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# Prevalence of and factors associated with diabetes mellitus among people living with HIV in Vietnam

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**Abstract:** Studies have shown that people living with HIV (PLWH) have a higher risk of having non-communicable diseases (NCDs) than do people without HIV. In Vietnam, HIV remains a major public health concern, and with recent rapid economic growth, NCDs such as diabetes mellitus (DM) have become a significant disease burden. This cross-sectional study was conducted to examine the prevalence of DM and the factors associated with DM among PLWH on antiretroviral therapy (ART). In total, 1,212 PLWH were included in the study. The age-standardized prevalence of DM and pre-diabetes were 9.29% and 10.32%, respectively. In the multivariate logistic regression analysis, male sex, age above 50 years, and body mass index ≥ 25 kg/m$^2$ were associated with DM, and borderline p-value was found for associations with current smoking and years on ART. The results suggest higher DM prevalence among PLWH and that longer time on ART could be an important risk factor for DM among PLWH. These findings also suggest that interventions such as weight control and smoking cessation support could be provided at outpatient clinics. Integration of HIV/AIDS and NCDs services is essential to address health needs comprehensively and enhance health-related quality of life for PLWH.

***Keywords*:** non-communicable disease, communicable disease, low- middle-income countries

## Introduction

Recent advances in antiretroviral therapy (ART) have improved the life expectancy of people living with HIV (PLWH), and the global HIV population is both aging and increasing. Aging increases comorbidity; therefore non-communicable diseases (NCDs) are posing new public health problems for PLWH in low- and middle-income countries (LMICs) (*1*). Studies have shown that because of HIV infection and treatment toxicity, PLWH have a higher risk of having NCDs such as cardiovascular disease (CVD), diabetes mellitus (DM), and non-AIDS-related cancers compared to people without HIV (*2-4*).

The burden of disease from DM has become significant in Vietnam. According to the International Diabetes Federation, the prevalence of DM was 6.1% in 2021, and was projected to reach 7.1% by 2045 (*5*). Vietnam has experienced rapid economic growth and urbanization since the Doi-Moi policy (transitioning to a market economy) was introduced in 1986. There is a concern that traditional risk factors such as smoking, poor diet, and a sedentary lifestyle could be more prevalent because of these social and demographic changes (*6*), further leading to increased prevalence of DM in the future.

The HIV epidemic remains a major public health problem in Vietnam. While AIDS-related mortality and new infections have declined in recent decades, the percentage of PLWH aged 50 years and above has been increasing (*7,8*). In addition, excess alcohol intake and smoking are known risk factors for DM (*9,10*), and those factors were more prevalent among PLWH than in the general population (*11,12*). Therefore, it is essential to understand the magnitude of the DM burden among PLWH in Vietnam.

Prevalence data on DM is vital for medical decision-making and the appropriate allocation of healthcare resources. Nonetheless, very few studies have investigated DM prevalence among PLWH in Vietnam. According to a literature review using PubMed, Web of Science, Cochrane library, and Global Health with keywords of diabetes AND Vietnam AND HIV, two studies were found, which investigated DM among PLWH in the Asian- Pacific region including Vietnam. However, no study focused on PLWH in Vietnam for DM prevalence. In addition, it is important to understand factors associated with DM to design an effective

strategy. Several studies have investigated factors associated with DM among PLWH in LMICs. However, most of these were conducted in Sub-Saharan Africa, with only a few conducted in the Asian-Pacific region (*13*). Because DM is associated with lifestyle factors, contextual differences may influence the onset of DM among PLWH. Moreover, the investigated factors and reported results have varied across studies (*13-16*). Few studies have examined HIV-related and traditional factors simultaneously, including lifestyle factors such as dietary patterns and physical exercise, to explore which factors are more likely to affect NCDs among PLWH.

Therefore, to overcome these limitations of past studies, we conducted the present study to examine the prevalence of DM among PLWH on ART and investigate the associations between DM and traditional and HIV-related factors.

