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The prevalence of undiagnosed hyperglycemia in
middle-aged and older adults and its associated
risk factors in Ba Vi district, Viet Nam

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The prevalence of undiagnosed hyperglycemia in
middle-aged and older adults and its associated
risk factors in Ba Vi district, Viet Nam

Directed by Professor Heejin Kimm

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DECLARATION

I, **Khieu Trang Ly**, do hereby declare that this thesis titled “**The prevalence of undiagnosed hyperglycemia in middle-aged and older adults and its associated risk factors in Ba Vi district, Viet Nam**” is the result of my work and efforts. Any work that is not my own has been cited and referenced accordingly. This thesis has not been accepted for any degree and has concurrently not been submitted in the candidature of any other degree.

Khieu Trang Ly

Korea, December 2022.

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LIST OF ACRONYMS

NIHE	National Institute of Hygiene and Epidemiology
WHO	World Health Organization
ADA	The American Diabetes Association
MoH	Ministry of Health
NCD	Non-communicable Disease
CHS	Commune health station
CHW	Commune health worker
DHW	District health worker
IFG	Impaired fasting glucose
IGH	Increased glycated hemoglobin
BMI	Body mass index
WHR	Waist-to-hip ratio
HTN	Hypertension
WC	Waist circumference
WHR	Waist hip ratio
T2DM	Type 2 diabetes mellitus
MetS	Metabolic syndrome
95% CI	95% Confidence Intervals
FPG	Fasting plasma glucose
OGTT	Oral glucose tolerance test
HbA1C	Hemoglobin A1C test

ABSTRACT

The prevalence of undiagnosed hyperglycemia in middle-aged and older adults and its associated risk factors in Ba Vi district, Viet Nam

Background: A sign of diabetes is high blood sugar levels, which is known or referred to as hyperglycemia. Many individuals develop type 2 diabetes covertly because the symptoms of hyperglycemia are not typically present until the glucose levels are very high. The illness negatively impacts health even before its discovery. This study aimed to explore the prevalence of hyperglycemia and some risk factors associated with it in Viet Nam – which, in the last decade, has been a rapidly urbanized country.

Methods: The researchers conducted a cross-sectional study in nine communes in Ba Vi district, a mixed urban and rural area, which is outside Ha Noi's capital. The study was conducted within a period of two months, in 2021. The researchers recruited 1,814 participants who were over the age of 40 years old using a purposive and convenient sampling technique. In addition to conducting in-person interviews, the researchers measured the participants' height, weight, waist-hip ratio, blood pressure, and venous blood sampling. Although the multivariate regression analysis can identify the factors associated with hyperglycemia, descriptive statistics were applied to demonstrate the status of high blood sugar levels.

Results: All participants' crude prevalence of intermediate hyperglycemia was 48.9% (95% CI, 46.6-51.2), and hyperglycemia was 10% (95% CI: 8.7-11.5). The standardized-

age prevalence of intermediate hyperglycemia and hyperglycemia was 47.8% (95% CI: 44.6-50.9) and 9.2% (95% CI: 7.9-10.6), respectively. Furthermore, the increase in cases of high blood sugar levels in individuals with normal BMI, overweight and obese is a more notable trend. The findings of this study indicate that the incidence of hyperglycemia increases with the BMI as the normal, overweight, and obese groups were 9.2% (95% CI: 7.4-11.1), 10.8% (95% CI: 7.9-13.9) and 14.3% (95% CI: 10.4-18.7), respectively. In addition, individuals with high blood pressure are more likely to have high blood sugar levels than those with normal blood pressure. The prevalence of hyperglycemia in participants with high blood pressure was 14.2% (95% CI: 11.7-16.6), while for participants with standard blood pressure recorded only 7.8% (95% CI: 6.2-9.6). The multivariate regression model exhibits that alcohol users were 1.39 times more likely than non-drinkers, to have increased blood sugar levels (95% CI: 1.03-1.86). In comparison to the low-weight group, those with normal BMI, those who were overweight, and those who were obese had blood sugar levels that were higher (1.57, 1.55, and 1.76 times, respectively). Individuals with large waists were 1.33 times more likely to have blood sugar levels ≥ 5.6 mmol/l as opposed to those with a regular waist circumference (95% CI: 1.03-1.72).

Conclusions: At age 40 and older, a significantly higher percentage of individuals, as opposed to the general population, have intermediate hyperglycemia and hyperglycemia. Multiple factors may cause the participants of the study to have abnormal blood sugar levels. Society conditions, behavioral characteristics, and biological factors are also

related to a high blood glucose status in Ba Vi district, Viet Nam. There is a need for governments to present public health solutions focusing on the education of health so that individuals can alter their behavioral patterns and lower their risk of developing diabetes or other common NCDs in their middle life.

Keywords: Diabetes, pre-diabetes, hyperglycemia, high blood sugar levels.

I. INTRODUCTION

1.1. Background

A sign of diabetes is high blood sugar levels, which is known or referred to as hyperglycemia. This means that the body cannot use the insulin properly or it does not produce any or enough of it. The symptoms of hyperglycemia do not frequently appear until the glucose levels in the body are very high, which makes it harmful. Despite having high blood sugar levels, individuals who have been diagnosed with type 2 diabetes and who have had it for a while, may not exhibit any symptoms - undiagnosed type 2 diabetes, however, affects a large population (Deborah Weatherspoon, 2019).

Furthermore, unlike diabetes and pre-diabetes, repeat testing is not required to confirm hyperglycemia and intermediate hyperglycemia (Brandon Orr-Walker & Coppel, 2012). Hyperglycemia is identified by at least one of the biochemical tests such as: (1) the fasting plasma glucose test (FPG); (2) the oral glucose tolerance test (OGTT); or (3) the hemoglobin A1C test (HbA1c). In Viet Nam, the FPG test is more commonly used as it is more convenient and has higher cost savings (Association, 2021). In an individual who is not endocrine sick, a single FPG result between 5.6 mmol/l (100 mg/dl) and 6.9 mmol/l (125 mg/dl) is classified as intermediate hyperglycemia, while an FPG result of 7.0 mmol/l (126 mg/dl) or higher is defined as hyperglycemia.

Every year, 5 to 10% of individuals with intermediate hyperglycemia develop diabetes, however, 5 to 10% return to normoglycemia (Group, 2002; Twigg et al., 2007). On other hand, type 2 diabetes can develop in up to 70% of those with moderate hyperglycemia

over a long period of time (Twigg et al., 2007). In comparison to individuals with normoglycemia, those with intermediate hyperglycemia have a relative risk with regard to type 2 diabetes that is six times higher (Tabák et al., 2012). The chance to prevent the development of diabetes and lower the risk of problems that are in connection with the disease should be seen in the identification and management of individuals with intermediate hyperglycemia and hyperglycemia (Gillies et al., 2007; Group, 2002). The number of individuals who progress to clinical diabetes can be decreased by 30% to 60% with appropriate and effective intervention, lifestyle changes, and the beginning of metformin when appropriate (Bertram et al., 2010; Fradkin et al., 2012; Gillies et al., 2007). Treatment is considered to be both safe and cost-effective.

The American Diabetes Association (ADA) recommends comprehensive screening for pre-diabetes and diabetes by checking blood sugar levels. It helps to identify and treat these conditions earlier rather than later to prevent the disease from progressing and resulting in adverse outcomes (Force et al., 2021). The screening is offered to all adults within the age range of 35-45 years of age or older, that are independent of risk factors. In addition, the screening of adults who are overweight or obese with one or more risk factors, regardless of their age is also offered. If individuals have typical results that are inconclusive, it is recommended that the test is repeated at least 3 years apart to record any differences (Federation, 2021).

Viet Nam's transformation, from being one of the world's poorest countries to now being a middle-income economy in a generation that has been assisted by economic reforms

implemented as a result of the start of Doi Moi in 1986, as well as positive global trends (TheWorldBank, 2022b). According to the latest World Bank statistics, the gross domestic product has increased more than three times from the year 2006 (~US\$66.4 billion) to the year 2020 (~US\$271.1 billion) (TheWorldBank, 2022a). Despite this, Viet Nam's healthcare system still faces multiple issues and challenges - some of these health issues have been identified by the health sector. These include an aging population, inadequate capacity of the health system and an emerging double burden of noncommunicable diseases (such as cardiovascular diseases, diabetes, cancer, etc.) as well as infectious diseases (HIV/AIDS, MERS-CoV, etc.).

The diets and lifestyles of individuals have changed substantially over the past decade, along with the economy's growth. Vietnamese adults tend to consume more total fat and animal protein (National Institute of Nutrition & UNICEF, 2012), while being less active physically (Bui et al., 2016). Some research studies have exhibited that adults with pre-diabetes and type 2 diabetes are more likely to be overweight or obese; other risk factors include advanced age, family history, and dietary and lifestyle factors (Rubin et al., 2017; Zheng et al., 2018). According to a STEPS survey that was conducted in the year 2020 (19.5%), the prevalence of Vietnamese adults being overweight was about six times greater than in the year 2000 (3.5%); the BMI of individuals from urban areas was also much higher than that of individuals from rural areas (21.3% and 12.6%, respectively) (Ha do et al., 2011; Ministry of Health, 2022).

Additionally, 1.6% of individuals that are aged between 25 to 64 years old had increased fasting glucose in 2009-2010 and 3.6% in 2015. This led to an increase in the prevalence of diabetes mellitus from 1.5% in the 1990s to 3% in 2010, 4% in 2015, and a predicted 4.5% by 2030. Elevated fasting blood glucose contributed to 6.3% of all fatalities and 3% of all DALYs lost in 2010 (Nguyen & Hoang, 2018).

In terms of the sub-urban areas, the Ba Vi district is an area outside of Ha Noi's capital. There are some differences with regard to the population characteristics in this area compared to those in the inner-city areas with nearly a quarter of the population being over the age of 40 years old. The government has focused on raising the standard of living and the quality of life of the inhabitants including medical activities, especially those related to the prevention and treatment of common NCDs today. Several national healthcare policies are being implemented such as the National strategy to prevent and control non-communicable diseases, during the time period of 2015-2025 (Minister, 2015), guidelines with regards to the prevention of the diseases, their early detection, the diagnosis, the treatment and the management of some common NCDs for primary health care (MinistryofHealth, 2018).

To collect the primary data as evidence so that the policy makers can provide health programs on NCDs prevention to residents that are living in this region, this study was conducted. The research study aims to screen participants who are likely to have hyperglycemia and intermediate hyperglycemia, in order to provide the participants with timely guidance to prevent the syndrome as well as its treatment. The promotion of health

will be supported in order to reduce the growth of risk factors that are related to diabetes and NCDs in general.

1.2. Purpose

1.2.1. Research question

What was the prevalence of undiagnosed hyperglycemia in middle-aged and elderly individuals, as well as the factors affecting them in sub-urban areas, in Viet Nam?

1.2.2. Objectives

General Objective:

To determine the prevalence of undiagnosed hyperglycemia and associated factors among individuals that are aged 40 years old and over in the sub-urban areas of HaNoi, Viet Nam in 2021.

Specific Objectives:

- To determine the prevalence of undiagnosed hyperglycemia among individuals who are ≥ 40 years of age in Ba Vi district, HaNoi city, VietNam.
- To determine the associated factors with hyperglycemia among the individuals who are ≥ 40 years of age in Ba Vi district, HaNoi city, VietNam.

II. LITERATURE REVIEW

2.1. Non-communicable diseases and Diabetes mellitus

2.1.1. Worldwide

NCDs, also known as chronic diseases, are a global challenge and a huge burden on society and the health system. The main types of NCDs are cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes. Globally, non-communicable illnesses accounted for 7 of the top 10 causes of mortality in 2019. These seven diseases accounted for 44% of all deaths or 80% of the deaths caused by the top 10 causes of mortality. However, in total, 74% of the mortality rate globally was caused by NCDs. Ischemic heart disease is the leading cause of death worldwide, accounting for 16% of all fatalities. This disease has exhibited the highest increase in deaths since 2000, with 8.9 million deaths in 2019, an increase of more than 2 million deaths. The second and third most common causes of death are strokes and chronic obstructive pulmonary disease, which account for 11% and 6%, respectively, among all fatalities (figure 1) (WHO, 2020).

According to the Global NCDs Report, in 2014, about 42% of NCD deaths were among individuals under the age of 70 years of old; 48% of NCD deaths are in low- and middle-income countries; and 28% are in developed countries (Mendis, 2014). By 2030, the number of deaths caused by NCDs in low-income countries will be eight times higher than in high-income countries (Nikolic et al., 2011).

