Original Article

Prevalence of undiagnosed diabetes and pre-diabetes and its associated risk factors in Vietnam

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ABSTRACT

Background: Diabetes mellitus (DM) has rapidly become a significant public health concern in Vietnam. Although the prevalence of DM has been studied in northern and southern Vietnam, little data are available for the central region of the nation. Hence, this study aimed to estimate the prevalence of undiagnosed diabetes and prediabetes and its risk factors in a mixed urban and rural setting.

Methods: We conducted a cross-sectional study in Khanh Hoa Province with 865 subjects (349 men and 516 women), who were aged 45 years and over and were randomly sampled by probability proportional to size method. The data of residents were collected by interviewing, anthropometric and clinical measurements — these factors associated with undiagnosed diabetes that were analyzed by using Logistic regression model.

Results: Based on using the age-standardized method, the prevalence of undiagnosed type 2 diabetes mellitus (T2DM) and prediabetes in Vietnam based on fasting plasma glucose or hemoglobin A1c were 8.1% and 50.1%, respectively. Risk factors were significantly increased the prevalence of both of undiagnosed T2DM and prediabetes including waist circumference, visceral fat level, metabolic syndrome, history of family diabetes, history of hypertension.

Conclusion: The findings of our study were showed that the high proportions of prediabetes and undiagnosed diabetes in Vietnam. Our results suggest that the barriers to accessing screening programs and factors related to inadequate glycemic control should be investigated. Hence, the public health system should be playing the role of increasing awareness of and screening for diabetes in the community.

Keywords: Undiagnosed type 2 diabetes; Prediabetes; Risk factors; Vietnam

INTRODUCTION

Type 2 diabetes mellitus (T2DM) as one of the major non-communicable diseases (NCDs) that has become a growing public health concern nowadays.¹ Like many other developing countries, the model of disease of Vietnam population is undergoing epidemiological transition speed, resulting in an increased burden on NCDs. In these countries, the

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Author Contributions

Conceptualization: Nguyen VD, Vien QM, Nguyen HC, Chon Y; Data curation: Nguyen VD, Vien QM, Do TH, Phan CD, Nguyen VT; Formal analysis: Nguyen VD, Chon Y; Investigation: Nguyen VD, Nguyen DL, Nguyen VT, Vien QM; Methodology: Nguyen VD, Vien QM, Do TH, Chon Y, Sir WS; Validation: Nguyen VD, Vien QM, Nguyen HC, Chon Y; Writing - original draft: Nguyen VD, Chon Y; Writing - review & editing: Nguyen VD, Chon Y, Sir WS.

prevalence of T2DM, as same as those of chronic diseases, has been rising steadily, and Vietnam is no exception. According to the national survey in 2012, the prevalence of T2DM was estimated at about 5.4%, the figures in rural areas (5.2%) and urban areas (6.7%), which increase in double than previous surveys (1.4% in the northern in 1994; and 3.8% in the southern in 2004).²⁻⁴ Availability and accessibility of health care service and other known and unknown personal condition are major barriers that introduce a delay in diagnosis of T2DM.

Diabetes has complex health consequences. Additionally, patients may experience unexpected serious health problems in later life if it remains undiagnosed for long time. These patients are at greater risk of experiencing coronary heart disease, a stroke, peripheral vascular disease, and dyslipidemia.⁵ In Vietnam, up to 70% of diabetes patients were treated without diagnosis so that more than 85% of them are found to have serious complications that are hard to treat.⁶ According to the literature review, the information on national wide prevalence of T2DM is very limited and especially, there is no data regarding the undiagnosed T2DM and pre-diabetes in each geographical region (urban and rural) in Vietnam.³ Therefore, we conducted this study to obtain the estimate of prevalence of prediabetes and undiagnosed T2DM and investigate their risk factors.

METHODS

Study design

This study is a population-based cross-sectional study.