## Methods

### *Study design and participants*

This study employed a cross-sectional design and recruited PLWH in a hospital-based cohort, the Hanoi cohort, at the National Hospital for Tropical Diseases (NHTD) in Hanoi, Vietnam. Inclusion criteria for the Hanoi cohort were: *i*) aged 18 and above, *ii*) on ART at NHTD, *iii*) provide written consent for study participation. Participants were excluded if physicians deemed them inappropriate to participate in the study. NHTD is a central hospital specializing in infectious diseases that has one of the largest HIV outpatient clinics in Vietnam. In the cohort, clinical data were prospectively collected every six months under the Japan Initiative for Global Research Network on Infectious Diseases (2006-2018) and the Science and Technology Research Partnership for Sustainable Development (SATREPS, 2019-present) programs. For the cross-sectional study, relevant clinical data was obtained from the database of the cohort, and a self-reported questionnaire survey on lifestyles and blood glucose testing were conducted between December 2020 and January 2021. The study protocol was approved by the Human Research Ethics Committee of NHTD (No:15/ HDDD-NDTU). All study participants provided a written informed consent for participation and for the use and publication of their clinical and laboratory data for research. This study was conducted in accordance with the principles of the Declaration of Helsinki.

### *Measurements*

#### *DM case identification*

Fasting plasma glucose was measured using the Roche Cobas 6000 analyzer (Roche Molecular Diagnostics, Pleasanton, CA). Based on World Health Organization (WHO) diagnostic criteria, participants were considered to have DM if plasma glucose was ≥ 7.0 mmol/L without DM treatment or if participants had a history of DM diagnosis. Pre-diabetes was identified if 6.1 mmol/L ≤ plasma glucose < 7.0 mmol/L without DM treatment and previous DM diagnosis (*17*).

#### *Traditional factors*

The questionnaire recorded the following sociodemographic and traditional factors: sex, age, occupation, monthly household income, exercise intensity level, smoking, alcohol drinking, fruit intake, and vegetable intake. Age was divided into four groups: < 40 years, 40-49 years, 50-59 years, and 60 years and above. Occupation was categorized as government employee, non-government employee, farmer, self-employed, student, and unemployed. Monthly household income was divided into four categories: < 4,000,000 Vietnamese dong (VND), 4,000,000-7,999,999 VND, 8,000,000 VND and more, and unknown. Exercise intensity level was measured by the International Physical Activity Questionnaire (IPAQ) (*18*). According to the guideline, the metabolic equivalent task (MET)-minutes per week of each activity (vigorous-intensity activity, moderate-intensity activity, and walking) was calculated and classified into one of three categories: low, moderate, and high. Data on smoking, alcohol drinking, and fruit and vegetable intake were collected based on the WHO STEPS surveillance questionnaire (*19*). Participants were considered current smokers if they answered smoking either daily or less than daily, and current alcohol drinkers if they answered they had had alcohol drinks in the last 12 months. Bodyweight was measured when the questionnaire was administered, and body mass index (BMI) was calculated by dividing weight by height squared ($kg/m^2$). Participants with a BMI ≥ $25kg/m^2$ were classified as overweight/obese.

#### *HIV-related factors*

The following data on HIV-related factors were collected from the Hanoi cohort database: latest CD4 counts (/μl), latest plasma viral load (pVL) (copies/ml), years since HIV diagnosis, years on ART, and duration of didanosine (ddI), stavudine (d4T), and lopinavir/ritonavir (LPV/r) exposure. Exposure to LPV/r, ddI and d4T were selected because several studies have reported that the use of protease inhibitors and nucleoside reverse transcriptase inhibitors increases the risk of hyperglycemia or DM (*20-22*).

#### *Statistical analysis*

The overall prevalence of DM and pre-diabetes were calculated by standardizing according to the age distribution of the National Survey on the Risk Factors

of Non-Communicable Diseases (STEPS) Vietnam 2015 (*23*). The direct standardization method was used. To match the age distribution, study participants aged 70 years and above were excluded when standardization was performed.

