

# Predictors of virologic failure among adults receiving first-line antiretroviral therapy in the Sunyani Municipality, Ghana

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## Abstract

**Introduction:** Antiretroviral therapy (ART) is designed to lower viral loads in people living with HIV (PLWHIV), improving their quality of life and reducing HIV-related illnesses and mortality. However, in 2022, the Sunyani Municipal Health Directorate (SMHD) reported low rates of viral suppression. Supporting this, a study by Abban et al. (2021) also revealed that PLWHIV on ART often failed to reach the expected viral suppression levels in the area. This study identified predictors of virologic failure among adults receiving ART in the Sunyani Municipality to inform targeted interventions.

**Methods:** A 1:2 unmatched case-control study was conducted from October to November 2022, involving 585 adults (195 cases with viral loads  $\geq 1000$  copies/mL and 390 controls with  $< 1000$  copies/mL) who had been on ART for at least six months. Data on socio-demographic, clinical, ART-related, and health facility-related factors were extracted from medical records using Kobo Collect and analysed with STATA 16.1. Adherence to ART was measured using the pill count method, and multivariate logistic regression was used to identify predictors of virologic failure, with statistical significance set at  $p$ -value  $\leq 0.05$ .

**Results:** The mean age of participants was 42 years (SD:  $\pm 11$  years), with cases averaging 41 years (SD:  $\pm 11$ ) and controls 43 years (SD:  $\pm 11$ ). Females contributed 80.00% (156/195) of cases and 74.87% (292/390) of controls. Predictors of virologic failure included rural residence (aOR=2.86, 95% CI: 1.70-4.81), non-disclosure of HIV status (aOR=2.32, 95% CI: 1.45-3.70), poor adherence to ART (aOR=3.68, 95% CI: 2.05-6.59), opportunistic infections (aOR=7.19, 95% CI: 3.94-13.09), and alcohol consumption (aOR=4.22, 95% CI: 1.93-9.26). Having at least Sec/Tech/Voc education (aOR=0.58, 95% CI: 0.32, 0.85) and being self-employed (aOR=0.52, 95% CI: 0.32-0.85) were protective.

**Conclusions:** Key predictors of virologic failure in Sunyani Municipality include rural residence, non-disclosure, poor adherence, opportunistic infections, and alcohol consumption. Health authorities should enhance social support and implement targeted education to improve adherence among PLWHIV.

**Keywords:** Virologic failure, Sunyani Municipal, Antiretroviral Therapy, HIV

## Citation

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## Introduction

Ghana, like many sub-Saharan African countries, has made significant strides in HIV treatment and prevention. However, national viral suppression rates remain suboptimal, posing a barrier to achieving epidemic control[1]. Despite the expansion of Highly Active Antiretroviral Therapy (HAART) programs in Ghana, the country fell short of meeting the 90-90-90 UNAIDS targets by the end of 2020 [2]. Notwithstanding the widespread ART availability in the year 2021, only 73% of PLWHIV in Ghana were receiving treatment, and just 79% of those on ART had achieved viral suppression[3].

Despite efforts to reduce new infections, such as “know your status campaigns”, the Bono Region had the highest HIV prevalence (4.2%) in the 2020 HIV Sentinel Survey, exceeding the national rate of 2.0%[4]. Within this region, Sunyani Municipality had a district prevalence of 2.8%, with a high burden of new infections and treatment failures. Data obtained from the Sunyani Municipal Health Directorate indicated that of the 4,497 patients on ART in 2022, less than 50% achieved viral suppression, far below the national rate of 73%[5]. This low suppression rate underscores the need for targeted interventions to address factors contributing to virologic failure.

Virologic failure among patients on ART is associated with poor immune reconstitution, increased risk of opportunistic infections and higher morbidity and mortality rates[6,7]. Additionally, persistent viral replication can lead to the emergence of drug-resistant HIV strains, reducing the efficacy of first-line ART regimens and necessitating more expensive second-line treatments[8,9].