Study setting

This study was conducted from April 2016 to October 2017 in Khanh Hoa Province in Southern Central of Vietnam where is an area of almost 5,218 km² and its population is about 1.3 million in 2017. This province is the hub for the economy, tourism and culture in the southern central Vietnam where 32 ethnic groups are gathered. Also, this province is a center for medical access where some national health institutions are located.⁷

Inclusion and exclusion criteria

We targeted adult residents of Khanh Hoa Province aged 45 years old and over who agreed to participate and signed a consent form. The exclusion criteria include: pregnant women or those who gave birth within previous 3 months; people with diseases such as hyperthyroidism, pancreatitis, pancreatic cancer, Cushing's syndrome, pheochromocytomatous; people who are using drugs that affects on blood glucose level such as: corticoids, estrogen, diuretics, antidepressants, non-steroid anti-inflammatory drugs. People who has been diagnosed with pre-diabetes or diabetes with another testing and/or who was not willing to participate and did not sign a consent form were also excluded.

Sample size and sampling

The required sample size was 765 as determined using the equation $n = Z^2_{(1-\alpha/2)} \times p(1-p) \times DE/d^2$ to estimate the prevalence of disease in the community where a level of confidence (Z) of 1.96 for a 95% confidence interval (CI), an estimated prevalence of DM (p) of 0.21.⁸ A design effect of 3.0, and d = 0.05 were assumed. As a precaution, due to the lack of sample size for some reason, people who may not want to participate to the study or be disqualified by not reaching that standard object selection. Thus, we took an additional 20% (i.e., 153 persons) in the sample (the total of sample size is considered as = 918). This study was conducted in 30

Fig. 1. Geographical of sample selection.

residential areas, so each cluster should enrolled 31 persons ($918/30 = 30.6$ persons). Thus, the final sample size is 30 times 31 that equals 930.

At first stage, we randomly selected 30 communes/wards out of 137 communes/wards by applying probability proportionate to size (PPS) from list of the population in Khanh Hoa Province. Then we randomly selected 2 villages from each of commune/ward by PPS at the 2nd stage. Finally, we randomly selected a total of 865 residents from the list of residents. The rate of acceptance to enroll in the study was around 93%. The geographical layout of 30 communes/wards is shown in Fig. 1.

Data collection

The data of this study was collected through face-to-face interviews using a questionnaire (Supplementary Data 1), which has been validated and standardized for the Vietnamese population in 2009. Interview for subjects with regards to demographics, medical history, or lifestyle habit questionnaires and the collection of 5 mL of blood sampling were conducted. Blood samples were sent to the laboratory department of Pasteur Institute in Nha Trang and tested for hemoglobin A1c (HbA1c), glucose, and lipid.

Case definitions

Participants' blood were collected after fasting at least 8 hours following the instructed in invitation letters which were sent by staffs of commune health centers. In our study, undiagnosed diabetes was defined as not having self-reported T2DM at the time of acceptance to participate in the study but having blood glucose measures that meet American Diabetes Association (ADA) guidelines 2017 for diagnostic diabetes, HbA1c $\geq 6.5\%$ or fasting plasma glucose (FPG) ≥ 7.0 mmol/L. Prediabetes was defined as HbA1c between 5.7% and 6.4% or FPG between 5.6 and 6.9 mmol/L.⁹ Residential areas were categorized as either rural or urban communes which were determined in each commune by the government. Height was determined without shoes by using HM200P (Charder company, Tokyo, Japan). Body mass index (BMI) was calculated with the equation of body weight (kg) divided by the square of height (m^2) and it classified participants into 4 groups: < 18.5 (underweight), 18.5–22.9 (normal), 23.0–24.9 (overweight) and ≥ 25.0 (obese). Waist circumference (WC) was measured at the midpoint of the last palpable rib and the top of the hip bone horizontally (mostly at