Given the exploratory nature of this study, the cut-offs were chosen for fruit intake, vegetable intake, years since HIV diagnosis, years on ART, and duration of ddI, d4T, and LPV/r exposure based on visual analysis of DM case distribution using histograms. Because few DM cases have been exposed to ddI, exposure to ddI and d4T were merged into one category, *i.e*., duration of ddI or d4T exposure. Fruit intake and vegetable intake were grouped into two categories: consume every day and less than every day. The latest CD4 count and pVL were divided into two categories: < 200 and 200 and above. Years since HIV diagnosis and years on ART were divided into two categories: < 11 years and 11 years and above. Duration of ddI or d4T exposure and duration of LPV/r exposure were divided into the following categories: < 3 years and 3 years and above; < 7 years and 7 years and above, respectively.

Associations between DM and traditional and HIV-related factors were explored in a univariate logistic regression analysis. Variables that were significant for the univariate analysis ($p < 0.1$) were included in the multivariate analysis. Before the variables to be included in multivariate analysis were identified, Spearman's correlation coefficient was calculated. If the coefficient was 0.6 or higher, variables were excluded from the multivariate analysis to avoid multicollinearity. Two multivariate models were adopted to explore the impacts of traditional factors on DM before and after adjustment for HIV-related factors. Model 1 includes traditional factors; model 2 includes traditional and HIV-related factors.

To minimize selection bias, multivariate imputation using chained equations was used to calculate values of the missing variables. The number of missing values ranged from 0 to 11.86% for any single variable. All statistical analysis was performed using Stata software (version 16, StataCorp LLC, College Station, TX).

## Results

Since October 2007, a total of 2,198 patients had registered for the Hanoi cohort, and 1,225 were followed up in December 2020 and January 2021. Of those, 13 were excluded from the analyses: 11 who did not receive blood tests because of time limitations, and two who did not answer more than half of the questions on the questionnaire. The analysis therefore included data from 1,212 PLWH.

### *Baseline characteristics*

Baseline characteristics are shown in Table 1. The mean age was 43.8 years, and 57.34% of the participants were men. Age-standardization did not greatly change mean age (mean age after exclusion of those aged 70 and above = 43.35 years). Approximately half of participants were self-employed (43.32%), followed by farmers (20.0%). Approximately one-fourth of participants' monthly household income was below 4,000,000 VND (approx. 177 USD) per month. The mean body weight and BMI were 57.56 kg and 21.92, respectively. The mean number of years since ART initiation was 10.25, and the mean of the latest CD4 count was 549.5. Most participants (99.26%) achieved a viral load below 200 copies/ml. The percentage of those exposed to LPV/r for 7 years and above was 8.25%, and 12.54% had been exposed to either ddI or d4T for 3 years or more.

### *Prevalence of DM and pre-diabetes*

Among the participants, 86 were identified as having DM and 112 were identified as pre-diabetic, accounting for 9.29% (95% CI: 7.11-11.47%) and 10.32% (95% CI: 8.11-12.52%), respectively. There were no DM cases among those with a viral load of 200 copies/ml and above.

### *Univariate analysis*

Table 2 shows the results of the univariate analysis and the multivariate analysis of the factors associated with DM. Males had 3.2-fold higher odds of having DM than did females (OR = 3.27, 95% CI: 1.95-5.47). Those aged 40-49 had approximately 2-fold higher odds, and those aged 50-59 and those aged 60 and above had approximately 7-fold higher odds of having DM than did those below 40 years (OR = 2.27, 95% CI: 1.21-4.27; OR = 6.78, 95% CI: 3.36-13.71; OR = 6.95, 95% CI: 3.11-15.53, respectively). Those who were unemployed (OR = 2.67, 95% CI: 1.06-6.73 *vs.* government employees), current smokers (OR = 2.04, 95% CI: 1.33-3.13 *vs.* non-smokers), and those with BMI ≥ 25kg/m$^2$ (OR = 2.8, 95% CI: 1.69-4.62 *vs.* BMI < 25 kg/m$^2$) had higher odds of DM compared to the reference group. There were no significant associations between DM and monthly household income, exercise intensity level, current alcohol drinking, or fruit and vegetable intake.