Several studies have explored factors influencing virologic failure, identifying a range of sociodemographic, clinical, ART-related, and healthcare system factors[10–13] in different settings. Key sociodemographic factors include age, sex, educational level, marital status, and employment status, which may influence adherence and treatment-seeking behaviours. Clinical factors such as baseline WHO clinical stage, co-infections, and the presence of non-communicable diseases (NCDs) also play a role in treatment outcomes. Additionally, ART-related factors- including drug toxicity, duration on treatment, non-disclosure and poor adherence have been identified as critical determinants of virologic suppression[14][15]. Healthcare system factors, such as drug availability, healthcare provider attitudes, and confidentiality concerns, further impact treatment adherence and success[18,19].

Given the high virologic failure rate in the municipality, coupled with limited published work on the predictors of virologic failure in the Sunyani Municipality, there is a need for localised research to inform targeted interventions. This study sought to determine predictors of virologic failure among adults on first-line ART in the Sunyani

Municipality. By understanding these factors, healthcare providers and policymakers can implement evidence-based strategies to improve ART treatment outcomes and ultimately reduce HIV transmission.

## Methods

### Study design and setting

An institution-based unmatched case-control study was conducted from August to October 2022 in the Sunyani Municipality, Bono Region, Ghana. Sunyani serves as the municipal capital and is one of 12 administrative districts in the region, covering an area of 829.3 square kilometres. The municipality shares borders with Sunyani West, Asutifi, Tano North, and Dormaa East districts and had an estimated population of 159,778 in 2021.

The Municipal Health Directorate (MHD) oversees 33 health facilities across six sub-municipalities. The HIV treatment services are provided at five ART clinics: Bono Regional Hospital, Sunyani Municipal Hospital, Seventh Day Adventist (SDA) Hospital, Yawhima Health Center, and Abesim Health Center, serving over 4,497 PLWHIV on ART. In 2020, the municipality recorded an estimated 3,285 PLWHIV, with a district HIV prevalence of 2.8%.

### Population and case definition

The study included PLWHIV on first-line ART attending ART clinics in the Sunyani Municipality. A case was defined as an adult living with HIV on active ART for at least 6 months and whose current measurement of plasma viral load was  $\geq 1000$  copies/ml. A control was defined as an adult living with HIV on active ART for at least 6 months and whose current measurement of plasma viral load was  $<1,000$  copies/ml. All adults living with HIV  $\geq 18$  years and on active ART for at least 6 months, and whose viral load has been estimated. People living with HIV aged  $\geq 18$  years on first-line ART who meet the inclusion criteria but whose complete records were not available for review.

### Sample size

The sample size was established using Epi Info™ 7.2.2.2 software Statcalc programme, unmatched case control formula, with the following assumptions: advanced WHO clinical stage[stages 3 and 4], from a prior study, an important predictor of viral failure, whose proportion of controls exposed was 46.5% and an odds ratio of 1.73 [13]. This variable was used because it gave the largest sample size in most literature among all the variables being considered in the study, and is one of the most important factors of interest in this study. Additionally, we used a 95% confidence interval, 80% power and 1: 2 case to control ratio. The minimum computed sample size was 510 (170 cases and 340 controls). Nevertheless, 10% more of the sample was added, bringing the total sample size to

581 in order to increase the power of the study (187 cases and 374 controls). However, in the end, a total of 585 participants (195 cases and 390 controls) were included in the study.

### Sampling

The study involved a total of 4,497 patients receiving ART across five health facilities in the Sunyani Municipality. A proportional sampling method was applied to ensure fair representation from each facility. At Abesim Health Center, out of 200 total patients, 27 participants were selected, comprising 9 cases and 18 controls. At Yawhima Health Center, with a total of 14 patients, 3 participants were included, consisting of 1 case and 2 controls. At Sunyani Municipal Hospital, which had 1,276 ART patients, 165 participants were selected, including 55 cases and 110 controls. At Seventh Day Adventist (SDA) Hospital, out of 376 total patients, 48 participants were recruited, comprising 16 cases and 32 controls and finally at Bono Regional Hospital, which had the highest number of ART patients at 2,631, a total of 340 participants were selected, including 113 cases and 227 controls. A total of 585 participants were enrolled in the study, consisting of 195 cases and 390 controls.