the height of bellybutton). Hip circumference (HC) was measured around the maximum circumference of the buttocks horizontally. Waist to hip ratio (WHR) was derived as the ratio of WC over HC. Central obesity was defined as WHR > 0.85 cm (women) or > 0.9 cm (men). Blood pressure (BP) was measured twice in a sitting position after participants rested for at least 5 minutes. The mean of the 2 values was used in the analysis. Hypertension (HTN) was defined as an elevated BP of systolic BP ≥ 140 mmHg and/or diastolic BP ≥ 90 mmHg. Hyperlipidemia was determined as the existence of any of following factors: 1) high triglyceride level as ≥ 1.7 mmol/L; 2) low high-density lipoprotein cholesterol (HDL-C) level as < 1.0 mmol/L for males and < 1.3 for females. Metabolic syndrome (MetS) was defined as the existence of any 3 of the following 5 factors: 1) WC ≥ 90 cm for males or ≥ 80 cm for females in the Asian population; 2) triglyceride level ≥ 1.7 mmol/L (150 mg/dL); 3) HDL-C level < 1.03 mmol/L (40 mg/dL) for males and < 1.29 mmol/L (50 mg/dL) for females; 4) systolic BP ≥ 130 mmHg and/or diastolic ≥ 85 mmHg; and 5) FPG level ≥ 5.6 mmol/L (100 mg/dL). Body fat percentage was measured by bioelectrical impedance method using OMRON scale (HBF-375; OMRON Healthcare Co., Kyoto, Japan) with criteria: low: male < 10%, female < 20%, normal: 10% < male < 20%, 20% < female < 30%; high: male $\geq 20\%$, female $\geq 30\%$, respectively. Level of physical activity for job was defined as: low: no work; moderate: not heavy work (e.g., office worker, teacher, retired worker, and houseworker, etc.); high: heavy work (e.g., farmer and manual worker, etc.). Monthly household income was defined as: poverty: < 700,000 Vietnamese Dong (VND) for rural area; < 900,000 VND for urban area; near poverty: 700,000–< 1,000,000 VND for rural area; 900,000–< 1,300,000 VND for urban area; medium level or higher: > 1,000,000 VND for rural area; > 1,300,000 VND for urban area.¹⁰

The process of the survey

We were divided 2 survey teams with 6 supervisors and 18 surveyors who were selected among researchers at Pasteur Institutes in Nha Trang and medical officers at Endocrinology central of Khanh Hoa Provincial Health Service. Two-days of pre-survey training including pretest of questionnaire and trial of procedure in the survey were conducted, and the questionnaire was also finalized - the general information on this survey and instruction of 8-hours-fasting for the test of fasting blood glucose in an announcement letter to participants.

The study was conducted at 30 Community Health Centers by inviting participants living in 60 villages. After explaining the study's purpose, the participants who had agreed to participate and sign an informed consent would be referred by doctors for the check-up of eligibility criteria of the study. If participant is eligible for the study, venous blood sample (5 mL) was taken from each participants and it would be divided into ethylenediaminetetraacetic acid or plain blood tubes. The former tubes were kept in the special blood container (CubeCooler; Forte Grow Medical Co., Ltd., Tochigi, Japan) at 0°C–5°C. Blood in the latter tubes was centrifuged at 3,000 rpm for 15 minutes within 30 minutes after blood drawn, and the supernatant serum was transferred into microtubes, which were kept into a box with an ice pack in order to avoid degrading glucose level by time in whole blood at room temperature. In next steps, the participant moved to another room for anthropometric measurement, including height, weight, BP, waist, and HC, body fat percentage and visceral fat level. All the anthropometric data was recorded on the questionnaire. After measures, a face-to-face interview was arranged to obtain a brief questionnaire comprising socio-demographic profile, lifestyle activities, and habits, medical history. All questionnaires were reviewed by supervisors in study staffs to ensure that all the information were appropriately marked.

Laboratory analysis

A venous blood sample (5 mL) was taken from each participant, which transported to the lab in Pasteur Institute in Nha Trang. The blood sample was tested for HbA1c, glucose, total cholesterol, HDL-C, and triglyceride. The HbA1c level was measured with high-pressure liquid chromatography method with HLC-723 G8 (Tosoh, Tokyo, Japan).