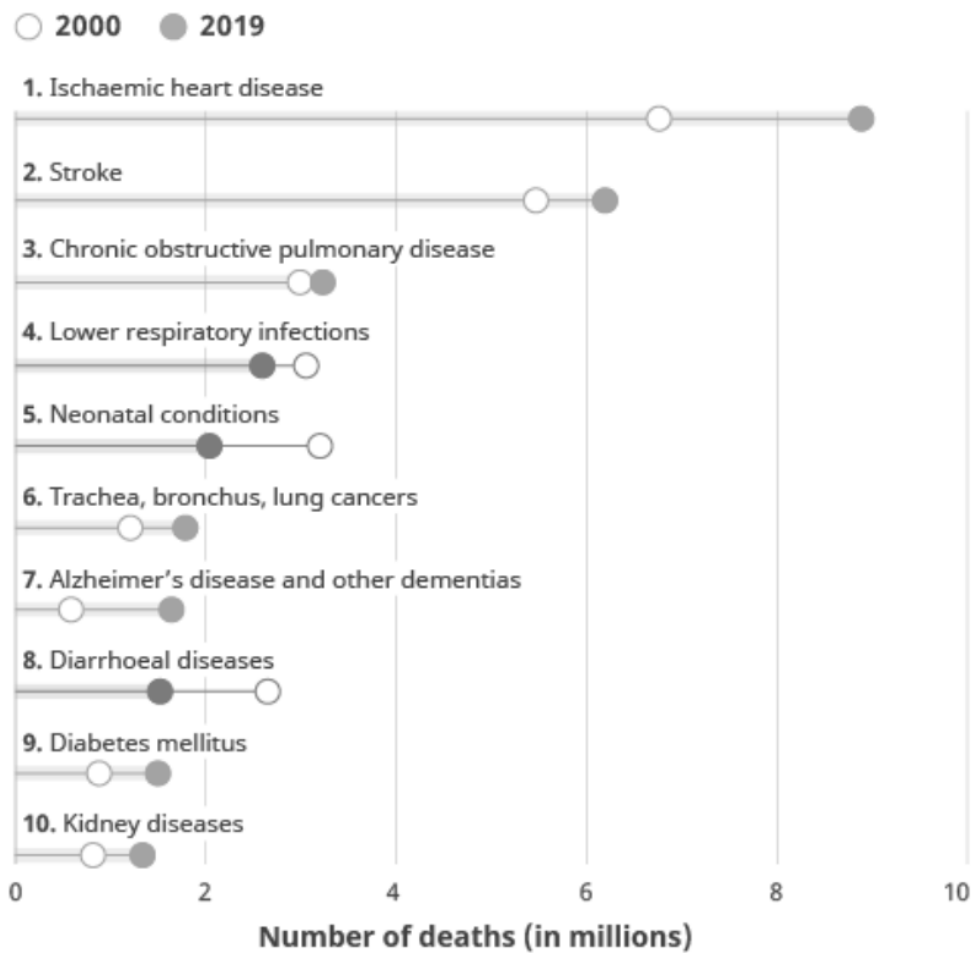


Figure 1: Ten leading causes of death globally

In most countries (except Sub-Saharan countries), NCDs cause at least 50% of all healthy years of lives that have been lost. This figure exhibits as high as 80% in Australia, Japan, and the rich countries of Western Europe and North America. It is estimated that the share of DALYs caused by NCDs in low- and middle-income countries will increase from 33% in 2002 to about 45% by 2030 (Minister, 2015).

Diabetes is reported to be one of the four major non-communicable diseases and ranks as the 9th leading cause of death globally. The International Diabetes Federation (IDF) has been documenting the prevalence of diabetes on a national, regional, and international scale since 2000. Diabetes was estimated to affect 285 million individuals in 2009 (Federation, 2009); this number increased to 366 million in 2011 (Federation, 2011), 382 million in 2013 (Federation, 2013), 415 million in 2015 (Federation, 2015), 425 million in 2017 (Federation, 2017), 463 million in 2019 (Federation, 2019) and 536 million in 2021 (Federation, 2021). Based on the predictive models indicating a dark future, the number of individuals with diabetes will be around 578 million by 2030 and 783 million by 2045 among adults that are within the age range of 20-79 years of age (Saeedi et al., 2019) (Sun et al., 2022).

At a glance	2021			2045		
World Bank income classification	Number of people with diabetes (millions)	Diabetes prevalence ⁱ (%)	Comparative diabetes prevalence ⁱⁱ (%)	Number of people with diabetes (millions)	Diabetes prevalence ⁱ (%)	Comparative diabetes prevalence ⁱⁱ (%)
World	536.6	10.5%	9.8	783.2	12.2%	11.2
High-income countries	103.9	11.1%	8.4	117.7	12.4%	10.3
Middle-income countries	414.0	10.8%	10.5	623.3	13.1%	12.0
Low-income countries	18.7	5.5%	6.7	42.2	6.1%	7.0
Number of deaths due to diabetes	6.7 million		–		–	

i Prevalence is standardised to each national population for the respective year

ii Prevalence is standardised to world population for the respective year

Figure 2. Estimation of the number of individuals (20-79 years) with diabetes in 2021 and 2045

There are four types of diabetes mellitus, namely: type 1; type 2; gestational diabetes; and “other specific types”. All four groups of diabetes have a significant burden with regard to the amount of money spent on health, as the growth recorded in 2007 is 232 billion USD and 966 billion USD in 2021. This has increased by 316% over the past 15 years. The direct expenses associated with diabetes are expected to rise further. The IDF predicts that by 2030 and 2045, the overall cost of medical expenses related to diabetes will be USD 1.03 trillion and USD 1.05 trillion, respectively. The high-income countries spend the most on healthcare in relation to diabetes as a percentage of GDP (1.16%), followed by the middle-income nations (1.08%), and considerably behind them are low-income countries (0.51%). In terms of individual nations, the United States of America (USD 379.5 billion) is in the first place, with China coming second and Brazil in third place for the most amount spent on medical expenses that are related to diabetes (USD 165.3 billion and USD 42.9 billion, respectively) (Federation, 2021).

By identifying individuals with diabetes or pre-diabetes through screening, the early management of the disease is made possible, which could lower the likelihood of complications in the future. A patient with risk factors for diabetes such as obesity, high blood pressure, and a family history of the disease, should be examined frequently. Different methods are used to diagnose diabetes in different individuals such as: the FPG test; the OGTT; or the HbA1C test (Association, 2022a). Impaired glucose tolerance (IGT) and Impaired fasting glycemia (IFG) are intermediary states

in the progression from normalcy to diabetes. Type 2 diabetes can develop in individuals with IGT or IFG, although this is not inevitable (Baynest, 2015).

2.1.2. Prevalence of diabetes in Viet Nam

During the last 20-year period, more and more Vietnamese individuals have transitioned from rural to large metropolitan regions, with a 40% estimated urbanization rate at the beginning of 2020. The environment has gotten worse as a result of the increase in urbanization, which has also increased air pollution (TheWorldBank, 2022b). The lifestyle habits of individuals have also gotten worse, this includes changes in nutrition and physical inactivity; as a result, the healthcare system is now under a lot of stress as there are more patients with health-related issues (Bui et al., 2016).

The considerable decrease in communicable diseases has resulted in an incredible financial achievement with regard to cost savings. However, NCDs have replaced communicable diseases and are now one of the top causes of mortality and morbidity. The statistical yearbook of the Ministry of Health in the years 1976, 1996, 2006, and 2013 exhibits that the proportion of NCDs among hospitalized patients is increasing. This rate increased from 42.65% (1976) to 50.02% (1996), to 62.40% (2006) and 63.5% (2013) (MinistryofHealth, 2014). In Viet Nam, hospital admissions for NCDs increased from 38% to 66% and the mortality rate from 42% to 73% between 1986 and 2015 (Nguyen et al., 2022).

According to surveys conducted in the early 1990s, diabetes was prevalent in HaNoi (1.01%), Hue (0.96%), and Ho Chi Minh city, the three representative cities in the north, center, and south of Viet Nam (Quoc et al., 1994). The OGTT test and cluster sampling were used in a survey conducted in 2008 to determine the prevalence of diabetes in Ho Chi Minh city, the participants were 720 men and 1421 women. Type 2 diabetes was significantly more prevalent among individuals who were aged 15 years and older in 2001 (6.6% vs. 2.5% in 1993), and it was also more prevalent among those within the age range of 30 to 70 years old (11.4 vs. 15.9% in 2009) (Ta et al., 2010) (Duc Son et al., 2004).

According to a national survey conducted every 10 years by the National Endocrine Hospital, which comprised 64.5% newly identified cases from 9122 individuals within the age range of 30 to 64 years old, who were randomly chosen from six ecological zones around the nation, estimated that 0.7 million Vietnamese adults (2.7%) had T2DM in 1999 (HospitalofEndocrinology, 2002). In 2009, the survey was held for the second time with 11,191 individuals within the age range of 30 to 69 years old covering the same geographical areas, the estimated number of individuals with T2DM increased to roughly 2 million (5.4% national population) (HospitalofEndocrinology, 2012). The third survey conducted from July to December 2020 with adults within the age range of 30 to 69 years old reported that the rate of diabetes was 7.3% and the rate of pre-diabetes was 17.8% nationwide. This figure among men and women was 8.6% and 18.1%; 6.2% and 17.6%, respectively, with

regards to the number of surveys conducted (HospitalofEndocrinology, 2022). Based on this poll, the pre-diabetes and diabetes rates are rising at alarming rates, with diabetes being more common in large cities and less common in isolated regions like the highlands (Nguyen et al., 2015).

According to the forecasting model of J.E. Shaw in 2009, the number of individuals with diabetes in Viet Nam by 2030 will be about 3.4 million individuals. However, the actual data of the IDF Diabetes Atlas in 2015 was that 3.5 million adults in Viet Nam have diabetes. This increase in the number of individuals with diabetes is based on the rapid population and economic growth (Shaw et al., 2010). There is currently no study or assessment in relation to the overall economic impact of NCDs in Viet Nam. The amount of socio-economic damage brought on by NCDs is, however, somewhat reflected in studies on several topics (Minister, 2015).

2.2. Undiagnosed diabetes and Hyperglycemia

As a result of the lack of a national NCD surveillance system in Viet Nam, most NCD surveillance initiatives are carried out independently and at various scales without any kind of overarching coordination. Some of the data collected are mainly based on hospital reporting systems and several surveys/studies in different scopes. The data underrepresents Viet Nam's large rural population. There are, however, still a few small studies conducted to collect data as evidence for the relevant policies.

Firstly, a study was conducted in 2011 in Ha Nam province which included 3,000 participants within the age range of 40 to 64 years, which made use of the FPG test and the OGTT test with 75 grams of glucose. The results exhibited that the prevalence of intermediate hyperglycemia (FPG 5.6-6.9mmol/l) was 8.7% (95%CI 7.0-10.5) with a higher proportion of males than females 8.9% (95%CI:7.1-10.8) and 8.6% (95% CI:7.0-10.2) respectively (Quang Binh et al., 2012).

Secondly, a cross-sectional study was organized based on the screening program in the community of Thai Nguyen province, Viet Nam for a period of three years, from 2011-2013. A total of 16,282 participants within the age range of 24–87 years old took part in the screening (5,602 men and 10,680 women). The findings exhibited that the prevalence of mild hyperglycemia (FPG 6.1-6.9mmol/l) was 13.3% (12.4-14.2 95% CI) and this figure was estimated to be 15.7% (15.0-16.4 95% CI) for the year 2035. Individuals in urban areas have higher rates of diabetes and pre-diabetes than their counterparts who are in rural/mountainous areas (Pham & Eggleston, 2016).

According to the three STEP surveys conducted in 2010, 2015, and 2021 which took place nationwide, the data collected on intermediate hyperglycemia and hyperglycemia indicated a significant increase (MinistryofHealth, 2022; Nguyen & Hoang, 2018). The FPG in the classification of the WHO from 6.1 mmol/l to 6.9 mmol/l was 1.6% (2.0% in males and 1.2% in females) in 2010. This proportion increased to 3.6% in 2015 with the figures for men and women increasing to 3.9% and 3.1% respectively. After more than five years, in 2021, the intermediate

hyperglycemia rate had more than tripled to 11% (95%CI 9.22-12.8). Men experienced a far greater increase in this rate than women did. Women experienced an increase of about 2.5 times more (7.92% 95%CI 5.53-10.3) as opposed to men who experienced an increase of more than 4 times (14.3% 95%CI 14.9-16.7). In Viet Nam, adults within the age range of 18-69 years old now have a blood sugar rate that is seven times higher than it was 10 years ago.