### Selection of study participants

We used a stratified random sampling technique to select cases and controls for each study site. All adults living with HIV whose current measurement of plasma viral load was  $\geq 1000$  copies/ml were selected as cases and those with VL levels  $<1,000$  copies/ml were selected as controls. A sampling frame was prepared using the patients' medical record numbers (MRN) from the patients' folders of each ART clinic for cases and controls separately. For each ART clinic, the overall sample sizes of the cases and controls were determined proportionally to the number of cases and controls. The selection of cases and controls based on their respective sampling intervals was then done using systematic random sampling. The first person was chosen by a simple random sampling. Pieces of paper of equal size were numbered one [1] to the last, placed in a box and juggled. A piece of paper was picked to determine the participant to begin with for the systematic sampling and then continue based on the sampling interval until the sample size was reached.

### Data collection tools and procedure

Data extraction form containing all relevant variables was developed using the Kobo Collect software. The data collection process was carried out in three systematic phases to ensure accuracy and completeness. In the first phase, viral load (VL) data abstraction was conducted. This involved extracting viral load results for both cases and controls from the VL registers and documenting them

in the data extraction form.

The second phase focused on retrieving demographic and clinical data for each patient. Using patient identification numbers, medical records were accessed, and relevant variables were recorded. Demographic factors included age, sex, educational level, marital status, employment status, religion, and place of residence. Behavioural factors such as alcohol consumption and HIV disclosure status were also documented. Additionally, clinical and treatment-related data were collected, including baseline WHO staging, co-infections, HIV type, presence of non-communicable diseases (NCDs), ART regimen at baseline, current ART regimen, and duration on ART.

During this phase, ART adherence was assessed by using the pill count method. The adherence rate was calculated using WHO guidelines, based on the number of prescribed pills taken compared to the total expected refill per month. Adherence was categorized as good ( $\geq 95\%$  of prescribed doses taken), fair (85–94% of prescribed doses taken), or poor ( $<85\%$  of prescribed doses taken). For each participant, adherence rates were determined using data from the last six ART clinic visits prior to their most recent viral load test and the average adherence rate recorded.

The third and final phase involved documenting information on ARV stockouts. Data on the occurrence of antiretroviral drug shortages were obtained from the pharmacy drug dispensing register and recorded accordingly in the data extraction form.

### Data quality control

Four health professionals with ART training received a one-day training before beginning the actual data collection. The primary investigator reviewed the data abstraction forms for accuracy, closely supervised the entire data gathering process each day, and provided the appropriate feedback during the data collection process. Data was double-entered into Epi Info and merged in order to detect errors. We back up all data online using Kobo Collect.

### Pre-test of the data collection tool

The data extraction form was pre-tested before the start of the actual data collection on 5% [30] of the sample size at the Sampa Government Hospital ART clinic located outside the study area, and necessary adjustments were made to ensure that it was appropriate for the research goal and objectives. This was done during the one-day training of the field workers who were going to be responsible for data collection. The result has been password-protected.

### Data processing and analysis

The data abstracted into the Kobo collect for each participant were reviewed for completeness, downloaded and entered into Excel 2016, where data cleaning, validation, and quality checks were done. For additional management and analysis, the data were subsequently imported into STATA version 16.1. In order to describe demographic, clinical, and treatment-related characteristics as well as HIV positive status disclosure and ART adherence, descriptive statistics, such as frequencies, means, and percentages, were performed. Bivariate analysis was performed for all independent variables with the outcome variable (virally suppressed or not suppressed). The variables with p value <0.05 were entered into a multivariate logistic regression model to identify the independent predictors of virologic failure. Finally, the adjusted odds ratio with 95% CI and variables with p value <0.05 were considered significant predictors of virologic failure in this study.

### Ethical considerations

Ethical approval was obtained from the Ghana Health Service Ethical Review Committee (GHS-ERC-038/07/22). Since this was a retrospective review of routinely collected programmatic data, the requirement for individual informed consent was waived by the Committee. To ensure confidentiality, all data were de-identified before analysis, and access to the dataset was restricted to the research team.