Statistical analysis

All questionnaire and data collected in the study was entered into Epidata 3.1 software. For data analysis, we proceeded the univariate tests and checked the effect modification between independent variables. Variables used for the final logistic model needed to show the statistical significance from univariable test (with $P < 0.05$). All statistical analyses were performed using R language and SPSS version 20.0 (IBM, Armonk, NY, USA).

Ethical considerations

The general information of study was given to each participant with verbal briefing and explanation in the invitation letter to subjects. All participants signed or provide thumbprint in a informed consent before the conduct the interview, anthropometric measurements, blood sample, and the examined medical records were delivered to participants. Ethical approval of this protocol was approved by Khanh Hoa Province People's Committee and the Provincial Health Department (01/HĐĐĐ-SYTKH).

RESULTS

A total of 930 participants were approached and invited for participation, the 865 study participants were recruited (participation rate of 93%). The reasons for the failure of enrollment were moving out of area, away for work in forests or Ho Chi Minh City in the South of Vietnam for a certain period, or refusal of participation.

Table 1 presents the general demographic characteristics of participants, women accounted for 59.7% of all participants. Rural residents accounted for 56.8% and 50.5% of all participants were age group 45–54 years' old. More than 82% of subjects were married. Approximately 20% of participants attended no school — primary school uncompleted, and the majority of occupations of participants were farmer (32.8%) where majority of participants were doing daily physical activity or exercise somehow. The level of household income was so quite high in medium level or higher level (65.6%). Among the participants, 34.7% and 47.4% of men and women, respectively were classified as overweight/obesity according to BMI, 16.9% and 51.9% as having high WC, and 33.0% and 85.5% as having high WHR. Systolic BP and diastolic BP in men were higher than women (47.3% vs. 39.1%, 38.7% vs. 31.2%, respectively) and, 53.6% and 44.8% of men and women are classified as having HTN, respectively, 10.9% and 28.9% as having MetS, 63.9%, and 75.8% as having high percent body fat, and 43.0% and 29.1% as having high visceral fat level.

Table 2 presents that the age-specific prevalence of undiagnosed diabetes or prediabetes were consistently higher with increasing age regardless of gender. In all subjects, the crude prevalence of diabetes was 7.7% (95% CI, 5.96–9.53), and prediabetes was 50.6% (95% CI, 47.29–53.97). The age-standardized prevalence rate of diabetes and prediabetes were 8.1% (95% CI, 6.24–10.13) and 50.1% (95% CI, 46.63–53.52), respectively. Notably, there was higher prevalence of diabetes among women than men after adjustment (9.1% vs. 7.0%),