Among the univariate analysis of HIV-related factors, years on ART and duration of ddI or d4T exposure were associated with DM. Those on ART for 11 years or more had 1.8 times higher odds of having DM compared to those on ART less than 11 years (OR = 1.84, 95% CI: 1.21-2.8). Those exposed to ddI or d4T for less than 3 years had 1.7 times higher odds of having DM (OR = 1.7, 95% CI: 1.04-2.75 *vs.* non-exposed). Those exposed more than 3 years also showed a non-significant trend toward higher odds of DM (OR = 1.53, 95% CI: 0.84-2.79 *vs.* non-exposed). In this study, the duration of LPV/r exposure was not associated with DM.

**Table 1. Baseline Characteristics**

| Variables ($n$ = 1,212) | $n$ | % | Variables | $n$ | % |
|---|---|---|---|---|---|
| Sex | | | Eat fruit every day | | |
| Male | 695 | 57.34 | No | 569 | 46.95 |
| Female | 517 | 42.66 | Yes | 591 | 48.76 |
| Age | | | Missing | 52 | 4.29 |
| < 40 | 394 | 32.51 | Eat vegetable every day | | |
| 40-49 | 612 | 50.50 | No | 212 | 17.49 |
| 50-59 | 133 | 10.97 | Yes | 934 | 77.06 |
| ≥ 60 | 73 | 6.02 | Missing | 66 | 5.45 |
| Mean (SD) | 43.80 (3.24) | | Weight | | |
| Injection drug use | | | Mean (SD) | 57.56 (8.88) | |
| No | 946 | 78.00 | BMI ≥ 25 kg/m$^2$ | | |
| Yes | 266 | 22.00 | No | 1,046 | 86.30 |
| Occupation | | | Yes | 140 | 11.55 |
| Government employee | 112 | 9.24 | Missing | 26 | 2.15 |
| Non-government employee | 118 | 9.74 | Mean (SD) | | |
| Farmer | 239 | 20.00 | Years since HIV diagnosis | | |
| Self-employed | 525 | 43.32 | < 11 years | 608 | 50.17 |
| Student | 10 | 0.83 | ≥ 11 years | 604 | 49.83 |
| Unemployed | 187 | 15.43 | Mean (SD) | 11.64 (4.04) | |
| Missing | 21 | 1.73 | Years on ART | | |
| Household monthly income | | | < 11 years | 736 | 60.73 |
| < 4,000,000 VND | 317 | 25.74 | ≥ 11 years | 476 | 39.27 |
| 4,000,000-7,999,999 | 515 | 42.49 | Mean (SD) | 10.25 (3.24) | |
| 8,000,000 or more | 261 | 21.53 | Latest CD4 count | | |
| Unknown | 65 | 5.36 | ≥ 200 | 1,180 | 97.36 |
| Missing | 59 | 11.86 | < 200 | 32 | 2.64 |
| Exercise level (IPAQ) | | | Median (IQR) | 527 (408-679) | |
| Low | 389 | 32.10 | Latest pVL | | |
| Moderate | 496 | 40.92 | < 200 copies/mL | 1,203 | 99.26 |
| High | 225 | 18.56 | ≥ 200 copies/mL | 9 | 0.74 |
| Missing | 102 | 8.42 | Duration of LPV/r exposure | | |
| Smoking | | | No exposure | 1,079 | 89.03 |
| Not at all | 793 | 65.43 | < 7 years | 33 | 2.72 |
| Less than daily | 115 | 9.49 | ≥ 7 years | 100 | 8.25 |
| Daily | 237 | 19.55 | Mean (SD) | 8.27 (3.66) | |
| Missing | 67 | 5.53 | Duration of ddI/d4T exposure | | |
| Alcohol current drinker | | | No exposure | 810 | 66.83 |
| No | 629 | 51.90 | < 3 years | 250 | 20.63 |
| Yes | 528 | 43.56 | ≥ 3 years | 152 | 12.54 |
| Missing | 55 | 4.54 | Mean (SD) | 2.87 (1.94) | |

ART, antiretroviral therapy; HIV, human immunodeficiency virus; IPAQ, International Physical Activity Questionnaire; SD, standard deviation; VND, Vietnamese dong.