## Results

### Socio-demographic and lifestyle characteristics of study participants

A total of 585 adults living with HIV (195 cases and 390 controls) participated in the study. The mean age of participants was 42 years (SD: ±11 years). The mean age of the cases was 41 years (SD: ±11) and that of the control was 43 years (SD: ±11). Females contributed 80.00% (156/195) of cases and 74.87% (292/390) of controls. Of the total participants, (45.47%) had at least Secondary/Tech/Vocational school education, of whom 41.54%( 81/195) were cases and 47.44% (185/390) were controls. Over half, 58.72% (229/390) of controls and 46.15% (90/195) of cases were married.

Concerning participants' employment status, 56.15% (219/390) of controls and 44.62% (87/195) of cases were self-employed. Majority, 84.10% (328/390) of the controls and 88.66% (172/195) of the cases were Christians. The majority of the cases, 69.74% (136/195) as well as controls 87.69% (342/390) were urban dwellers. A total of 14.36% (28/195) cases and 3.85% (15/390) controls consume alcohol. Moreover, 67.18% (131/195) of the cases and 43.08% (168/390) of the controls had not disclosed their

HIV positive status to anyone in their social circle (Table 1). Majority of the HIV patients on ART who had Virologic failure failed to disclose their seropositive status compared to the controls.

**Table 1.** Sociodemographic characteristics of PLWHIV patients receiving ART at ART clinics, Sunyani Municipality 2022 (N=585)

Variable	Cases (n=195)	Control (n=390)	X <sup>2</sup>	p-value
<b>Age (years)</b>				
<35	54 (27.69)	92 (23.59)	1.18	0.280
≥35	141 (72.31)	298 (76.41)		
<b>Sex</b>				
Male	39 (20.00)	98 (25.13)	1.91	0.167
Female	156 (80.00)	292 (74.87)		
<b>Education</b>				
No formal	54 (27.69)	71 (18.21)	6.99	0.031
Primary	60 (30.77)	134 (34.36)		
Secondary/Tech	81 (41.54)	185 (47.44)		
<b>Marital status</b>				
Single	67 (34.36)	106 (27.18)	12.12	0.007
Married	90 (46.16)	229 (58.72)		
Widowed	12 (6.15)	28 (7.18)		
Divorced/Separated	26 (13.33)	27 (6.92)		
<b>Employment</b>				
Unemployed	80 (41.03)	103 (26.41)	12.94	0.002
Self-employed	87 (44.62)	219 (56.15)		
Employed by others	28 (14.36)	68 (17.44)		
<b>Religion</b>				
Christianity	172 (88.66)	328 (84.11)	2.27	0.324
Moslem	20 (10.31)	55 (14.10)		
Traditional	2 (1.03)	7 (1.79)		
<b>Residence</b>				
Rural	59 (30.29)	48 (12.31)	28.02	0.001
Urban	136 (69.71)	342 (87.69)		
<b>Ethnic group</b>				
Akan	174 (89.23)	352 (90.26)	1.70	0.430
Dagaati	11 (5.64)	26 (6.67)		
Grusi	10 (5.13)	12 (3.08)		
<b>HIV status disclosure</b>				
No	131 (67.18)	168 (43.08)	30.23	0.001
Yes	64 (32.82)	222 (56.92)		
<b>Alcohol consumption</b>				
No	167 (85.64)	375 (96.15)	21.10	0.001
Yes	28 (14.36)	15 (3.85)		

### ART medication- related and health facility- related characteristics of study participants

This study revealed that 76.15% (297/390) of the controls and 69.2.3% (135/195) of the cases were on TDF+3TC+DTG first-line ART regimen at baseline, while 86.41% (337/390) of the controls and 79.49% (155/195) of the cases were on TDF+3TC+DTG. The mean period that PLHIV had been on ART was 1.37 years (SD: ± 0.74 years), and more than half, 54.87% (214/390) of the controls and 47.17% (92/195) of the cases had been on ART for more than four years.

Thirteen (3.67%) of the cases and 0.26% (1/390) of the controls experienced drug toxicity, while 3.08% (6/195) of the cases and 0.66% (1/390) of the controls had a history of at least 1 to 3 times per year of ARVs not served due to drug shortage. With respect to ART adherence, 33.85% (66/195) of the cases and 8.46% (33/390) of the comparison group

were poorly adherent to their ART (Table 2).