The data on hyperglycemia was also recorded over three periods, 2.7% in 2010, 4.1% (95%CI: 3.2-5.0) in 2015, and 7.06% (95%CI: 5.97-8.16) in 2021. The prevalence of high blood sugar levels was consistently higher in men than in women over the period in the three surveys. The male and female rates were 2.8% and 2.6% in 2010, 4.5% (95%CI 3.1-4.9) and 3.6% (95%CI 2.7-4.6) in 2015, and 7.29% (95%CI 5.89-8.69) and 6.85% (95%CI 5.2-8.5) in 2021, respectively. The prevalence of hyperglycemia in Viet Nam has increased more than 2.5 times between 2010 and 2021, and this rate is comparable for both sexes (MinistryofHealth, 2022; Nguyen & Hoang, 2018).

A survey conducted in 2017 in the province of Khanh Hoa included 865 participants who were over the age of 45 years old and in good health. The study's goal was to gather data on the incidence of undiagnosed diabetes and pre-diabetes in the province. The study's diagnostic criteria were taken from the American Diabetes Association (ADA) recommendations published in 2017 with regards to diagnostic diabetes, which states that HbA1c levels must be $\geq 6.5\%$ or that the FPG levels must be ≥ 7.0 mmol/L; Pre-diabetes was classified as HbA1c levels between 5.7% and 6.4% or FPG levels

from 5.6 to 6.9 mmol/L. The data here exhibits that the overall prevalence of pre-diabetes was 50.6% (95% CI: 47.29-53.97) while the overall prevalence of undiagnosed diabetes was 7.7% (95% CI: 5.96-9.53). The prevalence rates of undiagnosed diabetes and pre-diabetes, when the age is standardized, was 8.1% (95% CI, 6.24-10.13) and 50.1% (95% CI, 46.63-53.52), respectively (Nguyen et al., 2019).

Table 1. Categories of increased risk for diabetes (ADA)

	FPG	OGTT	HbA1C
Normal	< 5.6 mmol/l	< 7.8 mmol/l	< 5.7%
Pre-diabetes/ Intermediate Hyperglycemia	5.6 – 6.9 mmol/l	7.8 – 11.0 mmol/l	5.7% - 6.4%
Diabetes/ Hyperglycemia	≥ 7.0 mmol/l	≥ 11.1 mmol/l	≥ 6.5%

In addition, according to the study of Binh et al. in Ha Nam in 2011, 75% of the total diabetic participants were newly diagnosed cases as the number of cases recorded was higher than the new cases recorded in a previous report from 2002 (Binh & Uoc, 2005). Based on the findings of the study, the author estimated that there were 137,900 individuals with diabetes, 100,600 patients who had not yet been identified, and 547,900 cases of pre-diabetes in the Ha Nam district's population of 3,727,000 individuals between the ages of 40 and 64 years old (Quang Binh et al., 2012).

The nationwide percentage of undiagnosed diabetes is 62.6% according to the most recent statistics available from the National Hospital of Endocrinology from the national census in 2020. Based on the data examined in this study, the predictive

model predicted that by 2025, there will be more than 4.2 million individuals living with diabetes, with the prevalence of the disease expected to be 8.7% (growing by 1.4% after 5 years) (HospitalofEndocrinology, 2022).

Table 2. Individuals (20-79 years) with undiagnosed diabetes in 2021

	Proportion undiagnosed	Number of individuals with undiagnosed diabetes
High-income country	28.8 %	29.9 million
Middle-income country	48.4 %	200.4 million
Low-income country	50.5 %	9.5 million

In 2012, the WHO issued a warning that hyperglycemia was directly responsible for 2.2 million fatalities worldwide, while diabetes was shown to be responsible for 1.6 million deaths in 2015 with type 2 accounting for over 90% of occurrences (Campus et al., 2022; Chen et al., 2011).

Furthermore, the prevalence of undiagnosed diabetes was approximated for 147 nations (68.4%), which either had low-quality or no in-country data on the condition. Nearly one-half (44.7%, 239.7 million) of the individuals with diabetes (20-79 years old) were found to be uninformed of their condition in 2011. An early diabetes diagnosis is essential for preventing or delaying complications, avoiding premature death, and enhancing the quality of life (Ogurtsova et al., 2022). The low rates of clinical diabetes diagnosis are frequently caused by limited access to care and under-

capacity in current healthcare systems. There is, therefore, an urgent need for low-cost screening methods that combine diagnostic tests with validated diabetes risk scores to detect diabetes earlier and increase access to clinical care, preventive counseling, and diagnosis (Ekoe et al., 2018; Wareham et al., 2019). Low and middle-income nations account for 87.5% of all diabetes cases worldwide, with low-income countries having the largest percentage of undiagnosed cases (50.5%). But even in high-income nations, 28.8% of those with diabetes have not received a diagnosis (Ogurtsova et al., 2022).

2.3. Health behaviors and some risk factors

2.3.1. Socioeconomic condition

Different age groups are affected by the prevalence of diabetes. In a research study conducted on the male population of Al-Kharj, 6.5% of adult males over the age of 35 years old were found to have diabetes. The prevalence grew to 11% between the ages of 55 and 64 years old, and between the ages of 65 years old and older, it soared to 23% (El-Hazmi & Warsy, 1989).

According to the STEPS survey conducted in Benin in 2019, the prevalence of hyperglycemia increased significantly with age ($p = 0.004$), and the risk of being hyperglycemic increased by 1.03 with each increase of one unit of age (1.02–1.73) (Campus et al., 2022).

A study conducted in 2012 in relation to the prevalence of intermediate hyperglycemia and diabetes in six U.S. regions exhibited that there was a difference in the prevalence of the disease between men and women. Considering the exception of Belize, where

the prevalence of diagnosed and undiagnosed diabetes was more than twice as high among women (10.5% and 7.1%, respectively) than it was among men (4.7% and 3.6%), the adjusted-age prevalence of diabetes was comparable among men and women in other locations (Barcelo et al., 2012). Additionally, gender, marital status, and family history (hypertension or diabetes) were associating factors related to the prevalence of hyperglycemia in a study conducted in the rural area of North Sudan ($p<0.001$) (Abdelaziz et al., 2018).

2.3.2. Behavioral risk factors

There are four primary behavioral risk factors for NCDs, namely: cigarette use; alcohol abuse; physical inactivity; and an unhealthy diet.

Cigarette (Tobacco) use

The only modifiable risk factor shared by the four major NCDs is the smoking of tobacco (Wipfli, 2012). By 2030, LMICs will account for 70% of all tobacco-related deaths as a result of the increase in the usage of tobacco and linked mortality. The lower-income populations have a higher likelihood of using cigarettes in every region of the world (WHO, 2008). In general, men are more likely than women to smoke, and as a result, the use of tobacco contributes more to the illness of men as opposed to women (Lim et al., 2012). There is a need for increased efforts to assist both men and women in quitting smoking.

Alcohol use

Metabolic syndrome and CVD are linked to the heavy use of alcohol regularly. There is evidence to support the notion that it is more common in lower socio-economic levels and among men than among women (Ziraba et al., 2009). Alcohol usage was the eighth most common risk factor, with regards to NCDs, among women in 2010 (3%), whereas it was the third most common risk factor among men (7.4%) (Lim et al., 2012).

Physical inactivity

It has been demonstrated that exercising regularly reduces the risk of coronary heart disease, stroke, diabetes, hypertension, certain malignancies, and depression. The increased risk of being overweight and obese is linked to an imbalance between too much energy input from an individual's dietary intake and insufficient energy expenditure through physical activity (WHO, 2018). Cardiovascular fitness is improved by engaging in enough moderate physical activity (150 minutes per week). Individuals in countries with higher incomes typically engage in less physical activity overall (Alwan, 2011).

Unhealthy diet

The risk of CVD and diabetes is increased by consuming large amounts of trans fats, saturated fats, processed and refined foods, sugar, salt, and sugary beverages, however, the risk of coronary heart disease and stroke is decreased by eating enough fruits and vegetables (Alwan, 2011; Dauchet et al., 2006). A socio-economic gradient can be observed in the consumption of an unhealthy diet. An individual's diet is also

impacted by both sex and education. The lower levels of education are correlated with diets that are unhealthy. In 2001, the burden of diseases among men was 50 percent higher than that of women as a result of the low fruit consumption by men (Groth et al., 2001).

2.3.3. Biological factors

A factor that is associated with the rate of hyperglycemia is hypertension. A study conducted in North Sudan exhibited an association between the prevalence of hyperglycemia and the hypertensive groups ($p < 0.01$) (Abdelaziz et al., 2018).

Obesity is established as an associated factor of hyperglycemia. In Benin's study, the research team found a significant association between hyperglycemia and obesity in their univariate analysis ($COR = 1.97$ (1.05-3.69); $p = 0.030$) (Campus et al., 2022).

Okumiya et al, reported in their study that obese individuals were 1.77 times more exposed to hyperglycemia compared to individuals who had normal BMI scores (95%CI: 1.33-2.36; $p < 0.0001$) (Okumiya et al., 2016). Similarly, Binh et al. conducted a study in the rural population in Viet Nam; out of a sample of 2,710 individuals, the conclusion that obesity is a factor associated with hyperglycemia was established ($OR = 2.41$, 95%, CI: 1.41-4.11) (Quang Binh et al., 2012).

2.4. Study area

Ba Vi is a semi-urban district in the northwest of Ha Noi's capital. The district has a total area of 424 km², including 31 commune-level administrative units, one town, and 30 communes. The mountainous areas, the Red River delta region, and the hilly

parts make up 46.5%, 34.7%, and 18.8%, of the district's total area, respectively. The entire Ba Vi National Park and 7 mountainous communes are included in the mountainous area (Government, 2022).

The district's economy is still developing slowly as a result of its geographic distance from the city and steep terrain. The region, which is in transition between the plains and the mountains, is home to numerous craft villages and trades. In the past 10 years, the local government has focused on developing the existing advantages of the district such as its agriculture and tourist resorts. However, compared to the general level of the city, the life of individuals in Ba Vi district is still limited in terms of living standards, education, and access to health care.

In Ba Vi, 131,000 of the district's more than 300,000 residents are aged 40 years and older. Individuals that are of working age move away from the area in search of employment, causing continuous changes in the population. As a result of non-communicable illnesses having long-term risk factors with regard to formation and progression, medical surveillance, and access to health care are needed for patients suffering from several drawbacks. In addition, there is only 1 general hospital in the whole district with a capacity of 280 beds, which is insufficient to provide healthcare for everyone living nearby. Thirty-one communal health stations focus on immunization or investigation of infectious disease cases; the lack of activities for older adults in health care and the prevention of fundamental NCDs such as hypertension and diabetes (BaviHospital, 2022).