Table 1. Characteristic of enrolled subjects in Vietnam, 2016–2017

Category	No. (%)		
	Total	Men	Women
No. of participants	865 (100.0)	349 (40.3)	516 (59.7)
Age group			
45–54	437 (50.5)	178 (51.0)	259 (50.2)
55–64	273 (31.6)	106 (30.4)	167 (32.4)
≥ 65	155 (17.9)	65 (18.6)	90 (17.4)
Marital status			
Currently married	715 (82.7)	332 (95.1)	383 (74.2)
Never married	22 (2.5)	4 (1.1)	18 (3.5)
Divorced/widowed	128 (14.8)	13 (3.7)	115 (22.3)
Residential area			
Urban	374 (43.2)	159 (45.6)	215 (58.3)
Rural	491 (56.8)	190 (54.4)	301 (41.7)
Educational level completed			
No school — primary school uncompleted	156 (18.0)	37 (3.4)	119 (11.1)
Primary school	204 (23.6)	69 (19.8)	135 (26.2)
Secondary school	271 (31.3)	118 (33.8)	153 (29.7)
High school	182 (21.1)	104 (29.8)	78 (15.1)
College/university	52 (6.0)	21 (6.0)	31 (6.1)
Occupation			
Farmer	284 (32.8)	146 (41.8)	138 (26.7)
Office worker	47 (5.4)	24 (6.9)	23 (4.5)
Service worker	78 (9.0)	54 (15.5)	24 (4.7)
Business	107 (12.4)	15 (4.3)	92 (17.8)
Homemaker, No job	169 (19.5)	7 (2.0)	162 (31.4)
Retired	70 (8.1)	35 (10.0)	35 (6.8)
Other	110 (12.8)	68 (19.5)	42 (8.1)
Level of job physical activity			
Low	754 (87.2)	301 (86.2)	453 (87.8)
Moderate	65 (7.5)	27 (7.7)	38 (7.4)
High	46 (5.3)	21 (6.1)	25 (4.8)
Household income			
Poverty level	142 (16.4)	51 (14.6)	91 (17.6)
Near poverty	156 (18.0)	59 (16.9)	97 (18.8)
Medium level or higher	567 (65.6)	239 (68.5)	328 (63.6)
BMI			
Underweight	117 (13.5)	63 (18.1)	54 (10.5)
Normal	382 (44.2)	165 (47.3)	217 (42.1)
Overweight	190 (22.0)	70 (20.1)	120 (23.2)
Obese	176 (20.3)	51 (14.6)	125 (24.2)
WC	327 (37.8)	59 (16.9)	268 (51.9)
WHR	556 (64.3)	115 (33.0)	441 (85.5)
Systolic BP	367 (42.4)	165 (47.3)	202 (39.1)
Diastolic BP	296 (34.2)	135 (38.7)	161 (31.2)
HTN	418 (48.3)	187 (53.6)	231 (44.8)
High percent body fat	614 (71.0)	223 (63.9)	391 (75.8)
High visceral fat level	300 (34.7)	150 (43.0)	150 (29.1)
MetS (n = 499)*	190 (21.6)	38 (10.9)	149 (28.9)
Hyperlipidemia (n = 499)*	363 (72.7)	163 (46.7)	265 (51.4)

BMI = body mass index; WC = waist circumference; WHR = waist to hip ratio; BP = blood pressure; MetS = metabolic syndrome; HTN = hypertension; DM = diabetes mellitus.

*Number of subjects with missing value were damaged 6 samples (67 cases undiagnosed DM and 432 case pre-DM).

Prevalence of undiagnosed diabetes and risk factors in Vietnam

Table 2. Age-standardized of the prevalence of undiagnosed diabetes and prediabetes (95% CI) in Vietnam

Category	Percentage (95% CI)					
	Undiagnosed diabetes			Prediabetes		
	Based on HbA1c (n = 49)	Based on FPG (n = 49)	Based on HbA1c or FPG (n = 67)	Based on HbA1c (n = 396)	Based on FPG (n = 192)	Based on HbA1c or FPG (n = 438)
Age group						
45–54	3.4 (1.71–5.14)	5.3 (3.16–7.36)	5.7 (3.53–7.90)	42.4 (37.68–47.15)	21.0 (17.07–24.95)	49.5 (44.66–54.36)
55–64	6.2 (3.34–9.11)	4.4 (1.94–6.84)	8.1 (4.80–11.30)	55.4 (49.33–61.59)	25.7 (20.33–31.00)	61.8 (55.69–67.80)
≥ 65	11.0 (5.99–15.94)	9.0 (4.46–13.59)	12.9 (7.56–18.23)	54.3 (45.93–62.76)	27.0 (19.53–34.36)	58.5 (50.10–66.93)
Unadjusted	5.7 (4.12–7.20)	5.7 (4.12–7.20)	7.7 (5.96–9.53)	45.8 (42.45–49.10)	22.1 (19.42–24.97)	50.6 (47.29–53.97)
Age-adjusted*	6.1 (4.38–7.81)	6.1 (4.35–7.74)	8.1 (6.24–10.13)	45.5 (42.06–48.91)	22.0 (19.17–24.89)	50.1 (46.63–53.52)
Gender*						
Men	4.0 (1.87–6.15)	5.6 (3.06–8.17)	7.00 (4.19–9.81)	45.8 (40.37–51.20)	22.3 (17.79–26.85)	51.2 (45.77–56.64)
Women	7.6 (5.13–10.11)	6.4 (4.09–8.65)	9.1 (6.39–11.71)	45.2 (40.86–49.70)	21.7 (18.06–25.37)	49.3 (44.90–53.77)
Residential area*						
Urban	7.7 (4.80–10.64)	8.1 (5.21–11.17)	9.7 (6.51–12.89)	45.3 (40.21–50.56)	22.8 (18.44–27.15)	49.6 (44.41–54.85)
Rural	4.8 (2.82–6.87)	4.4 (2.52–6.33)	7.0 (4.62–9.44)	45.7 (41.13–50.24)	21.4 (17.67–25.23)	50.5 (45.94–55.09)