**Table 2.** ART Medication-related and Health facility-related characteristics of PLWHIV patients receiving ART at ART clinic, Sunyani Municipality 2022 (N=585)

Variable	Cases n (%)	Control n (%)	X <sup>2</sup>	p-value
<b>Baseline ART Regimen</b>				
AZT+3TC+EFV	15 (7.69)	19 (4.87)	16.14	0.001
TDF+3TC+DTG	135 (69.23)	297 (76.15)		
TDF+3TC+EFV	35 (17.95)	72 (18.44)		
TDF+3TC+NVP	10 (5.13)	2 (0.51)		
<b>Current ART Regimen</b>				
AZT+3TC+NVP	15 (7.69)	19 (4.87)	20.56	0.001
TDF+3TC+DTG	155 (79.49)	337 (86.41)		
TDF+3TC+EFV	16 (8.21)	34 (8.72)		
TDF+3TC+NVP	9 (4.62)	0 (0.00)		
<b>Duration on ART</b>				
<2 years	31 (15.93)	57 (14.62)	3.25	0.197
2-4 years	72 (36.19)	119 (30.51)		
>4 years	92 (47.82)	214 (54.87)		
<b>ART medication adherence</b>				
Good (≥95%)	101 (51.88)	286 (73.33)	59.75	0.001
Fair (80-94%)	28 (14.28)	71 (18.21)		
Poor (<80%)	66 (33.84)	33 (8.46)		
<b>ARVs not served due to shortage</b>				
0 per year	189 (96.92)	389 (99.74)	0.007	
1-3 times per year	6 (3.08)	1 (0.26)		
≥4 times per year	0 (0.00)	0 (0.00)		
<b>ARV toxicity</b>				
No	182 (93.33)	389 (99.74)	22.88	0.001
Yes	13 (6.67)	1 (0.26)		

**Patient clinical-related characteristics of PLWHIV receiving ART**

According to the WHO clinical stage classification, 96.92% (378/390) of the controls and 94.87% (185/195) of the cases were classified as stage I at baseline. One- third, 33.3% (65/195) of cases and 7.44% (29/390) of the controls had a history of opportunistic infection, while 23.59% (46/195) of cases and 23.59% (92/390) of the controls had non- communicable diseases. Moreover, 99.23% (387/390) of the controls and 97.95% (191/195) of the cases were infected with HIV 1 (Table 3).

**Determinants of virologic failure among PLWHIV receiving ART, Sunyani Municipality**

This study found that the odds of developing virologic failure among patients with at least Sec/Tech/Voc School education was 0.58 times (aOR =0.58, 95%CI: 2.30 – 48.75) compared to those who had no formal education. Again, participants who were divorced/separated were twice (aOR =2.04, 95% CI: 0.96, 3.94) as likely to develop virologic failure as compared to those who were married. Self-employed patients were 0.52 times (aOR= 0.52, 95% CI: 0.32- 0.85) as likely to have virologic failure compared to the unemployed patients. The odds of HIV virologic failure were almost 3-fold (aOR=2.88, 95% CI: 1.70 – 4.81) higher in patients who lived in rural areas compared

with urban dwellers. Odds of virologic failure were 2-fold (aOR=2.32, 95% CI: 1.45 – 3.70) higher in patients who did not disclose their HIV status compared with those who disclosed. Patients who adhered to their ART poorly were approximately four times (aOR= 3.68, 95% CI: 2.05-6.59) more likely to experience virologic failure than those who adhered. Patients who adhered to their ART fairly had equal likelihood of virologic failure (aOR= 1.04, 95% CI: 0.58-1.88) compared to their counterparts who adhered. Patients who had a history of opportunistic infections were 7 times (aOR 7.19, 95%CI: 3.94-13.09) more likely to have viral non-suppression than those who had no such history of opportunistic infections. Moreover, the likelihood of developing virologic failure for patients who consume alcohol was about 4 times (aOR = 4.22, 95%CI: 1.93-9.26) as likely as compared to their counterparts who do not consume alcohol (Table 4).