*Multivariate analysis*

In model 1, physical activity intensity was included despite non-significant associations in the univariate analysis. Male participants had twice the odds of DM compared to females (OR = 2.06, 95% CI: 1.13-3.76). Current smokers and BMI ≥ 25 kg/m$^2$ remained strongly associated with DM (OR = 1.68, 95% CI: 1.00-2.82; OR = 2.43, 95% CI: 1.44-4.13, respectively). Those aged 50 and above were also strongly associated with DM (aged 50-59, OR = 5.25, 95% CI: 2.52-10.91; aged 60 and above, OR = 5.21, 95% CI: 2.11-12.8). Unemployment status and physical activity intensity were not associated with DM.

In model 2, physical activity intensity, past exposure to LPV/r, ddI, and d4T were included despite non-significant associations in the univariate analysis. To avoid collinearity with years on ART, years since HIV diagnosis was excluded. After adjusting for the effect of HIV-related factors, the association between DM and males, those aged 50 and above, and those with BMI ≥ 25 kg/m$^2$ remained. Although there was no significance, we found borderline $p$-values in current smokers (OR = 1.67, 95% CI: 0.99-2.83, $p$ = 0.057) and years on ART (OR = 1.65, 95% CI: 0.99-2.77, $p$ = 0.056) in model 2. Those on ART for 11 years and above had approximately 1.6 times higher odds of DM than did those on ART for less than 11 years.

## Discussion

The study examined the prevalence of DM among PLWH on ART at the national hospital in Hanoi, and the factors associated with DM. In the multivariate analysis, males, those aged above 50 years, and those with BMI ≥ 25 kg/m$^2$ were significantly associated with higher