CI = confidence interval; HbA1c = hemoglobin A1c; FPG = fasting plasma glucose.

*Age adjustments were made with direct method, using total national Vietnam population data (2009).

however, the prevalence of prediabetes relatively high in men than women (51.2% vs. 49.2%, respectively) and similar pattern were shown in different geographic region, with 49.6% (95% CI, 45.77–56.64) in urban vs. 50.5% (95% CI, 49.54–55.09) in rural.

Table 3 presents the univariate analysis and multivariate logistic regression for prediabetics. Kinh ethnic, older age, overweight and obese by BMI, high WC, high WHR, high BP, high

Table 3. Risk factors associated with prediabetes in Vietnam (n = 438)

Category	Univariate analysis	Multivariate analysis
	OR (95% CI)	aOR (95% CI)
Ethnic		
Ethnic minorities	Ref.	Ref.
Kinh	2.30 (0.26–0.84)	0.60 (0.31–1.05)
Age group		
45–54	Ref.	Ref.
≥ 55	1.60 (1.18–2.08)	1.50 (1.12–2.02)
BMI		
Normal + underweight	Ref.	Ref.
Overweight + obese	1.70 (1.25–2.22)	1.40 (1.02–2.00)
WC		
Normal	Ref.	Ref.
High	1.80 (1.33–2.40)	1.33 (0.88–2.00)
WHR		
Normal	Ref.	Ref.
High	1.50 (1.01–1.95)	1.10 (0.80–1.50)
BP		
Normal	Ref.	Ref.
HTN	1.48 (1.12–1.95)	1.22 (0.90–1.65)
History of HTN		
No	Ref.	Ref.
Yes	1.63 (1.17–2.27)	1.31 (0.92–1.88)
Percent body fat		
Normal	Ref.	Ref.
High	1.61 (1.19–2.19)	1.18 (0.84–1.70)
Visceral fat level		
Normal	Ref.	Ref.
High	1.30 (0.96–1.75)	-

The multivariate logistic model included all variables in the table.

OR = odds ratio; CI = confidence interval; aOR = adjusted odds ratio; Ref. = reference; BMI = body mass index; WC = waist circumference; WHR = waist to hip ratio; BP = blood pressure; HTN = hypertension.

percent body fat and visceral fat level, participants with a history of HTN were associated with increasing prevalence of prediabetes in univariate analysis. In the adjusted model, only older age and overweight/obese by BMI are positively and significantly associated with increasing prevalence of prediabetes with adjusted odds ratio (aOR), 1.5 (95% CI, 1.12–2.02), aOR, 1.4 (95% CI, 1.02–2.00), respectively.

Table 4 shows the univariate analysis and multivariate logistic regression analysis result for undiagnosed diabetes. In the adjusted model showed that visceral fat level, MetS, family history diabetes, history of HTN that were independently associated with undiagnosed T2DM. The individuals with high visceral fat level were 2.27 times more likely to be undiagnosed T2DM than normal individuals (aOR, 2.27; 95% CI, 1.14–4.50). Individuals with MetS were 30.3 times more likely to have undiagnosed T2DM as compared to the non-MetS individuals (aOR, 30.3; 95% CI, 4.01–229.50). Study subjects who have a family history of diabetes, history of HTN that were showed higher odds (2.3 and 1.9 times, respectively) of undiagnosed T2DM than other.

