feasibility of considering the test in population-based screening and diagnosis.

The current study is a comprehensive assessment of NCD risk factors with screening for blood glucose and blood pressure in the selected rural population. Cross-sectional nature of the study limits the temporal association of risk factors with the occurrence of prediabetes and diabetes. There could be underreporting of tobacco and alcohol in this study due to social desirability bias. This paper did not include an analysis of sensitivity and specificity for FBS, OGTT and HbA1C in detecting T2DM.

Implications and recommendations

The study has highlighted that NCD risk factors, prediabetes and diabetes are significant problems undetected in rural villages in Karnataka. The recent results on the pattern of metabolic NCDs in India revealed two concerning trends. Firstly, the study found an alarming rise in the prevalence of prediabetes in rural areas, with overall proportions of prediabetes being similar in rural and urban India. Secondly, it highlighted the spread of the NCD epidemic to the rural areas that lack sufficient health infrastructure to effectively diagnose and manage these conditions.[39] As a result, it is imperative to strengthen the public healthcare system and enhance its capacity to diagnose and manage prediabetes and diabetes through the implementation of OGTT in both community and hospital settings.

More than one-third of the diabetes mellitus and three-fourths of hypertension were newly diagnosed from the screening camp. This merits further referral and confirmation of diagnosis for those individuals. This also highlights the need for population-based screening and early diagnosis of hypertension and T2DM in this population. Early diagnosis and treatment of undiagnosed diabetes mellitus and hypertension by the National NCD Programme (NP-NCD) and the health and wellness centres of the Ayushman Bharat's Universal Health Coverage scheme are equally important.[40] Robust health system performance along with targeted individual-level interventions are required from screening to initiation of treatment, adherence to treatment and prevention of complications of diabetes so as to ensure continuum of care for diabetes.[41]

Role of primary care physicians and family practitioners

The findings of our study underscore the critical role of primary care physicians and family practitioners in addressing the escalating burden of prediabetes and diabetes within their patient populations. Primary care physicians are well-equipped to engage with their patients on a personal level, considering individual preferences, cultural practices and socio-economic constraints when devising personalized management plans. They are uniquely positioned to implement preventive measures and lifestyle interventions that can effectively curb the progression

of prediabetes to overt diabetes. With early identification and intervention, primary care providers can empower patients to make meaningful lifestyle modifications, such as dietary changes, increased physical activity and weight management, which have demonstrated efficacy in preventing or delaying the onset of diabetes. By establishing trust and rapport with their patients, family physicians can facilitate sustained behaviour change and adherence to recommended interventions, ultimately reducing the long-term burden of diabetes-related complications on both individual health outcomes and healthcare systems.

Conclusion

The study has reinforced that health transition of rural population is an important public health concern to be addressed. National programmes and policies should plan the inclusion of specific diagnostic tests like the OGTT for accurate and early diagnosis at the village level. Better screening, health promotion to prevent prediabetes and health system monitoring of prediabetes and diabetes individuals are all crucial interventions that need to be strengthened in rural populations to 'Halt the rise of DM', one of the National NCD targets of India. The findings of this study underscore the indispensable role of primary care physicians and family practitioners in addressing the epidemic of prediabetes and diabetes at the community level.

Acknowledgements

We would like to acknowledge the study participants for their interest to participate, district and taluk health officials for administrative permissions, village leaders, Anganwadi workers and school teachers for their support during the conduct of the study. The work carried out by ICMR-NCDIR staff in the field is much acknowledged.

Ethical approval

The study was approved by the Institutional Ethics Committee of ICMR-NCDIR.

Financial support and sponsorship

The study was supported by intra-mural grant of ICMR-NCDIR.

Conflicts of interest

There are no conflicts of interest.