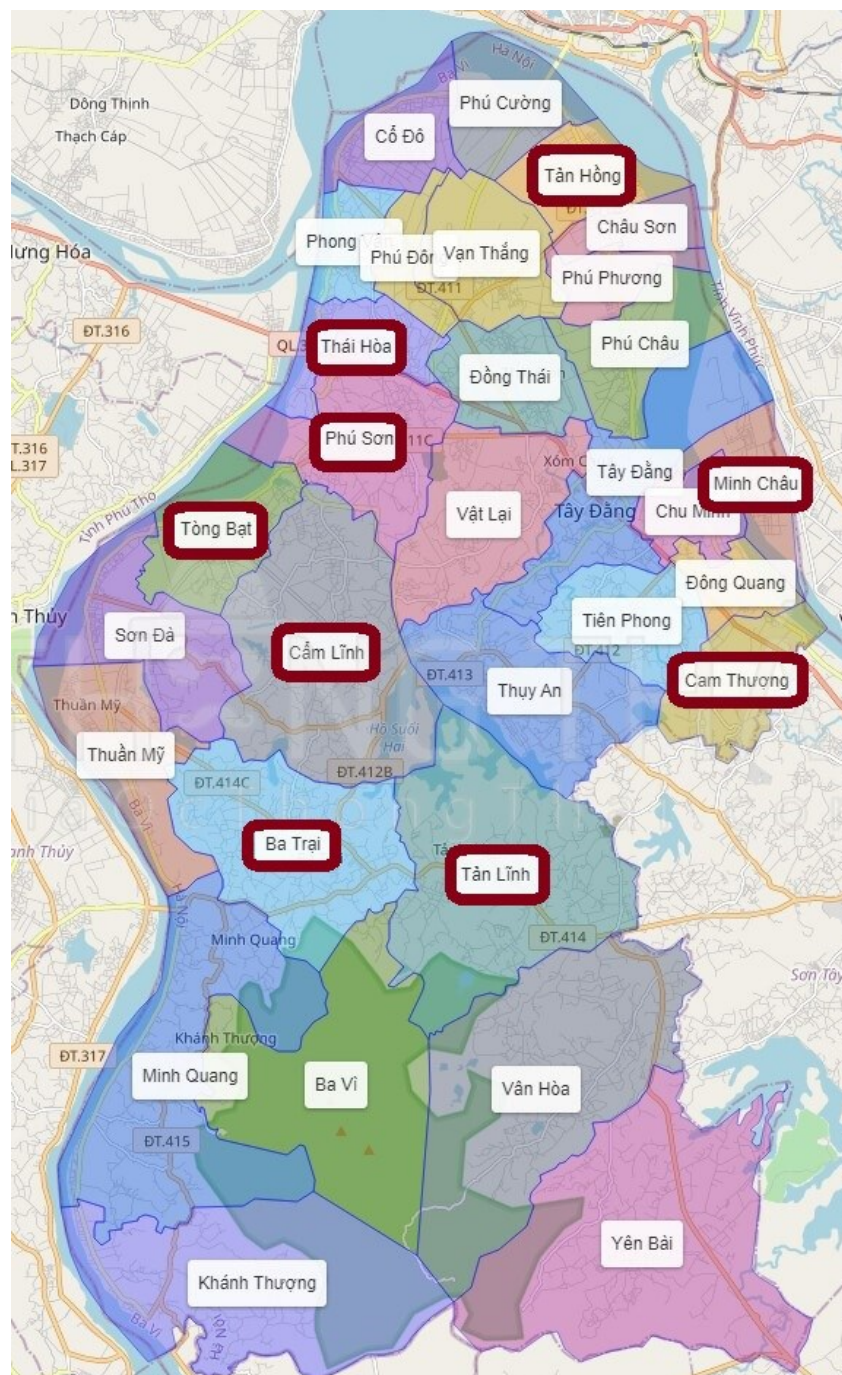


Figure 4. Map of Ba Vi district, Ha Noi city, Viet Nam

2.5. Operational definition

2.5.1. Non-communicable diseases

NCDs, also known as chronic diseases, tend to last a long time and are the result of a mix of genetic, physiological, environmental, and behavioral factors. The four primary categories of NCDs are diabetes, cancer, chronic respiratory diseases, and cardiovascular disorders (WHO, 2022). There are common, modifiable risk factors that underlie the major NCDs. They include smoking; drinking alcohol harmfully; eating poorly; getting little to no exercise; being overweight or obese; and having high blood pressure, high blood sugar levels, or cholesterol (Organization, 2022).

2.5.2. Diabetes mellitus

Diabetes mellitus, more commonly known as diabetes, is a dangerous, chronic disorder that develops when a person's blood glucose levels are elevated as a result of their body's inability to make any or enough insulin or its failure to efficiently make use of the insulin that it does produce. Insulin is an important hormone that is generated by the pancreas. It enables the circulation of glucose to reach the body's cells, where it is transformed into energy. A long-term deficiency of insulin can harm numerous organs in the body and can result in life-threatening and severe health consequences such as cardiovascular disorders, nerve damage, kidney damage, and eye disease (Federation, 2019).

2.5.3. Pre-diabetes

When blood sugar levels are higher than they should be but not high enough for an individual's doctor to diagnose diabetes, they are considered to have pre-diabetes. The doctors may refer to it as poor glucose tolerance or impaired fasting glucose. Pre-diabetes typically occurs before type 2 diabetes. It typically does not result in symptoms. Even if type 2 diabetes runs in the family, blood sugar levels can return to normal by eating healthy meals, engaging in physical activity regularly, and maintaining a healthy weight. The same lifestyle changes can assist adults in avoiding type 2 diabetes (Association, 2022b).

2.5.4. Fasting plasma glucose test

The FPG test measures the levels of glucose (sugar) in the blood. The FPG levels are determined by taking a blood sample from participants who have fasted for at least 8 hours. It can be calculated in mg/dL or mmol/L. It is a relatively quick, reliable, and affordable test that can check for diabetes and issues related to the production or use of insulin in the body (Diabetes.co.uk, 2019).

The FPG results are defined by the American Diabetes Association and are as follows:

(1) Normal: below 5.5 mmol/l (100 mg/dl); (2) Pre-diabetes: between 5.6- 6.9 mmol/L (100 to 125 mg/dl) changes in lifestyle and monitoring glycemia are recommended in this regard; (3) An FPG result of 7 mmol/l or higher (≥ 126 mg/dl) on two separate tests, indicates that diabetes is present and the patient is then diagnosed.

Hyperglycemia and intermediate hyperglycemia are the results after a one-time checkup of venous/ capillary blood, a sign that an individual is at risk of developing diabetes or pre-diabetes. The national mean of the FPG test is used as a proxy for the promotion of healthy eating habits and lifestyle choices as well as the management of diabetes (Association, 2022a)

III. METHODS

3.1. Conceptual framework

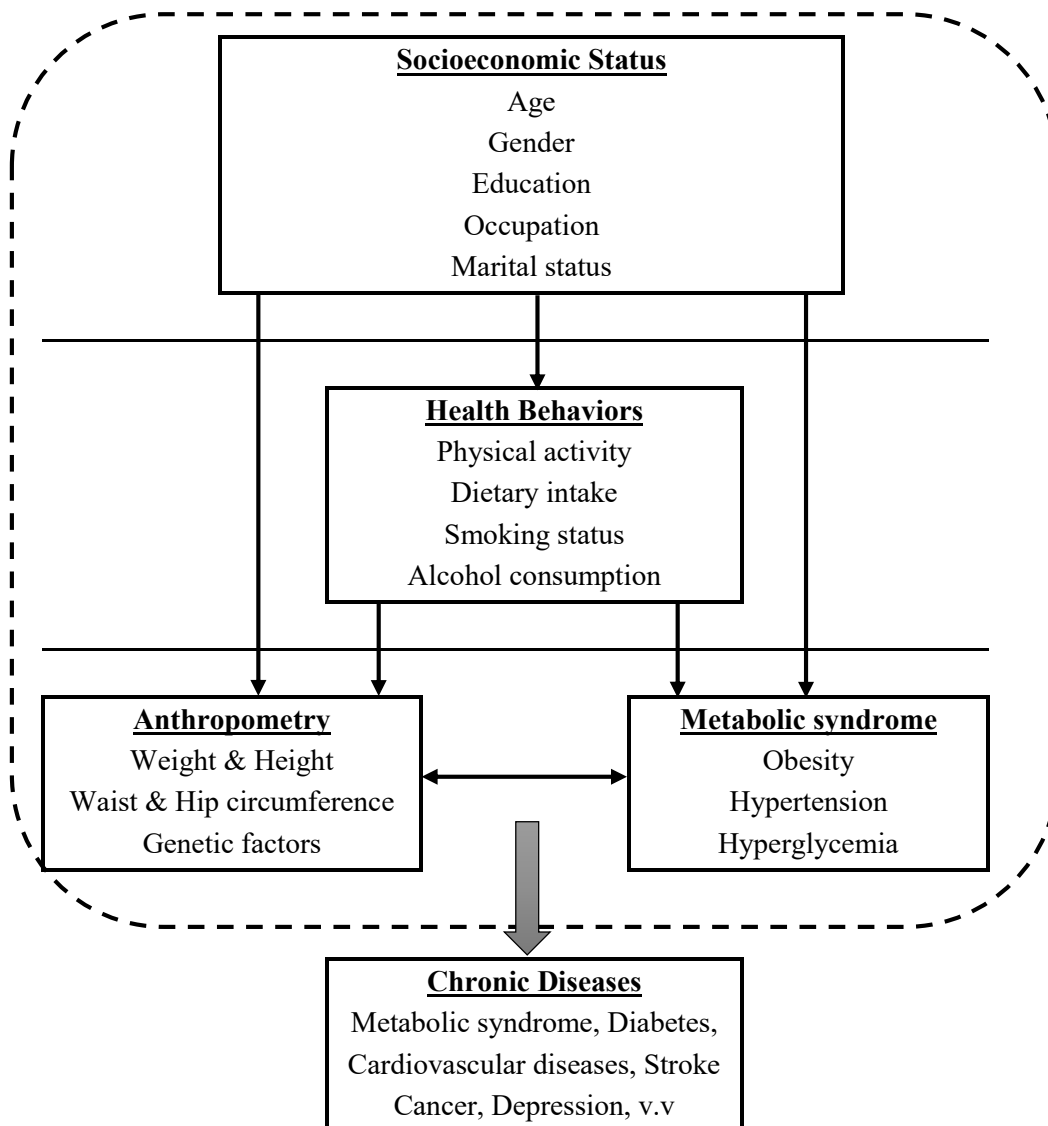


Figure 5. Conceptual framework between NCDs and associated factors

The model is referenced from the analysis models of factors related to NCDs (Craig et al., 2021; Katel, 2018; Sampa et al., 2020; Zeiher et al., 2019)

3.2. Study design

A cross-section study design was applied in this study to determine the prevalence of hyperglycemia among individuals over the age of 40 years old, including hypertension and some related factors in nine communes of Ba Vi district, Ha Noi city, Viet Nam.

3.3. Participants

The targeted participants of this study are middle-aged and older individuals, currently living in nine communes (Minh Chau, Cam Linh, Tong Bat, Phu Son, Thai Hoa, Tan Hong, Cam Thuong, Tan Linh, Ba Trai), Ba Vi district, Ha Noi city, Viet Nam.

3.3.1. Inclusion and exclusion criteria

The inclusion criteria were as follows:

- 40 years of age or over;
- Permanently living in nine communes, Ba Vi district, Ha Noi (individuals who have lived regularly in this area within the past 12 months);
- Able to understand the Vietnamese language and participate in the interviews;
- Having a health status stable enough to participate in the study.

The exclusion criteria were as below:

- Visitors or tourists; Patients that are being treated at medical facilities or home;
- Individuals who have lost their mental and behavioral capacity;
- Women who are pregnant or have given birth within the previous three months;

3.3.2. Individuals who have been diagnosed with diabetes or are taking medication that affects blood sugar levels such as corticosteroids, estrogens, diuretics.

3.3.2. Sample size estimation

The sample size was calculated using the following formula (Nguyen et al., 2019):

$$N = Z_{1-\alpha/2}^2 \frac{p(1-p)}{d^2} DE$$

With:

- Z: The standard normal deviation for α , $\alpha = 0.05 \Rightarrow Z_{1-\alpha/2}^2 = 1.96^2$
- d: Tolerated margin of error, $d = 0.04$ (*The acceptable margin of error usually falls between 4% and 8% at the 95% confidence level*) (ZOHO, 2022).
- p: The sample proportion, $p = 0.5$ (*the prevalence of individuals who have pre-diabetes in the research in Viet Nam, 2019*) (Nguyen et al., 2019).
- DE: The design effect, $DE = 3$. (*DE can be calculated from the trial study. If there is no condition to calculate the design factor, the design factor can be chosen as 3*).

We can therefore say: $N = 1.96^2 * \frac{0.5(1-0.5)}{0.04^2} * 3 = 1800$

As a precaution and as a result of the lack of sample size for some reason, participants who were invited to participate in the study again refused to participate or did not meet all the criteria of sampling. As a result, the research team accepted an additional 10% of participants (180 individuals) to be part of the sample. Therefore, the total number of participants to be collected was 1980. Through the data collection, a total of **1,814 participants** met the criteria and were included in the research study list.

3.3.3. Sampling

Initially, the researchers used a random sample collection method based on the population structure (aged 40 years and older) in each commune. Then, nine communes and a defined sample of healthy individuals over the age of 40 years old were selected for the sample.

The formula for selecting the participants in each area was as follows:

$$x = \frac{\text{no. people} \geq 40 \text{ years}}{49492} * 1980$$

Table 3. Sampling estimate of study participants selected for each commune

No	Commune	No. individuals ≥40 years	Sample (x)	No. collected	%
1	Minh Chau	4861	194	176	90.72
2	Cam Linh	6113	245	226	92.24
3	Tong Bat	5410	216	198	91.67
4	Phu Son	5387	215	197	91.63
5	Thai Hoa	6935	277	259	93.50
6	Tan Hong	5111	204	186	91.18
7	Cam Thuong	5832	233	215	92.27
8	Tan Linh	4783	191	173	90.58
9	Ba Trai	5060	202	184	91.09
Total		49,492	1,980	1814	91.62

This study made use of purposive and convenient sampling. The village health workers and commune health workers at nine commune health stations in the study collected a list of candidates who met the selection criteria. The candidates were then invited to participate in the study and were guided to the commune health station for the collecting of their venous blood samples, health checkup, and interview.