Table 4. Risk factors associated with undiagnosed diabetes in Vietnam (n = 67)

Category	Univariate analysis	Multivariate analysis
	OR (95%CI)	aOR (95%CI)
Age group		
45–54	Ref.	Ref.
55–64	1.40 (0.79–2.61)	1.07 (0.56–2.05)
≥ 65	2.40 (1.31–4.53)	1.40 (0.70–2.90)
Marital status		
Currently married	Ref.	Ref.
Never married	1.30 (0.29–5.68)	1.90 (0.32–10.70)
Divorced/widowed	2.00 (1.08–3.56)	1.60 (0.77–3.21)
BMI		
Normal	Ref.	Ref.
Underweight	0.50 (0.18–1.63)	0.60 (0.20–2.03)
Overweight	1.30 (0.68–2.62)	0.70 (0.31–1.68)
Obese	2.60 (1.42–4.69)	0.70 (0.24–2.05)
WHR		
Normal	Ref.	Ref.
High	3.03 (1.60–5.80)	1.73 (0.79–3.80)
BP		
Normal	Ref.	Ref.
HTN	2.90 (1.69–5.06)	1.77 (0.96–3.25)
Percent body fat		
Normal	Ref.	Ref.
High	2.50 (1.23–4.89)	1.74 (0.77–3.91)
Visceral fat level		
Normal	Ref.	Ref.
High	2.60 (1.61–4.43)	2.27 (1.14–4.50)
MetS		
No	Ref.	Ref.
Yes	5.90 (3.56–10.00)	30.30 (4.01–229.50)
Family History of diabetes		
No	Ref.	Ref.
Yes	2.30 (1.26–4.46)	2.30 (1.12–4.62)
History of HTN		
No	Ref.	Ref.
Yes	3.30 (1.98–5.45)	1.90 (1.06–3.37)

CI = confidence interval; OR = odds ratio; aOR = adjusted odds ratio; Ref. = reference; BMI = body mass index; WHR = waist to hip ratio; BP = blood pressure; MetS = metabolic syndrome; HTN = hypertension.

DISCUSSION

The findings of our study are crucial and potentially contribute to the alarming high proportions of prediabetes, and undiagnosed diabetes. The percentage of prediabetes, undiagnosed diabetes after adjusted by the age were 50.1% and 8.1%, respectively. There is a rapid increase in the prevalence of prediabetes, especially the prevalence of undiagnosed diabetes in Vietnam. In the study conducted in 2014–2015, the prevalence of diabetes in the adult population aged 20–70 in Khanh Hoa Province was 7.2%¹¹ while the prevalence of prediabetes in this area was 21% in 2010.⁸ Our study showed that the figure is higher than one in previous studies in the Northern or Southern area. In 2010, a study in Ho Chi Minh city illustrated that, in a random sample of 2,142 individuals including subjects with normal, prediabetes, undiagnosed diabetes, diabetes in the population setting, about 10% subjects were found as undiagnosed diabetes using FPG criteria. On the other hand, the Vietnam osteoporosis study initiated in 2015 also showed that 9.7% (342/3,523) individuals were classified as having diabetes by HbA1c, only 30% had come to clinical attention or were taking diabetes medication.¹² The previous study was limited by sample size, younger and in a highly urban population.^{2,13,15}

Currently, most epidemiological studies on in this field only focus in the Northern and Southern area where reported prevalence rate of diabetes were varying, 1.4% to 11% from period 1990 to 2010.² The prevalence of undiagnosed diabetes in our study was higher than the diabetes prevalence after adjusted to the national population conducted in 2015 “STEP survey” (5.8%) based on a population-based study of 3,750 subjects.¹⁶ However, the results of our study after adjusted (8.1%) was lower than the figure (10.8%) reported in a priority study among 721 men and 1,421 women urban inhabitants in southern Vietnam.¹⁷ The figure of our observation is much lower than the figure in China 11.3%.¹⁸ However, the present finding is much higher than the estimates of some countries such as Korea 3%,¹⁹ Thailand 4.1%,²⁰ and US 4.1%.²¹ The different prevalence in the international comparison could be understood by the various health care system and availability of health care service in each country.