References

1. GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: A systematic analysis for the Global Burden of Disease Study 2019. Lancet 2020;396:1204-22.
2. World Health Organization. Noncommunicable Diseases Country Profiles 2018. Geneva: World Health Organization; 2018.
3. Anjana RM, Deepa M, Pradeepa R, Mahanta J, Narain K, Das HK *et al.* Prevalence of diabetes and prediabetes in 15 states of India: Results from the ICMR–INDIAB population-based cross-sectional study. Lancet Diabetes Endocrinol 2017;5:585-96.
4. Centers for Disease Control and Prevention. Prediabetes: Your chance to prevent type 2 diabetes. Atlanta (GA): Centers for Disease Control and Prevention; 2021. Available from: https://www.cdc.gov/diabetes/basics/prediabetes.html. [Last accessed on 2024 Mar 18].
5. Tabak AG, Herder C, Rathmann W, Brunner EJ, Kivimaki M. Prediabetes: A high-risk state for developing diabetes. Lancet 2012;379:2279–90.
6. Prakoso DA, Mahendradhata Y, Istiono W. Family involvement to stop the conversion of prediabetes to diabetes. Korean J Fam Med 2023;44:303-10.
7. Ma RCW, Tong PCY. Epidemiology of type 2 diabetes. Holt RIG, Flyvbjerg A, editors. Textbook of Diabetes. 6th ed. ch 4. UK: Wiley-Blackwell, John Wiley & Sons Ltd; 2024. p. 55-74.
8. Kumar A, Gangwar R, Zargar AA, Kumar R, Sharma A. Prevalence of diabetes in India: A review of IDF Diabetes Atlas 10th Edition. Curr Diabetes Rev 2024;20:e130423215752.
9. Babu BV, Hazarika CR, Raina SK, Masoodi SR, Basappa YC, Thomas N, *et al.* Prevalence of type 2 diabetes among tribal population of India: A multi-centric cross-sectional study. J Natl Med Assoc. 2024;116:153-64.
10. Kosiborod M, Gomes MB, Nicolucci A, Pocock S, Rathmann W, Shestakova MV, *et al.* Vascular complications in patients with type 2 diabetes: Prevalence and associated factors in 38 countries (the DISCOVER study program). Cardiovasc Diabetol 2018;17:150.
11. Government of India. National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases, and Stroke. Operational guidelines (revised 2013-17). 2013. Available from: https://mohfw.gov.in/sites/default/files/Operational%20Guidelines%20of%20NPCDCS%20%28Revised%20-%202013-17%29.pdf. [Last accessed on 2020 Mar 07].
12. Madhu B, Prathyusha K, Prakruthi P, Srinath KM. Comparison of prevalence of life style risk factors and 10 year risk of CVD event among rural and tribal population of Kollegal Taluk, Chamrajanagar district, South India. Diabetes Metab Syndr 2019;13:2961-6.
13. Kavi A, Walvekar PR, Patil RS. Biological risk factors for coronary artery disease among adults residing in rural area of North Karnataka, India. J Family Med Prim Care 2019;8:148-53.
14. Jeyalakshmi K, Devi ES, Rao M, Shashidhara YN, Thunga G. Factors associated with dietary and exercise compliance among elderly with chronic conditions of hypertension and type 2 diabetes mellitus residing in rural areas of coastal Karnataka: A community-based cross-sectional study. J Edu Health Promot 2024;13:45.
15. Angadi N, Shubha DB. Social support and medication adherence among people with type 2 diabetes mellitus in central Karnataka, India. National J Comm Med 2023;14:834-41.
16. Muninarayana C, Balachandra G, Hiremath SG, Iyengar K, Anil NS. Prevalence and awareness regarding diabetes mellitus in rural Tamaka, Kolar. Int J Diabetes Dev Ctries 2010;30:18-21.
17. Poornima MP, Walvekar PR. Prevalence of type 2 diabetes mellitus among adults aged between 30 to 60 years residing in rural area: A cross sectional study. Int J Community Med Public Health 2018;5:3639-42.
18. Department of Planning, Programme Monitoring and

Statistics, Government of Karnataka. Economic Survey of Karnataka – 2021-22. March 2022. Available from: https://planning.karnataka.gov.in/storage/pdf-files/Reports/KARNATAKA%20ECONOMIC%20SURVEY%202021-22-M2_ENG_FINAL.pdf. [Last accessed on 2024 Mar 18].