**Table 2. Factors associated with DM among PLWH**

| *n* = 1,212 | | Univariate analysis | | Multivariate analysis | | | |
|---|---|---|---|---|---|---|---|
| | | | | Model 1 | | Model 2 | |
| Variable | Category | Odds ratio (95% CI) | *p** | Odds ratio (95% CI) | *p** | Odds ratio (95% CI) | *p** |
| Gender | Female | 1.00 | | 1.00 | | 1.00 | |
| | Male | 3.27 (1.95-5.47) | < 0.001 | 2.06 (1.13-3.76) | 0.019 | 2.04 (1.11-3.74) | 0.022 |
| Age group | < 40 | 1.00 | | 1.00 | | 1.00 | |
| | 40-49 | 2.27 (1.21-4.27) | 0.011 | 1.76 (0.92-3.38) | 0.087 | 1.5 (0.77-2.91) | 0.23 |
| | 50-59 | 6.78 (3.36-13.71) | < 0.001 | 5.25 (2.52-10.92) | < 0.001 | 4.7 (2.25-9.84) | < 0.001 |
| | ≥ 60 | 6.95 (3.11-15.53) | < 0.001 | 5.21 (2.12-12.85) | < 0.001 | 4.66 (1.87-11.64) | 0.001 |
| Injection drug use | No | 1.00 | | | | | |
| | Yes | 1.35 (0.84-2.16) | 0.213 | | | | |
| Occupation | Government employee | 1.00 | | 1.00 | | 1.00 | |
| | Non-govt. employee | 1.1 (0.36-3.38) | 0.867 | 1.31 (0.41-4.23) | 0.646 | 1.32 (0.4-4.31) | 0.647 |
| | Farmer | 1.43 (0.55-3.72) | 0.461 | 1.44 (0.54-3.89) | 0.468 | 1.47 (0.54-3.98) | 0.454 |
| | Self-employed/student | 1.44 (0.59-3.48) | 0.421 | 1.37 (0.55-3.42) | 0.496 | 1.4 (0.56-3.51) | 0.478 |
| | Unemployed | 2.67 (1.06-6.74) | 0.038 | 1.81 (0.69-4.75) | 0.229 | 1.81 (0.69-4.77) | 0.231 |
| Household monthly income | < 4,000,000 VND | 1.00 | | | | | |
| | 4,000,000-7,999,999 | 0.85 (0.51-1.41) | 0.519 | | | | |
| | 8,000,000 or more | 0.86 (0.46-1.58) | 0.617 | | | | |
| | Unknown | 0.83 (0.31-2.27) | 0.721 | | | | |
| Exercise level (IPAQ) | Low | 1.00 | | 1.00 | | 1.00 | |
| | Moderate | 1.41 (0.86-2.31) | 0.168 | 1.26 (0.74-2.12) | 0.395 | 1.25 (0.74-2.13) | 0.401 |
| | High | 1.1 (0.59-2.07) | 0.761 | 1.02 (0.53-1.97) | 0.959 | 0.97 (0.5-1.88) | 0.927 |
| Current smoker | No | 1.00 | | 1.00 | | 1.00 | |
| | Yes | 2.04 (1.33-3.13) | 0.001 | 1.67 (1-2.81) | 0.051 | 1.67 (0.98-2.83) | 0.059 |
| Current alcohol drinker | No | 1.00 | | | | | |
| | Yes | 1.2 (0.79-1.83) | 0.396 | | | | |
| Eat fruit every day | No | 1.00 | | | | | |
| | Yes | 1.08 (0.71-1.65) | 0.707 | | | | |
| Eat vegetables every day | No | 1.00 | | | | | |
| | Yes | 0.79 (0.46-1.37) | 0.404 | | | | |
| BMI ≥ 25 kg/m$^2$ | No | 1.00 | | 1.00 | | 1.00 | |
| | Yes | 2.79 (1.69-4.62) | < 0.001 | 2.43 (1.43-4.13) | 0.001 | 2.42 (1.42-4.12) | 0.001 |
| Years since HIV diagnosis | < 11 years | 1.00 | | | | | |
| | ≥ 11 years | 1.45 (0.95-2.21) | 0.084 | | | | |
| Years on ART | < 11 years | 1.00 | | | | 1.00 | |
| | ≥ 11 years | 1.84 (1.21-2.8) | 0.004 | | | 1.66 (0.99-2.78) | 0.056 |
| Latest CD4 count | ≥ 200 | 1.00 | | | | | |
| | < 200 | 1.69 (0.58-4.92) | 0.336 | | | | |
| Duration of LPVr exposure | No exposure | 1.00 | | | | 1.00 | |
| | < 7 years | 0.35 (0.05-2.61) | 0.307 | | | 0.41 (0.05-3.22) | 0.4 |
| | ≥ 7 years | 0.85 (0.38-1.88) | 0.685 | | | 0.63 (0.27-1.49) | 0.292 |
| Duration of ddI/d4T exposure | No exposure | 1.00 | | | | 1.00 | |
| | < 3 years | 1.70 (1.04-2.75) | 0.033 | | | 1.37 (0.8-2.34) | 0.249 |
| | ≥ 3 years | 1.53 (0.84-2.79) | 0.163 | | | 1.11 (0.55-2.26) | 0.77 |

ART, antiretroviral therapy; HIV, human immunodeficiency virus; IPAQ, International Physical Activity Questionnaire; VND, Vietnamese dong. Model 1 includes traditional factors; model 2 includes traditional and HIV-related factors. *Wald test

odds of DM among PLWH. Current smoking and longer time on ART with marginal p-values were also possibly attributable to developing DM. There were no cases of active opportunistic infections or other complications that could increase insulin resistance and be included in the multivariate model. To the best of our knowledge, this is the first study that focuses on PLWH in Vietnam for DM prevalence.

The age-standardized prevalence of DM and pre-diabetes were 9.29% and 10.32% in the study participants, respectively. According to the STEPS survey Vietnam 2015, the prevalence of DM and pre-diabetes were 4.1% and 3.6%, respectively (*23*). Our results imply the possibility of higher DM prevalence among PLWH. One study reported premature age-related comorbidities such as CVD and DM among PLWH (*25*); the prevalence of concurrent presence of two or more NCDs in PLWH was similar to that of a cohort of the general population who were 10 years older. The higher DM prevalence in this study population could be explained by premature aging. This finding supports early DM screening for PLWH.

Our results showed that BMI ≥ 25kg/m$^2$ was an important risk factor for DM, consistent with other study findings (*13,26,27*). The impact of weight gain on the risk of DM has been reported to be greater among PLWH than that of people without HIV (*28*). Furthermore, several studies have reported that the use of an integrase strand transfer inhibitor such as dolutegravir

(DTG) is associated with increased weight gain (*29,30*). Because the Vietnamese ART guideline issued in 2019 recommended a DTG-containing regimen as first-line treatment (*31*), weight increase should be carefully managed to reduce the risk of DM.