3.4. Data collection

3.4.1. Data collection process

Table 4. Field data collection process

Activities	Participations
Pre-Data collection	
All investigators were trained to explain to help participants understand study's objectives and the data collection techniques; Guidelines for using measuring and testing equipment.	CHWs: 45 medical staff/ 9 communes DHWs: 5 medical staff NCD Dep.t NIHE: 7 researchers
A pilot survey questionnaire was tested to ensure that the meaning and wording of the questions were easy to understand and then corrected to increase clarity.	
A list of candidates that fully meet the project's sampling requirements is established in each village of 9 communes.	VHWs: 54 individuals / 9 communes CHWs: 9 medical staff
Based on the allocated number and the list of qualified candidates, the village health worker met each subject in person to give invitations and notes on blood sampling.	VHWs: 54 individuals / 9 communes

Collecting Data	
The research team will collect data in each commune within 2 days.	CHWs: 5 medical staff DHWs: 4 medical staff
Subjects were invited to the commune health station to answer a questionnaire (interview face-to-face); To measure blood pressure, weight, height, waist, and hip; To take venous blood samples.	NCD Dep.t NIHE: 4 researchers
During the interview process, the research team designed a "1-way process", including 5 steps-5 tables with each specific purpose such as:	Around 120 minutes
Table 1: Welcome and check the invitation list	5 minutes
Table 2: Introduce research objectives, sign the research consents form, and interview according to questionnaires	15 minutes
Table 3: Measure blood pressure 2 times, each time measuring 5-10 minutes apart	15 minutes
Table 4: Measure height, weight, waist, and hip circumference	5 minutes
Table 5 Take capillary blood and run the monitor	60 minutes
Table 6 Give results and recommendations to participants	20 minutes
Post-Data collection	
The research team checked the collected information and destroy the blood sample according to the regulations	CHWs: 5 medical staff DHWs: 4 medical staff
The survey was conducted as a general health check-up for the study subjects. In the end, a total of 1814 qualifying records were collected for the research.	NCD Dep.t NIHE: 4 researchers

Table 5. Indicators of body measurements and blood samples

No	Index	Details
1	Blood pressure	Electronic blood pressure monitor (mmHg)
2	Weight, Height	Medical scale and height gauge (kg, cm)
3	Waist, Hip circumference	Plastic tape measure (cm)
4	The fasting plasma glucose test	5ml venous blood (mmol/l) (8-12h after eating)

3.4.2. Case definition

The FPG results are classified by the ADA as: (1) Normal: below 5.5 mmol/l (100 mg/dl); (2) Hyperglycemia: between 5.6 - 6.9 mmol/L (100 to 125 mg/dL) - changes in lifestyle and monitoring glycemia are recommended in this regard; (3) An FPG result of 7 mmol/L or higher (≥ 126 mg/dL) on two separate tests, intermediate hyperglycemia is defined (Association, 2022a; WHO, 2006).

The BMI ASIAN cut-off was calculated with the equation of the body weight (kg) divided by the square of height (m^2), which classified the participants into four groups: < 18.5 (underweight), 18.5-22.9 (normal), 23.0-24.9 (overweight) and ≥ 25.0 (obese) (Shrestha et al., 2019).

The waist circumference (WC) was measured at the mid-point of the last palpable rib and the top of the hip bone horizontally (mostly at the height of the bellybutton). The hip circumference (HC) was measured around the maximum circumference of the buttocks

horizontally. The waist-to-hip ratio (WHR) was derived as the ratio of the WC over HC. Central obesity was defined as WHR > 0.85 cm (women) or > 0.9 cm (men) (WHO, 1999).

The blood pressure (BP) was measured twice in a sitting position after participants rested for at least five minutes. The mean of the two values was used in the analysis. Hypertension (HTN) was defined as an elevated BP of systolic BP \geq 140 mmHg and/or diastolic BP \geq 90 mmHg.

The metabolic syndrome was defined as 3 factors: 1) WC \geq 90 cm for males or \geq 80 cm for females in the Asian population; 2) systolic BP \geq 130 mmHg and/or diastolic \geq 85 mmHg; and 3) FPG level \geq 5.6 mmol/L (100 mg/dL) (Alberti et al., 2006; Kassi et al., 2011).

3.4.3. Variables

The study tool was a 22-item interview questionnaire. Six variables were used in the general information questions in the first section. The second section of the survey included six questions about any historical hypertension, diabetes, and behavioral factors associated with NCDs. The ten variables on health indicators are included in the last part. Table 6 lists all of the variables used in this investigation in detail.

Table 6. Description of Variables and indicators

Category	Classification	Definition
General Characteristics		
Living area	1= Minh Chau; 2= Cam Linh; 3= Tong Bat; 4= Phu Son; 5= Thai Hoa; 6= Tan Hong; 7= Cam Thuong; 8= Tan Linh; 9= Ba Trai	Commune in which the participants are living
Gender	1= Male; 2= Female	Gender of the participants
Age	1= 40-49; 2= 50-59 3= 60-69; 4= 70 and over	Individuals completed 40 years and over
Education	1= Primary school or less 2= Secondary school or upper	The highest level of education that has already been completed
Marriage status	1= Single 2= Currently married	The marital status of participants

	3= Divorced/ Widowed	
Occupation	1= Farmer; 2 = Homemaker 3= Worker; 4= Retired; 5= Other	The jobs that participants spent the most time on
Behavioral Measurements		
Tobacco use status	1= Never; 2= Yes 3= Used to smoke, now quit	The participant's tobacco use status
Alcohol use status	1= Never; 2= Daily; 3= Sometime	Frequency of alcohol use per week
Eating vegetables, fruit status	Number of day(s)/ week Number of serving(s)/ day	The number of day(s) participants eat vegetables and the servings per day
Salt intake	1= Always; 2= Often 3= Sometimes; 4= Rarely	Frequency that participants add salt to food during cooking
Doing physical activities	Number of day(s)/ week Hours/ day	The number of day(s) participants do moderate-intensity activities
Sitting or reclining	Number of hours/day	The number of hour(s) participants do sit or recline per day

Physical and Biochemical Measurements		
Raised Blood Pressure/ Hypertension	1= Yes; 2= No	Participants were diagnosed with raised blood pressure or hypertension
Genetic factors with high blood pressure or hypertension	1= Yes; 2= No	Someone in the family (a blood relative) has high blood pressure/hypertension
Genetic factors with high blood sugar or diabetes	1= Yes; 2= No	Someone in the family (a blood relative) has high blood sugar/diabetes
Blood Pressure Reading 1	Systolic & Diastolic (mmHg)	1 st blood pressure reading
Blood Pressure Reading 2	Systolic & Diastolic (mmHg)	2 nd blood pressure reading
Height	Number (cm)	Participant's height
Weight	Number (cm)	Participant's weight
Waist circumference	Number (cm)	Participant's waist
Hip circumference	Number (cm)	Participant's hip
The fasting plasma glucose test (FPG)	Number (mmol/l)	Hyperglycemia level (after 8-12 hours of eating)

3.5. Data analysis

- IBM SPSS for Windows was used to analyze the data (version 26.0).
- Descriptive statistics were used to present the data, including the mean, standard deviation for continuous variables as well as the frequency, and the percentage for categorical variables. The Chi-square or Fisher's Exact test was used to determine the association between the participants' hyperglycemia levels.
- The multiple logistic regressions with 95% confidence intervals (95% CI) were used to analyze the relationships between the hyperglycemia levels, the socio-demographic characteristics, and the risk factors for NCDs.

3.6. Ethics statement

This research study was conducted under the supervision of The Research Ethics Council - The National Institute of Hygiene and Epidemiology (NIHE) in 2021. The informed consent form required participants to either sign it or have their fingerprints taken as confirmation of their consent to participate. This study's participants participated willingly, at their own free will, and were not coerced into participating. The participants had the right to decline to answer any questions or withdraw from the study at any moment. This study's data and sample materials will be kept secure, encrypted, and used only for research purposes. The standard operating procedures will be used in NIHE to manage all the information collected. The findings will be used to suggest and make recommendations for improving the healthcare system and any laws related to the health sector.

IV. RESULTS

4.1. Characteristics of the study population

Table 7. Distribution of demographic characteristics

Variable	Total (1814)		Men (689)		Women (1125)	
	N	%	N	%	N	%
Age (year) Mean (SD)	59.1 (8.9)		58.7 (8.5)		59.3 (9.2)	
Age group						
40-54	547	30.2	216	31.3	331	29.4
55-69	1063	58.6	415	60.2	648	57.6
≥ 70	204	11.2	58	8.4	146	13.0
Education						
Primary school or lower	449	24.8	185	26.9	264	23.5
Secondary school or upper	1365	75.2	504	73.1	861	76.5
Marital status						
Single	43	2.4	8	1.2	35	3.1
Current married	1582	87.2	660	95.8	922	82.0
Divorced/ Widowed	189	10.4	21	3.0	168	14.9
Occupation						
Farmer	1297	71.5	466	67.6	831	73.9
Homemaker	139	7.7	19	2.8	120	10.7
Worker	165	9.1	99	14.4	66	5.9
Retired	213	11.7	105	15.2	108	9.6

In nine communities in Viet Nam's Ba Vi district, 1,814 middle-aged and older individuals were enrolled to participate in the study. Table 7 provided a summary of the general characteristics of the study population. The participants' average age was 59.1 +

8.9 (SD). Men made up 37.58% of the population while women made up 62.02%. The majority of participants (87.2%) were married; 75.2% had completed secondary school or above; and 24.8% had only completed elementary school or lower. The farmers made up about a third of the population (71.5%), and the retirees were the next largest group.

Table 8. Distribution of health behavior factors

Variable	Total (1814)		Men (689)		Women (1125)	
	N	%	N	%	N	%
Tobacco use						
No	1293	71.3	191	27.7	1102	98.0
Yes	521	28.7	498	72.3	23	2.0
Alcohol use						
No	1321	72.8	242	35.1	1079	95.9
Yes	493	27.2	447	64.9	46	4.1
Salty food use						
Always	362	20	171	24.8	19	17
Often	518	28.6	230	33.4	288	25.6
Sometimes	541	29.8	176	25.5	365	32.4
Rarely	166	9.2	47	6.8	119	10.6
Never	227	12.4	65	9.4	162	14.4
Fruit and vegetable consumption						
Not enough	1290	71.1	513	74.5	777	69.1
Enough	524	28.9	176	25.5	348	30.9
Physical activities						
Not enough	299	16.5	119	17.3	180	16.0
Enough	1515	83.5	570	82.7	945	84.0

The factors in relation to the health behaviors of the participants are given in table 8. First, the smoking rate among men is 72.3% and only 2% among women. This proportion also has a similar difference with regard to the status of alcohol use - 64.9% and 4.1% in men and women, respectively. Furthermore, 78.4% of the participants tend to eat salty foods. The percentage of individuals who eat enough fruits and vegetables is a mere 28.9% for both sexes. On average, 83.5% of respondents engage in 150 minutes of moderate physical exercise each week; this percentage is 84% for women and 82.7% for males.