19. Dean AG, Sullivan KM, Soe MM. OpenEpi: Open Source Epidemiologic Statistics for Public Health. [updated 2013 April 06]. Available from: www.OpenEpi.com. [Last accessed on 2020 Apr].
20. Sarveswaran G, Kulothungan V, Mathur P. Clustering of noncommunicable disease risk factors among adults (18-69 years) in rural population, South-India. Diabetes Metab Syndr 2020;14:1005-14.
21. Anjana RM, Pradeepa R, Deepa M, Datta M, Sudha V, Unnikrishnan R, *et al*. The Indian Council of Medical Research-India Diabetes (ICMR-INDIAB) study: Methodological details. J Diabetes Sci Technol 2011;5:906-14.
22. World Health Organization; International Diabetes Federation. Definition and Diagnosis of Diabetes Mellitus and Intermediate Hyperglycemia: Report of a WHO/IDF Consultation. Geneva: World Health Organization; 2006.
23. World Health Organization. WHO STEPS surveillance manual: The WHO STEPwise Approach to Chronic Disease Risk Factor Surveillance. Geneva: World Health Organization; 2005.
24. National Institute of Medical Statistics and Indian Council of Medical Research (ICMR). IDSP Non-Communicable Disease Risk Factors Survey. Phase I. New Delhi, India; 2009.
25. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004;363:157-63.
26. World Health Organization. International Association of Study of Obesity, International Obesity Task Force: The Asia-Pacific Perspective. Redefining Obesity and Its Treatment. Available from: www.wpro.who.int/nutrition/documents/Redefining_obesity/en/. [Last accessed on 2020 Apr 07].
27. Indian Council of Medical Research-National Centre for Disease Informatics and Research (ICMR-NCDIR). National Noncommunicable Disease Monitoring Survey (NNMS) 2017–18, Bengaluru, India.
28. International Institute for Population Sciences (IIPS) and ICF. National Family Health Survey (NFHS-5), 2019-21: India. Volume I. Mumbai: IIPS; 2021.
29. Little M, Humphries S, Patel K, Dodd W, Dewey C. Factors associated with glucose tolerance, pre-diabetes, and type 2 diabetes in a rural community of south India: A cross-sectional study. Diabetol Metab Syndr 2016;8:21.
30. Prenissl J, Manne-Goehler J, Jaacks LM, Prabhakaran D, Awasthi A, Bischops AC, *et al*. Hypertension screening, awareness, treatment, and control in India: A nationally representative cross-sectional study among individuals aged 15 to 49 years. PLoS Med 2019;16:e1002801.
31. Tata Institute of Social Sciences (TISS), Mumbai and Ministry of Health and Family Welfare, Government of India. Global Adult Tobacco Survey GATS 2 India 2016-17.
32. Ambekar A, Agarwal A, Rao R, Mishra A, Khandelwal SK, Chadda RK, *et al*. Magnitude of Substance Use in India. New Delhi: Ministry of Social Justice and Empowerment, Government of India; 2019.
33. Mohan P, Lando HA, Panneer S. Assessment of tobacco consumption and control in India. Indian J Clin Med 2018;9:1–8.
34. Prasad R. Alcohol use on the rise in India. Lancet 2009;373:17-8.
35. Muthunarayanan L, Ramraj B, Russel JK. Prevalence of prediabetes and its associated risk factors among rural adults in Tamil Nadu. Arch Med Health Sci 2015;3:178-84.
36. Subramani SK, Yadav D, Mishra M, Pakkirisamy U, Mathiyalagen P, Prasad G. Prevalence of Type 2 diabetes and prediabetes in the Gwalior-Chambal region of Central India. Int J Environ Res Public Health 2019;16:4708-13.
37. Joshi H. Unpacking the burden of hypertension and diabetes in Karnataka: Implications for policy and practice based on NFHS-5 findings. Int J Diabetes Dev Ctries 2023;44:1-7.
38. Anderson P, Grills N, Singh R, Singh R, Evans RG, Sengupta P, *et al*. Prevalence of diabetes and pre-diabetes in rural Tehri Garhwal, India: Influence of diagnostic method. BMC Public Health 2019;19:817.
39. Anjana RM, Unnikrishnan R, Deepa M, Pradeepa R, Tandon N, Das AK, *et al*. Metabolic non-communicable disease health report of India: The ICMR-INDIAB national cross-sectional study (ICMR-INDIAB-17). Lancet Diabetes Endocrinol 2023;11:474-89.
40. National Health Systems Resource Centre. Operational Guidelines, Health and Wellness Centres for Comprehensive Primary Health Care. 2018. Available from: http://nhsrcindia.org/sites/default/files/Operational%20Guidelines%20For%20Comprehensive%20Primary%20Health%20Care%20through%20Health%20and%20Wellness%20Centers.pdf. [Last accessed on 2020 Mar 18].
41. Mathur P, Leburu S, Kulothungan V. Prevalence, awareness, treatment and control of diabetes in India from the countrywide National NCD Monitoring survey. Front Public Health 2022;10:748157.