A systematic review and meta-analysis reported that weight-reducing diets with or without exercise advice could reduce obesity in adults (*32*). To manage weight, healthy eating and exercise programs could be provided to PLWH. Although the association between vegetable intake and exercise intensity and DM was not statistically significant in this study, those factors might have been associated with weight gain. In general, vegetable consumption in Vietnam is high compared with that in other high-income countries (*33*). Also, a notable proportion of study participants engaged in farming, and approximately 60% of the participants reported moderate- to high-intensity exercise. However, there is a concern that rapid economic growth and urbanization may change dietary patterns and promote sedentary lifestyles (*6*). It is critical to preserve healthy dietary patterns and exercise habits among Vietnamese PLWH to maintain adequate weight and prevent DM.

Male sex was strongly associated with DM in this study, but the association between sex and DM has varied across different studies (*27,34*). Several studies have shown a higher risk of DM among female participants than among male participants (*27*). Also, it has been reported that female participants were more likely to gain weight following ART initiation (*35*), and therefore females may have higher risk of having DM. Although the result was not conclusive, both sexes should be similarly monitored with respect to weight gain.

Smoking has been identified as an important risk factor for DM, and it has been reported that prevalence of smoking was higher among PLWH than among the general population (*10,36*). In Vietnam, there is a large difference in smoking prevalence among men and women (45.3% among men and 1.1% among women in 2015). In addition, among males, the prevalence of current smoking was highest among those aged 45-64 years (55%), followed by those aged 25-44 years (53.3%), versus 24.3% in those aged 15-24 years (*37*). A smoking cessation program targeting older men living with HIV could be effective in preventing DM.

The results indicate possible associations of a longer period on ART with DM after adjustment for sociodemographic and traditional factors. Although it is generally considered that the traditional risk factors are primarily responsible for the higher risk of DM among PLWH (*2,38*), this result implies that HIV-related factors such as time on ART may be a contributor to hyperglycemia among PLWH in addition to traditional factors. Several studies have reported that the use of protease inhibitors such as LPV/r and nucleoside reverse transcriptase inhibitors such as ddI and d4T increased the risk of hyperglycemia or DM (*20-22*) although an association between duration of ddI, d4T and LPV/r exposure and DM was not found in our study. The association between longer ART period and DM might be partially explained by the effects of ddI, d4T and LPV/r on DM.

There were some limitations in the study. First, the study site was a large ART outpatient clinic at a specialized hospital, and most participants had been receiving ART at NHTD for several years, which may limit the generalizability of the study findings to other settings in Vietnam. Second, DM cases were identified based on plasma glucose. Unlike HbA1c, plasma glucose is prone to be affected by fasting status. The DM prevalence may have been overestimated if the fasting status of the participants were not fully ensured. Third, multiple factors are intricately associated with the pathogenesis of DM (*39*). The sample size of this study may not have been sufficient to detect a complex relationship between an array of factors; for example, only borderline p-values were found for the association between current smoking status and years on ART and DM. However, stronger associations may have been found if the sample size had been larger given the associations in univariate analysis. This study did not investigate the effect of Vietnamese-specific factors on DM, such as regional living habits. Future research could investigate the association.

## Conclusion

In conclusion, the findings of this study imply that DM and pre-diabetes prevalence among PLWH are higher than among the general population. In the multivariate analysis, male sex, older age, and BMI $\geq$ 25 kg/m$^2$ were significantly associated with and current smokers and years on ART were possible risk factors for DM. Years on ART could be an important risk factor that will require clinical attention. Encouraging careful glucose monitoring in routine care and management of other risk factors would be beneficial to prevent developing DM among those on ART longer. Our findings suggest that interventions such as weight control and smoking cessation support could be provided at HIV outpatient clinics, contributing to DM prevention and early diagnosis. Integration of HIV/AIDS and NCDs services is essential to address health needs comprehensively and enhance health-related quality of life among PLWH.

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