The adjusted prediabetes prevalence of prediabetics 50.1% in our study is quite higher than previous estimates for Vietnam, with values ranging from 1.6% in 1990 to 35% in 2015.¹⁶ Such a difference may be partly due to differences in the sampled cohorts in terms of socioeconomic status, dietary and lifestyle or environmental factors, or other aspects of study design and prevalence standardization. Our result is much higher than Ethiopia at 12%,²² Thailand 15.4%,²⁰ Qatar 16.7%,²³ Palestine 48.3%,²⁴ Korea 25%,¹⁹ Mexico 44.2%,²⁵ and Canada 38.3%.²⁶ As literature review shows that 5%–10% of prediabetes individuals may develop diabetes after 10 years.²⁷ Although there are some increased number of awareness programs and health educations which were performed in the nation, our finding showed that the public health system should play a role of increasing awareness of and screening for diabetes, lifestyle changes for prevention and also reduction in the burden of diabetes.

We also found that participant with older age, overweight and obese by BMI were more likely to have prediabetes. The individuals with high visceral fat level, MetS, family history diabetes, history of HTN were more likely to have undiagnosed diabetes. These factors would predict future developed T2DM, and form a basis for targeted testing of the high risk group. The positive associations of these factors are also consistent with previous studies in Vietnam. Notably, advancing age, high BMI, MetS, WC, and WHR as well as overweight/obesity, family history diabetes, HTN are known as the factors that contribute for increasing prevalence of diabetes of the nation.^{13,15,17,28} Besides, some studies also show that systolic BP and WHR as

the factors that can be used for identifying individuals at high risk of undiagnosed T2DM.¹⁷ This significant relationship also has been found consistently in the different population, for instance, Chinese, Canada, Ethiopian, and Qatar.^{22,23,26,29}

Prediabetes is associated with risk of diabetes and its complications, and their occurrences may differ depending on ethnic and socioeconomic circumstance. In this study, we found no significant difference between the prevalence of undiagnosed T2DM/prediabetes and socioeconomic circumstance. There are some reasons that might explain this association. First, we selected study participants aged from 45 years old and over who were at high risk of diabetes following the guidelines of ADA,⁹ and the Ministry of Health of Vietnam.⁶ Second, there is no significant difference in the distribution of population in urban and rural areas.

Our study also presents some strength that inclusion of large population who were selected by PPS method, thereby the study samples well represents the entire rural and urban population, given in high response rate of 93%. In addition, the study also carefully collected biomarker data from individuals, which were conducted at early morning in all most area of the province. Moreover, anthropometric measurements were collected by trained interviewers and reviewed by supervisors who were selected as researchers at Pasteur Institutes in Nha Trang and medical officers at Endocrinology central of Khanh Hoa Provincial Health Service. On the other hand, as per our knowledge, this is the first population-based study in Vietnam that used HbA1c and FPG, and also percent body fat and visceral fat level measured by bioelectrical impedance method (HBF-375; OMRON Healthcare Co.) to estimate the prevalence of undiagnosed diabetes and its risk factors in community with large population in rural and urban setting. We also used age adjustments analysis method that uses total national Vietnam population data which showed high prevalence of undiagnosed diabetics in Vietnam. Therefore, the national DM policy and strategy should include rural populations in addition to those in the capital and major cities. Moreover, developing the risk communication programs and also strengthening them in early detection, management and treatment of these populations at risks might be important strategy.

Despite the strengths of this study, some limitations should be taken into consideration. The study was designed as a cross-sectional investigation, and the age of participants were limited to 45 years old and over, so that we could not estimate the incidence of prediabetics and undiagnosed diabetes and the estimates of prevalence rates of prediabetes and undiagnosed diabetes in this study may not represent those of whole population. Also, the findings are not a cause-and-effect inference and are the association between undiagnosed diabetes and risk factors. Therefore, further researches are needed with a continued focus in large population and should be conducted population-based cohort study to prevent diabetes and NCDs.

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SUPPLEMENTARY MATERIAL

Supplementary Data 1

Questionnaire on demographic information and physical examination

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