The indicators of biological health are shown in Table 9 as average values for both men and women. Men typically have blood sugar levels of 6.1 mmol/l (± 1.3 SD), whereas women have values of 5.8 mmol/l (± 1.1 SD). There were 229 individuals, which accounted for 12.6% of the total sample size, whose family members had a diabetic relative of the same bloodline. While 52.4% of individuals had a BMI that was regarded as normal by Asian standards; being overweight and obese were prevalent as they were 22.7% and 17.9%, respectively. The percentage of participants who were diagnosed at the time of the study was 41.4%, hypertension appears to be a common non-communicable illness in this study population of participants. Importantly, metabolic syndrome

Table 9. Distribution of biological factors

Variable	Total (1814)		Men (689)		Women (1125)	
	Mean	SD	Mean	SD	Mean	SD
Weight (kg)	54.4	8.8	58.8	9.1	51.7	7.4
Height (cm)	155.3	7.3	161.2	6.2	151.7	5.3
BMI	22.4	2.8	22.5	3.0	22.4	2.7
Waist (cm)	79.2	8.7	81.0	9.6	78.1	7.8
Hip (cm)	90.4	6.2	91.2	6.4	89.9	6.0
Waist-hip ratio (WHR)	0.87	0.07	0.88	0.78	0.86	0.72
FPG test (mmol/l)	5.9	1.2	6.1	1.3	5.8	1.1
Diastolic (mmHg)	84.0	11.4	88.1	11.6	81.5	10.5
Systolic (mmHg)	133.9	18.8	138.3	18.5	131.2	18.4
	Total (1814)		Men (689)		Women (1125)	
	N	%	N	%	N	%
Diabetes Family member						
No	1585	87.4	618	89.7	967	86
Yes	229	12.6	71	10.3	158	14
Blood Pressure						
Normal	1063	58.6	319	46.3	744	66.1
High	751	41.4	370	53.7	381	33.9
BMI (Asia cut-off)						
Underweight	127	7.0	53	7.7	74	6.6
Normal	951	52.4	338	49.1	613	54.5
Overweight	412	22.7	157	22.8	255	22.7
Obese	324	17.9	141	20.5	183	16.3
Metabolic syndrome (MetS)						
No	1438	79.3	596	86.5	842	74.8
Yes	376	20.7	93	13.5	283	25.2

4.2. Prevalence of hyperglycemia in the study population

Table 10. Prevalence of hyperglycemia with the ADA classifications (n=1,814)

Category	N, %
Normal (< 5.6 mmol/l)	745 (41.1)
Intermediate Hyperglycemia (5.6-6.9 mmol/l)	887 (48.9)
Hyperglycemia (\geq 7.0 mmol/l)	182 (10.0)

Tables 10 and 11 present the general results of the prevalence of hyperglycemia according to the American Diabetes Association recommendations. The crude prevalence of mid-hyperglycemia was 48.9% (95% CI: 46.6-51.2) in all subjects, whereas hyperglycemia was only 10% (95% CI: 8.7-11.5). The standardized ages with regard to the prevalence rate of mid-hyperglycemia and hyperglycemia were 47.8% (95% CI: 44.6-50.9) and 9.2% (95% CI: 7.9-10.6), respectively. Notably, there was a higher prevalence of hyperglycemia among men than among women (13.5% vs. 7.9%). In the four BMI categories, the rate of moderate and hyperglycemia was additionally higher among obese individuals (48.5% and 14.3%, respectively). The prevalence of moderate hyperglycemia was 50% (95% CI: 46.3-53.6) in the group of patients with high blood pressure, whereas the prevalence of hyperglycemia was 14.2% (95% CI: 11.7-16.6).

Table 11. Age-standardized prevalence of hyperglycemia (n=1,814)

Variable	Percentage (95% CI)	
	Intermediate Hyperglycemia (n = 887)	Hyperglycemia (n = 182)
Age group		
40-54	45.3 (41.3-49.5)	7.7 (5.5-10.0)
55-69	50.3 (47.3-53.3)	11.1 (9.3-13.1)
≥ 70	51.0 (43.9-57.8)	10.8 (6.5-15.1)
Unadjusted	48.9 (46.6-51.2)	10.0 (8.7-11.5)
Age-adjusted*	47.8 (44.6-50.9)	9.2 (7.9-10.6)
Gender		
Men	53.3 (49.6-57.0)	13.5 (11.0-16.3)
Woman	46.2 (43.3-49.2)	7.9 (6.3-9.6)
BMI (Asia cut-off)		
Underweight	39.4 (31.0-48.4)	8.7 (4.1-14.0)
Normal	47.2 (44.2-50.4)	9.2 (7.4-11.1)
Overweight	47.0 (41.9-52.1)	10.8 (7.9-13.9)
Obese	48.5 (43.2-54.0)	14.3 (10.4-18.7)
Blood pressure		
Normal	44.4 (41.5-47.4)	7.8 (6.2-9.6)
High	50.0 (46.3-53.6)	14.2 (11.7-16.6)

**Age adjustments were made with direct method, using the completed results of the 2019 Viet Nam population and housing census (GeneralStatisticsOffice, 2020).*

Table 12. Factors associated with The fasting plasma glucose (FPG)

Variable	The fasting plasma glucose test			p-value
	Total	Mean	SD	
Total	1814	5.92	1.17	
Age group				0.007
40-54	547	5.79	1.18	
55-69	1063	5.97	1.15	
≥ 70	204	6.02	1.18	
Gender				<0.001
Men	689	6.07	1.28	
Women	1125	5.83	1.08	
Occupation				0.293
Farmer	1297	5.90	1.12	
Homemaker	139	5.93	1.38	
Worker	165	6.09	1.51	
Retired	213	5.92	0.98	
Tobacco use				<0.001
No	1293	5.86	1.09	
Yes	521	6.09	1.33	
Alcohol use				<0.001
No	1321	5.84	1.05	
Yes	493	6.14	1.41	
Salty food use				0.333
Always	362	5.89	1.16	
Often	518	5.86	1.14	
Sometimes	541	5.94	1.11	
Rarely	166	6.07	1.42	
Never	227	5.96	1.16	

Enough fruit and vegetable use				0.695
No	1290	5.93	1.21	
Yes	524	5.91	1.06	
Enough moderate activity				0.795
No	299	5.94	1.15	
Yes	1515	5.92	1.17	
Blood pressure				<0.001
Normal	1063	5.80	0.99	
High	751	6.09	1.36	
BMI (Asia cut-off)				0.003
Underweight	127	5.77	1.16	
Normal	951	5.85	1.04	
Overweight	412	6.02	1.31	
Obese	324	6.08	1.30	
Metabolic syndrome (MetS)				<0.001
No	1438	5.74	1.01	
Yes	376	6.62	1.43	

**The p-value (probability value) is ≤ 0.05 , which means statistical significance.*

The mean glycemic index for men and women is exhibited in Table 12, which is 6.07 mmol/l and 5.83 mmol/l, respectively; this difference was statistically significant ($p=0.001$). The groups with participants that made use of alcohol or tobacco, and the hypertensive group and MetS group exhibited similar differences ($p=0.001$). The mean FPG results differ significantly in each of the three age groups (40–54, 55–69, and ≥ 70) with the p -value=0.007 (5.79, 5.97, and 6.02 mmol/l, respectively). The participants' average glycemic index varied considerably depending on their body mass index ($p=0.003$).

4.3. Factors associated with the fasting plasma glucose level

Table 13. Demographic characteristics associated with hyperglycemia (n=1,814)

Fasting plasma glucose level	< 5.6mmol/l		≥ 5.6mmol/l		OR	95% CI	p-value
	N	%	N	%			
Gender							
Men	229	33.2	460	66.8	1.70	1.39-2.07	<0.001
Women	516	45.9	609	54.1	1.00		
Age group							
40-54	257	47.0	290	53.0	1.00		
55-69	410	38.6	653	61.4	1.41	1.14-1.73	0.001
≥ 70	78	38.2	126	61.8	1.43	1.03-1.98	0.032
Education							
Primary school or lower	181	40.3	268	59.7	1.00		
Secondary school or upper	564	41.3	801	58.7	0.95	0.77-1.19	0.707
Marital status							
Single	18	41.9	25	58.1	1.00		
Current married	648	41.0	934	59.0	1.04	0.56-1.92	0.906
Divorced/ Widowed	79	41.8	110	58.2	1.00	0.51-1.96	0.994
Occupation							
Farmer	542	41.8	755	58.2	1.00		
Homemaker	65	46.8	74	53.2	0.81	0.57-1.16	0.260
Worker	58	35.2	107	64.8	1.32	0.94-1.86	0.103
Retired	80	37.6	133	62.4	1.19	0.88-1.61	0.245

The demographic characteristics and factors associated with the participants' health behaviors and hyperglycemia were given in Tables 13 and 14. The results of the logistic regression univariate analysis revealed that men were 1.7 times more likely to have hyperglycemia and mid-hyperglycemia than women (95% CI: 1.39-2.07, $p<0.001$). When compared to the participants in the age range of 40-54 years old, individuals that were 55 years of age and older had a 1.41-1.43 times significantly higher rate of abnormal blood sugar level readings ($p<0.05$). The results also explained that the present alcohol and tobacco status were related to hyperglycemia and moderate hyperglycemia. The smokers were 1.67 times more likely than non-smokers to have high blood sugar levels (95% CI: 1.35-2.07, $p<0.001$). Similarly, alcohol users' blood sugar levels increased at a rate that was 1.71 times higher than that of the non-drinkers (95% CI: 1.38-2.13, $p<0.001$).

Table 14. Health behavior factors associated with hyperglycemia (n=1,814)

Fasting plasma glucose level	< 5.6mmol/l		≥ 5.6mmol/l		OR	95% CI	%
	N	%	N	%			
Tobacco use							
No	576	44.5	717	55.5	1.00		
Yes	169	32.4	352	67.6	1.67	1.35-2.07	<0.001
Alcohol use							
No	588	44.5	733	55.5	1.00		
Yes	157	31.8	336	68.2	1.71	1.38-2.13	<0.001
Salty food use							
Always	153	42.3	209	57.7	0.89	0.64-1.26	0.530
Often	228	44.0	290	56.0	0.83	0.60-1.15	0.267
Sometimes	210	38.8	331	61.2	1.03	0.75-1.42	0.830
Rarely	64	38.6	102	61.4	1.04	0.69-1.58	0.826
Never	90	39.6	137	60.4	1.00		
Fruit vegetable consumption							
Not enough	538	41.7	752	58.3	1.00		
Enough	207	39.5	317	60.5	1.10	0.89-1.35	0.388
Physical activity							
Not enough	111	37.1	188	62.9	1.00		
Enough	634	41.8	881	58.2	0.82	0.63-1.06	0.130

Table 15. Biological factors associated the hyperglycemia (n=1,814)

Fasting plasma glucose level	< 5.6mmol/l		≥ 5.6mmol/l		OR	95% CI	p-value
	N	%	N	%			
BMI (Asia cut-off)							
Underweight	66	52.0	61	48.0	1.00		
Normal	401	42.2	550	57.8	1.48	1.02-2.15	0.037
Overweight	164	39.8	248	60.2	1.63	1.09-2.44	0.016
Obese	114	35.2	210	64.8	1.99	1.31-3.02	0.001
Blood pressure							
Normal	487	45.8	576	54.2	1.00		
High	258	34.4	493	65.6	1.62	1.33-1.96	<0.001
Waist circumference							
Normal	519	42.8	693	57.2	1.00		
High	226	37.5	376	62.5	1.25	1.02-1.52	0.031
Waist hip ratio							
Normal	362	43.1	478	56.9	1.00		
High	383	39.3	591	60.7	1.17	0.96-1.41	0.103
Diabetes Family member							
No	659	41.6	926	58.4	1.00		
Yes	86	37.6	143	62.4	1.18	0.88-1.57	0.248

The findings in Table 15 demonstrate the association between biological factors and blood sugar status by making use of the logistic regression univariate analysis. In comparison to the low-weight group, those with normal BMI, who were overweight, and obese had blood sugar levels that were higher (1.48, 1.62, and 1.99 times, respectively). This difference is statistically significant ($p<0.05$). Additionally, having a big waist and having high blood pressure levels are two risk factors with regard to issues related to

blood sugar. Men and women with large waists (Asia classification) were 1.25 times more likely to have blood sugar levels ≥ 5.6 mmol/l than those with a normal waist circumference (95% CI: 1.02-1.52, $p=0.031$). High blood glucose is 1.62 times more likely to develop in individuals with high blood pressure than in healthy individuals (95% CI: 1.33-1.96, $p<0.001$).

Table 16. Risk factors associated with hyperglycemia in Viet Nam

	B	Se	OR	95%CI	p-value
Gender					
Men	0.37	0.14	1.44	1.10-1.89	0.009
Women			1.00		
Age group					
40-54			1.00		
55-69	0.37	0.11	1.45	1.17-1.79	< 0.001
≥ 70	0.51	0.17	1.67	1.19-2.35	0.003
Alcohol use					
No			1.00		
Yes	0.33	0.15	1.39	1.03-1.86	0.03
BMI (Asia cut-off)					
Underweight			1.00		
Normal	0.45	0.20	1.57	1.07-2.30	0.022
Overweight	0.44	0.22	1.55	1.01-2.39	0.044
Obese	0.57	0.24	1.76	1.10-2.82	0.018
Blood pressure					
Normal			1.00		
High	0.34	0.10	1.40	1.15-1.71	0.001
Waist circumference					
Normal			1.00		
High	0.29	0.13	1.33	1.03-1.72	0.027

**The multivariate logistic model included all variables in the table.*

The significant statistics variables were entered into the multivariable regression analysis model following the univariate analysis of variables associated with the status of high

blood sugar levels. The six variables are presented in the final model, all of which are statistically significant ($p < 0.05$). Blood sugar levels are more likely to be elevated in older adults than in younger individuals. Smoking, being overweight as well as obese, having a large waistline and having high blood pressure were additional risk factors that displayed comparable trends. In this model, the odds ratio of having a high blood sugar condition was 1.44 times higher in men than in women (95% CI: 1.10-1.89, $p = 0.009$).