**Discussion**

This study identified predictors of virologic failure among adults living with HIV who are receiving first-line antiretroviral therapy (ART). The analysis revealed that being divorced or separated, residing in rural areas, non-disclosure of HIV status, non-adherence to ART, a history of opportunistic infections, and alcohol consumption were significant predictors of virologic failure. Conversely, having formal education and being self-employed were associated with viral suppression.

The odds of virologic failure were more than twice as high among divorced or separated individuals compared to married participants. This is consistent with findings from Ethiopia [11], where divorced individuals were nearly three times more likely to experience virologic failure. The elevated risk among divorced or separated individuals may stem from the absence of spousal support in adhering to treatment and maintaining clinical follow-up[17]. Social

**Table 3.** Clinical-related characteristics of PLWHIV patients on ART at ART clinics, Sunyani Municipality 2022 (N=585)

Variable	Cases n (%)	Control n (%)	X <sup>2</sup>	p-value
<b>Baseline WHO stage</b>				
Stage 1	185 (94.87)	378 (96.92)	1.51	0.219
Stage 2	10 (5.13)	12 (3.08)		
Stage 3	0 (0.00)	0 (0.00)		
Stage 4	0 (0.00)	0 (0.00)		
<b>History of opportunistic infection</b>				
No	130 (66.67)	361 (92.56)	64.65	0.001
Yes	65 (33.33)	29 (7.44)		
<b>Non-communicable diseases</b>				
No	149 (76.41)	298 (76.41)	0.00	1.00
Yes	46 (23.59)	92 (23.59)		
<b>HIV type</b>				
HIV1	191 (97.95)	387 (99.23)	2.77	0.250
HIV1&2	1 (0.51)	0 (0.00)		
HIV2	3 (1.54)	3 (0.77)		

**Table 4.** Determinants of Virologic Failure among adult HIV patients receiving ART attending ART clinics, Sunyani Municipality 2022 (N=585)

Variable	Cases n (%)	Control n (%)	COR (95% CI)	p-value	aOR (95% CI)	p-value
<b>Education</b>						
No formal education	54 (27.69)	71 (18.21)	Reference		Reference	
Primary	60 (30.77)	134 (34.36)	0.59 (0.37–0.94)	0.026	0.66 (0.37–1.16)	0.147
Sec/Tech/Voc Sch.	81 (41.54)	185 (47.44)	0.58 (0.37–0.89)	0.014	0.58 (0.33–0.99)	0.049
<b>Marital status</b>						
Single	67 (34.36)	106 (27.18)	1.61 (1.09–2.38)	0.017	1.18 (0.73–1.92)	0.499
Married	90 (46.15)	229 (58.72)	Reference		Reference	
Widowed	12 (6.15)	28 (7.18)	1.10 (0.53–2.24)	0.813	1.12 (0.45–2.82)	0.807
Divorced/Separated	26 (13.33)	27 (6.92)	2.45 (1.36–4.43)	0.003	2.04 (0.96–3.94)	0.044
<b>Employment status</b>						
Unemployed	80 (41.03)	103 (26.41)	Reference		Reference	
Self employed	87 (44.62)	219 (56.15)	0.51 (0.35–0.75)	0.001	0.52 (0.32–0.85)	0.009
Employed by others	28 (14.36)	68 (17.44)	0.53 (0.31–0.90)	0.019	1.09 (0.58–2.06)	0.786
<b>Residence</b>						
Rural	59 (30.29)	48 (12.31)	3.09 (2.01–4.75)	0.001	2.86 (1.70–4.81)	0.001
Urban	136 (69.71)	342 (87.69)	Reference		Reference	
<b>Disclosure of status</b>						
No	131 (67.18)	168 (43.08)	2.71 (1.89–3.88)	0.001	2.32 (1.45–3.70)	0.001
Yes	64 (32.82)	222 (56.92)	Reference		Reference	
<b>Adherence rate</b>						
Good	101 (51.79)	286 (73.33)	Reference		Reference	
Fair	28 (14.28)	71 (18.21)	1.12 (0.68–1.83)	0.661	1.04 (0.58–1.87)	0.893
Poor	66 (33.85)	33 (8.46)	5.66 (3.52–9.11)	0.001	3.68 (2.07–6.54)	0.001
<b>Opportunistic infection</b>						
No	130 (66.67)	361 (92.56)	Reference		Reference	
Yes	65 (33.33)	29 (7.44)	6.22 (3.85–10.07)	0.001	7.19 (3.94–13.09)	0.001
<b>Alcohol consumption</b>						
No	167 (85.64)	375 (96.15)	Reference		Reference	
Yes	28 (14.36)	15 (3.85)	4.19 (2.18–8.05)	0.001	4.22 (1.93–9.26)	0.001