V. DISCUSSION

5.1. The prevalence of hyperglycemia

This research study was conducted as a health screening tool for healthy individuals aged 40 years and older, living in sub-urban areas in Viet Nam. The findings explored the prevalence of hyperglycemia among individuals who were ≥ 40 years of age with some associated factors included. The researchers conducted face-to-face interviews with 1,814 older individuals who participated in the study.

Overall, according to two studies that were conducted more than a decade apart the biological characteristics of the individuals analyzed in Ba Vi in 2021 were higher than those analyzed in the province of Ha Nam in 2011. These research studies share the identical goal of choosing participants aged at least 40 years old to determine the prevalence of high blood sugar levels and associated factors in the sub-urban areas of Viet Nam. This demonstrates that the biological indicators of the study population have radically changed together with changes in living conditions, economic growth, and lifestyles. These factors may have an impact on the individuals' high blood sugar levels, which may therefore raise their risk of developing NCDs like diabetes or hypertension in the near future. The average systolic blood pressure and diastolic blood pressure were 115 mmHg and 70 mmHg respectively, whereas, in this study, this number rapidly increased to 140 mmHg and 84 mmHg, respectively. As opposed to the province of Ha Nam, the study's average BMI for both men and women was higher in Ba Vi (21.3 ± 2.7 and 21.4 ± 2.7 vs. 22.5 ± 3.0 and 22.4 ± 2.7). The participants' measurements of their hip and

waist circumferences in the study in Ha Nam were likewise slightly lesser than those in the study involving Ba Vi (WC: 74.4 ± 7.8 cm and 79.2 ± 8.7 cm; HC: 87.9 ± 5.6 cm and 90.4 ± 6.2 cm). As a result, the researchers can also confidently predict that the hip-to-waist ratio in the two experiments will differ significantly, the WHR for men was 0.86 ± 0.06 and for women was 0.84 ± 0.06 in the study conducted in 2011; whereas the WHR for men and women was 0.88 ± 0.78 and 0.86 ± 0.72 , respectively, in the study conducted in 2021 (Quang Binh et al., 2012).

First, the findings of this study with regard to hyperglycemia are crucial in predicting Viet Nam's prevalence of pre-diabetes and diabetes. The percentage of intermediate hyperglycemia and hyperglycemia after the adjustment by the participants age was 47.8% and 9.2%, respectively. The incidence of hyperglycemia is rising quickly in Viet Nam, particularly the prevalence of mid-level hyperglycemia. The STEPS survey conducted in 2015 found that in the adult population of Viet Nam between the age of 18-69 years old, the prevalence of mild hyperglycemia (6.1-6.9 mmol/l) and hyperglycemia (≥ 7.0 mmol/l) was 3.6% and 4.1%, respectively. When the survey was conducted in 2020, both figures had increased dramatically to 11% and 7.06%, respectively (Ministry of Health, 2022). This study shows a significantly larger number because the majority of the participants in the study were 40 years of age and above, who need to undergo screening every one to three years for risk factors related to underlying NCDs such as diabetes or hypertension. In 2018, using the FPG or HbA1c test (ADA standard), a study conducted in Khanh Hoa province exhibited that, in a random sample of 865 individuals, roughly 50.1% of the

participants had intermediate hyperglycemia and 8.1% of the participants had hyperglycemia (Nguyen et al., 2019). The results of this study are seen to be the most similar to the findings of the research conducted, and the difference is not significant when the participants of this study are healthy adults who are 45 years of age and older and were randomly chosen in Khanh Hoa province's rural and urban areas (the equivalence in the blood test method and the classification standards). Another study conducted in Ha Nam province in 2011 exhibited the prevalence of mid-hyperglycemia. The results of the representative, a population-based study showed that the age and sex-adjusted prevalences of intermediate raised blood sugar was 13% and it was 3.7% with regard to high blood sugar (Quang Binh et al., 2012). This finding indicates that, after ten years, the rate of patients with hyperglycemia was considerably higher in the Ba Vi area than in the Ha Nam province. The studies were both conducted with individuals aged 40 years old and over; whereas most of them lived in rural areas. In our study, the adjusted mid-hyperglycemia and hyperglycemia rates were 47.8% and 9.2%, respectively. These numbers are significantly higher than those seen in some previous studies. A discrepancy of such kind could be partially be explained by variations in the sampled cohorts' socio-economic situation, environmental characteristics, nutrition, lifestyle or by other characteristics of the study's design and standardization of prevalence.

At the same time, The Central America Diabetes Initiative survey was carried out between 2003 and 2006 using a probabilistic sample of six non-institutionalized Central American populations. There were 10,822 individuals who made up the total sample size

and 7,234 (67%) of them conducted anthropometry measurements, the FPG testing or two-hour OGTT testing. The prevalence of intermediate hyperglycemia differed more between the locations as opposed to hyperglycemia in terms of the prevalence across the six sites, which were 18.6% and 8.5% overall (Barcelo et al., 2012). The descriptive study was conducted in 2016 in the North Sudanese community of Alkhannag. A rural population of 430 individuals, both diabetic and not, participated in the study. The participants' ages ranged from 18-95 and 32.4% of all participants had random blood glucose readings ≥ 140 mg/dl. This investigation was conducted using random capillary blood glucose, which had the benefits of being conducted at any time of day, the participants did not need to fast, it is a straightforward process, and has a reasonable cost. The random capillary blood glucose of ≥ 140 mg/dl (7.7mmol/l) was found to correspond with a pre-prandial blood glucose of ≥ 5.6 mmol/l (Abdelaziz et al., 2018).

Similar to some previous studies, the prevalence of hyperglycemia in this study was higher (9.2%) than the rate in a rural Benin area, in 2019 (2.6%) (Campus et al., 2022), 5.6% in Malawi in 2009 (Msyamboza et al., 2011), 4% in Nepal in 2013 as well as 5.8% in 2019 (Aryal et al., 2015; Bista et al., 2021), 3.2% in Ethiopia in 2015 (Gebreyes et al., 2018), and 8.3% in Punjab, India in 2015 (Tripathy et al., 2017) based on the STEPS survey. Despite this, the prevalence of elevated fasting blood glucose was greater in Oman than in this study, at 15.7% (95% CI: 15.1-16.3) as opposed to 9.2% (95% CI: 7.9-10.6) (Al-Mawali et al., 2021), respectively. By comparing the results of the aforementioned research studies, it can be observed how the prevalence of hyperglycemia

varies depending on the age and study region of the participants. These studies all have a large-scale organization in low- and middle-income countries, the participants were between the ages of 18 and 69 years old, and a stratified sample selection was made use of.

Second, the findings of this study indicate that the prevalence of hyperglycemia is higher in males than in women, at 13.5% (95% CI: 11.0-16.3) and 7.9% (95% CI: 6.3-9.6), respectively. In recent years, there has been a difference between the proportion of men and women with hyperglycemia, according to studies conducted in Viet Nam and elsewhere.

In Ha Nam's study conducted in 2011, the figures were 4.6% (95% CI: 3.3-5.8) and 2.9% (95% CI: 2.2-3.7) (Quang Binh et al., 2012); whereas the STEPS survey that was conducted in 2020 in Viet Nam, had prevalences that were 7.3% (95% CI: 5.9-8.7) and 6.8% (95% CI: 5.2-8.5) (MinistryofHealth, 2022). There were similar findings from four research studies conducted in four other nations from 2010 to 2020, they exhibited that men are more likely to have a glycemic index of 7.0 mmol/l or higher as opposed to women; in Malawi 6.5% (95% CI: 2.8-10.3) and 4.7% (95% CI: 2.5-7.1) (Msyamboza et al., 2011), in Nepal 6.3% (95% CI: 4.6-8.5) and 5.3% (95% CI: 4.1-6.8) (Bista et al., 2021), in India 8.4% (95% CI: 6.7-10.3) 8.2% (95% CI: 7.0-9.7) (Tripathy et al., 2017) and in Ethiopia 3.3% and 3.0% (Gebreyes et al., 2018).

Third, both in this research study and in numerous other studies that are based on the same subject, the outcomes demonstrated an upward trend in the prevalence of

hyperglycemia, with older adults having a greater tendency to have higher blood sugar levels. The age group of 55-69 years old had the highest rate (11.1%) in Ba Vi district; 6.4% (95% CI: 5.0-7.7) in the age group of 60-64 years old in Ha Nam province in 2011 (Quang Binh et al., 2012) and 12.9% (95% CI: 7.56-18.23) of individuals ≥ 65 years of age had blood sugar levels ≥ 7 mmol/l in Khanh Hoa province (Nguyen et al., 2019). Some of the studies conducted in other nations, with age groupings close to Viet Nam's, also showed similar findings. In Ethiopia, the age group of 55-64 years old had the highest rate of hyperglycemia (4.5%) (Gebreyes et al., 2018); In Malawi in 2009, the age group of 55-69 years old was the age group with the highest rate of increased blood glucose, being at 6.8% (95% CI: 3.8-9.8) (Msyamboza et al., 2014) and in Nepal, the age group of 45-69 years old had the highest frequency with 10.2% (95% CI: 8.1–12.7) (Bista et al., 2021).

Despite the increase in the cases of hyperglycemia among individuals with normal, overweight, and obesity, the related BMIs in this regard are another trend that is even more remarkable. Four research studies from inside and outside Viet Nam revealed the greatest growth. The findings of this study indicate that the incidence of hyperglycemia increases with BMI: the normal, overweight, and obese group was at 9.2% (95% CI: 7.4-11.1), 10.8% (95% CI: 7.9-13.9) and 14.3% (95% CI: 10.4-18.7), respectively. The proportions in Ha Nam province were 2.8% (95% CI: 2.4-3.2), 4.7% (95% CI: 3.8–5.5), and 8.7% (95% CI: 6.6–10.7) (Quang Binh et al., 2012), respectively; in the North Sudan's study, the prevalences, which were gradually growing for three groups, were

35.5%, 44.6% and 45.2% (Abdelaziz et al., 2018) and the figures for Ethiopia were 2.6%, 6.7% and 8.2% (Gebreyes et al., 2018). The disparities in the socio-culture and lifestyle between the study sites could be used to explain this small discrepancy.

In addition, individuals with high blood pressure are more likely to have high blood sugar levels as opposed to those with normal blood pressure. The statistics evidently differentiate between those with and without hypertension. In this research study, the prevalence of hyperglycemia in individuals with high blood pressure was 14.2% (95% CI: 11.7-16.6), while for participants with standard blood pressure was only 7.8% (95% CI: 6.2-9.6). The prevalence of high blood sugar levels between healthy individuals and those with blood pressure $\geq 140/90$ mmHg is clearly different, according to similar research conducted in three different nations. The specific numbers in these countries respectively are as follows; the figure for North Sudan's study was 59.1% and 32.5% (Abdelaziz et al., 2018); India's study was 14.3% and 4.1% (Tripathy et al., 2017); the percentages of Ethiopia's study was 3.7% and 3.1% (Gebreyes et al., 2018).

5.2. Factors associated with hyperglycemia

To begin with, statistically relevant variables were chosen by the research team to include in the multivariate regression model following the univariate examination of factors related to fasting blood sugar problems. The team further decided to keep the final model's six variables—age group, gender, BMI, waist circumference, alcohol consumption, and hypertension - after consulting with prior studies. All of the model's

variables are statistically significant and show a strong association with the patients' fasting blood glucose levels.

The previous research in Khanh Hoa discovered a link between increased blood sugar and hypertension. If an individual had high blood pressure, they were 1.22 (95% CI: 0.90-1.65) times more likely to have pre-diabetes as opposed to the general population (Nguyen et al., 2019). According to a study conducted in 2011 in Ha Nam, participants with high blood pressure were 1.66 (95% CI: 1.24-2.22) times more likely to experience a fasting blood sugar problem than participants with normal blood pressure (Quang Binh et al., 2012). This study made use of a multivariable logistic regression analysis that produced similar outcomes. High blood pressure can increase the risk of having blood sugar problems by 1.4 times compared to those who have a healthy lifestyle. Surveys from all over the world have also shown that one of the elements contributing to the issue of high blood sugar was hypertension. In a survey conducted in Ethiopia, the high blood pressure group's hyperglycemia was 1.26 times (95% CI: 0.92-1.73) greater than that of the healthy group (Gebreyes et al., 2018). In India's study conducted in 2015, this figure was 2.0 times (95% CI: 1.4-2.8) (Tripathy et al., 2017).

The BMI is the second factor that is associated to increased blood sugar levels. In this study, the higher the BMI, the higher the risk of problems in relation to impaired fasting glucose. In comparison to the underweight group, the obese group was 1.76 times more likely to have high blood sugar levels (95% CI: 1.10-2.82). Similar associations have been found in other research studies both domestically and abroad, however, the

probability of hyperglycemia in the overweight and obese group was lower than what was recorded in this study when compared to the low and normal weight group; the overweight and the obese group had a 1.40 (95% CI: 1.02-2.00) greater risk of acquiring diabetes than the normal weight and low weight groups in the multivariable model of factors connected to pre-diabetes by author Nguyen Van Dat (Nguyen et al., 2019). A similar result occurred in the Ethiopian study which was conducted in 2015; the overweight and obese groups were, respectively, 1.12 (95% CI: 0.67-1.86) and 0.93 (95% CI: 0.46-1.92) times more likely than the underweight groups to experience hyperglycemia (Gebreyes et al., 2018). The obese group was 1.6 times (95% CI: 1.2-2.0) more likely to have diabetes as opposed to the group with a normal BMI reading, this is in accordance with a study conducted in India the same year that produced results that were comparable to this study but with lower outcomes (Tripathy et al., 2017). Moreover, the multivariate analysis model of factors associated with hyperglycemia in the rural population of Tanvè and De'kanmey in Benin in 2019 exhibited that the significance of hyperglycemia was 1.68 times (95%CI: 0.75-3.59) higher in the obese group, and 0.58 times (95%CI: 0.18-1.46) lower in the underweight group as compared to the normal BMI group (Campus et al., 2022).

Alcohol and tobacco are both considered two risk factors with regard to NCDs such as hypertension and diabetes. Although both factors were within the purview of this research study and were connected to the glycemic index (≥ 5.6 mmol/l) in the univariate analysis, only the alcohol consumption component was preserved when it was merged with other

covariates in the multivariate model. Alcohol users have a 1.39 (95% CI: 1.03-1.86) -fold higher risk of hyperglycemia than non-drinkers. A study conducted in Ha Nam in 2011 also had similar results as those who consumed two or more units of alcohol per day had a 2.29 (95% CI: 1.23-4.25) times greater chance of having impaired fasting blood sugar than non-alcoholics. The multivariate model used in Ha Nam's study also factored in smoking, and the results showed that current smokers have a lower risk of high blood glucose than non-smokers which was not statistically significant (Quang Binh et al., 2012).

The third important factor was individuals having a big waist circumference; in accordance with sex type, those with a large waist were more likely to develop hyperglycemia than those with a regular waist circumference. The studies conducted in India in 2015, in Benin in 2019, and Khanh Hoa province in Viet Nam all produced similar findings in this regard (Campus et al., 2022; Nguyen et al., 2019; Tripathy et al., 2017). When comparing the two groups with big and normal waist circumferences in terms of their chance of getting hyperglycemia, the study conducted in Benin's highest number was 2.8 times (95% CI: 1.29-6.16, $p=0.007$). The multivariate model incorporated the big waist circumference component along with other variables, and it was statistically significant in the research studies. This aspect of hyperglycemia, which can lead to the development of diabetes, is seen as being crucial. Individuals with big waistlines are perceived to be heavier, which is a result of their bad diet and lack of daily exercise.

Additionally, this study revealed that men were at a higher risk of developing high blood sugar compared to women ($p = 0.009$), $OR = 1.44$ (1.10-1.89). Nicolas et al. also found a significant association between hyperglycemia and the sex type in Benin. In their study, hyperglycemia was 2.93 times more frequent in men than in women (95%CI: 1.49-5.84; $p=0.023$) (Campus et al., 2022). On the contrary, Yeweyenhareg et al in Ethiopia found that the risk of hyperglycemia increased significantly in women as opposed to men. This risk was 2.25 times higher in women than in men (95% CI: 1.63-3.11) (Gebreyes et al., 2018). This gap could be explained by the fact that the location in which the study was conducted, is an almost agricultural environment where the bulk of populations, carry out daily rural work and small trade on foot while walking around the surrounding villages, thereby deploying a lot of energy. In contrast, Bahendeka et al, in Uganda did not find a significant association between hyperglycemia and the sex type ($p = 0.421$) (Bahendeka et al., 2016). Similar results were found in many other studies in Ha Nam province Viet Nam (Quang Binh et al., 2012), Thakur et al's research in North India conducted in 2017 (Thakur et al., 2019) and Bihungum et al's study in Nepal conducted in 2019 (Bista et al., 2021).

The prevalence of hyperglycemia increased significantly with age ($p<0.005$). In fact, for every age category that was added, the probability of having high blood sugar increased by 1.45 to 1.67. In Bahendeka et al's study the same conclusion was reached, as they found that the prevalence of hyperglycemia significantly increased with age ($p = 0.003$) (Bahendeka et al., 2016). The study conducted in Nepal in 2019 also revealed evidence of

elevated blood sugar with increasing age, with the age groups of 30-44 years old and 45-69 years old showing 2.33 and 3.88 times higher rates of the condition than the group of individuals aged 15-29 years old ($p<0.01$), respectively (Bista et al., 2021). Similar findings from the research study conducted in India about an increased risk of experiencing comparable hyperglycemia were also observed in patients in the age group of 45-69 years old ($p=0.001$) (Tripathy et al., 2017). Other studies, such as, Thakur et al.'s study which was conducted in Haryana, North India, have also shown that there is no change in the risk level of high blood sugar levels in different age groups ($p>0.05$) (Thakur et al., 2019).

Strengths and weaknesses of the study

We conducted comprehensive recruitment of subjects who met the inclusion criteria with the benefit of a sample size that was large enough. The data was collected by investigators who have extensive experience at the national level and with health workers in the study area.

However, this study had certain limitations. First, the collection of data was conducted in the third quarter of 2021, when the COVID-19 pandemic broke out. Additionally, the researchers had not assessed the impact of the pandemic on the health management behavior of individuals. Second, blood sugar measurements being taken during a single visit, are likely to be influenced by external factors such as an infection, an ongoing treatment, stress, or lack of rest; which may overestimate this study's results. Finally, this study has not been able to explore the factors of income, and economic conditions in the current context in the countryside in Viet Nam as these factors may be related to individuals' lifestyle behavior and indirectly related to the blood sugar levels of the individuals living in Viet Nam.

From the results of this study, the researchers can partly get clearer evidence about the situation of hyperglycemia in the sub-urban areas of Viet Nam, which can be applied to areas with similar economic conditions, society, and population structure. The governments can therefore change and issue some new prevention and treatment programs promptly.

VI. CONCLUSION AND SUGGESTION

6.1. Conclusion

This study aimed to utilize the public health initiatives and improve the by making them more relevant to the healthcare demands of the local residents. According to this study, 9.2% of adults over the age of 40 years old have high blood sugar levels (which can be used to diagnose diabetes) and 47.8% of adults may have pre-diabetes. These statistics are concerning when more than 50% of middle-aged individuals report having issues with blood sugar. Smoking, drinking alcohol and having an unhealthy diet all contribute to an increase in being overweight and obese, as well as high blood pressure, which are all risk factors for NCDs such as diabetes. In the case where the government does not implement public health programs to recommend and prevent high-risk factors associated with diabetes, the rates of pre-diabetes and diabetes may rise in the future and occur earlier in life. To improve an individual's health, the Ministry of Health and the Government should enhance health education and communication initiatives, as well as risk factor screening.

6.2. Suggestion

Although there is no definitive cure for diabetes, it can be prevented and its effects can be reduced if individuals start adhering to health advice right away. As a result, at the most basic level, the diabetes risk screening program should be made mandatory. A paper-based screen that is self-evaluated by the individual. Individuals will visit medical facilities to have diagnostic testing done if their scores are considered to be high-risk.

In some regions of Viet Nam today, paper-based screening has only recently been introduced. This activity is highly useful for predicting an individual's health status in advance as well as saving money before needing to conduct any blood test. Organizations in the neighborhood should promote this activity and repeat it (Appendix 2).

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Appendix 1. Questionnaire

Consent, Interview Language and Name	Response	Code
Interviewer ID	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	1
Consent has been read and obtained	Yes 1 No 2 If NO, END	2
Interview Language [Insert Language]	Vietnamese 1 [Add others] 2	3
Time of interview (24 hour clock)	<input type="text"/> <input type="text"/> : <input type="text"/> <input type="text"/> hrs mins	4
Full name		5
Contact phone number		6

A. Demographic Information		
Question	Response	Code
Commune	Minh Chau 1	A1
	Cam Linh 2	
	Tong Bat 3	
	Phu Son 4	
	Thai Hoa 5	
	Tan Hong 6	
	Cam Thuong 7	
	Tan Linh 8	
	Ba Trai 9	

Sex (Record Male / Female as observed)	Male 1 Female 2	A2
What is your year of birth?	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	A3
What is the highest level of education you have completed?	Primary school or lower 1 Secondary school or upper 2	A4
What is your marital status ?	Single 1 Currently married 2 Divorced/ Widowed 3	A5
Which of the following best describes your main work status over the past 12 months?	Farmer 1 Homemaker 2 Worker 3 Retired 4 Other 5	A6
B. Behavioral Measurements		
Do you smoke any tobacco products, such as cigarettes, cigars or pipes? (USE SHOWCARD)	Never 1 Yes 2 Used to smoke, now quit 3	B1
Have you ever consumed any alcohol such as beer, wine, spirits? (USE SHOWCARD)	Never 1 Daily 2 Sometimes (2-3 time/week) 3	B2
In a typical week, on how many days do you eat vegetables, fruit ? (USE SHOWCARD)	Number of days <input type="text"/> <input type="text"/> Serving per day <input type="text"/> <input type="text"/>	B3

How often do you add salt or a salty sauce such as soy sauce to your food during eating it? (USE SHOWCARD)	Always 1 Often 2 Sometimes 3 Rarely 4 Never 5	B4
For the last 7 days, Did you do any moderate-intensity sports, fitness or recreational (leisure) activities that cause a small increase in breathing or heart rate like [<i>cycling, yoga, cleaning the house, etc</i>] for at least 10 minutes continuously? (USE SHOWCARD)	Number of day(s)/ week <input type="text"/> Hours/ day <input type="text"/>	B5
For the last 7 days, How much time do you usually spend sitting or reclining?	Hour(s)/ day <input type="text"/>	B6
C. Physical and Biochemical Measurements		
Have you ever been told by a doctor or other health worker that you have raised blood pressure or hypertension?	Yes 1 No 2	C1
Have someone in your family (a blood relative such as a mother, father, sister or brother) who has or had:		
High blood pressure or hypertension?	Yes 1 No 2	C2
High blood sugar or diabetes?	Yes 1 No 2	C3

Blood Pressure 1	Systolic (mmHg)	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	C4a
	Diastolic (mmHg)	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	C4b
Blood Pressure 2	Systolic (mmHg)	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	C5a
	Diastolic (mmHg)	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	C5b
Height	in Centimetres (cm)	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> . <input type="text"/>	C6
Weight	in Kilograms (kg)	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> . <input type="text"/>	C7
Waist circumference	in Centimetres (cm)	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> . <input type="text"/>	C8
Hip circumference	in Centimetres (cm)	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> . <input type="text"/>	C9
The fasting plasma glucose test	mmol/l	<input type="text"/> <input type="text"/> . <input type="text"/> <input type="text"/>	C10

Thank you for participating!

Appendix 2. Diabetes risk assessment score in Viet Nam

Variables		Score
Age	< 45 year-olds	0
	45 - 49 year-olds	1
	> 49 year-olds	2
Sex	Female	0
	Male	2
Body mass index	< 23	0
	23 - 27.5	3
	≥ 27.5	5
Waist circumference	Male < 90 Female < 80	0
	Male ≥ 90 Female ≥ 80	2
Blood pressure	< 140/90	0
	$\geq 140/90$	2
Have someone in your family (a blood relative) who has or had diabetes	No	0
	Yes	4
	Total:

The total score ≥ 6 , there is a risk of diabetes.