and emotional support from partners often serves as a buffer against the psychosocial stressors of living with HIV and its absence can undermine treatment success[20].

Our findings also demonstrated that participants with at least secondary or vocational education had approximately 50% lower odds of virologic failure compared to those with no formal education. This aligns with evidence from Ethiopia [21], Ghana [2], and Nigeria, which collectively indicate that higher levels of education enhance understanding of ART adherence, improve access to health-related information, and empower individuals to navigate healthcare systems more effectively. Education thus acts as an enabling factor that strengthens patients' agency in managing their illness.

Interestingly, self-employed participants were less likely to experience virologic failure compared to those who were unemployed. Although this contrasts with evidence from Ethiopia[13], which reported no significant association, the reduced risk in our study may reflect the greater autonomy and flexibility that self-employment provides[22]. Such flexibility likely facilitates regular clinic attendance and

consistent medication adherence, both of which are critical for maintaining viral suppression. Additionally, a modest but consistent income may improve access to transportation and nutritional support, factors shown to enhance adherence.

Rural residence emerged as another significant predictor of virologic failure. This is consistent with reports from Haiti and Sub-Saharan Africa, where geographical barriers such as long travel distances, limited transport options, and weak infrastructure hinder ART adherence and viral suppression [23][24]. In many rural areas of Ghana, poor transportation infrastructure, irregular access to public transport, and high travel costs hinder timely clinic attendance and medication refills, ultimately compromising adherence[25]. These findings underscore the need to scale up differentiated service delivery (DSD) models, including community ART distribution, multi-month dispensing, and mobile outreach, to alleviate the treatment burden among rural populations.

Non-disclosure of HIV status was also associated with a twofold increase in the odds of virologic failure compared

to those who disclosed. Although lower than the fivefold risk reported in Zimbabwe [26] and Ethiopia [11], our findings underscore the critical role of disclosure in treatment outcomes. Disclosure facilitates access to social support, which has been shown to improve adherence [27]. In contexts where stigma remains pervasive, however, individuals may avoid disclosure due to fear of rejection, divorce, or discrimination [20]. This variability is evident in Zinabu et al. (2020), who found no significant association, suggesting that the relationship between disclosure and virologic outcomes is highly context-dependent. These findings emphasize the importance of stigma-reduction strategies and safe disclosure counseling as integral components of ART programs.

Adherence to ART was a strong predictor of virologic suppression. Participants with poor adherence exhibited a fourfold increase in VF risk, consistent with evidence across Sub-Saharan Africa [13,26,28]. Suboptimal adherence reduces drug plasma concentrations, permitting viral replication and resistance development [10]. Interventions such as peer-led adherence clubs, digital adherence technologies, and psychosocial support should therefore remain central to Ghana's ART strategy [29,30].

A history of opportunistic infections was another strong predictor of virologic failure in this study. Our results revealed higher odds of virologic failure among those with such a history, compared to the twofold increase reported by Endalamaw [31]. The presence of co-infections may compromise immunity, making it more difficult for ART to suppress viral replication [2]. While opportunistic infections could be viewed as clinical manifestations of advanced disease progression following VF [32], the occurrence of OIs can themselves complicate HIV treatment and contribute to VF [33,34].

First, OIs often require concomitant medications, which may interact with antiretroviral therapy, leading to reduced efficacy, altered drug metabolism, or increased toxicity. Again, OIs may exacerbate pill burden and treatment fatigue, thereby reducing adherence to ART [35]. Also, severe OIs may cause gastrointestinal complications, malabsorption, or hospitalization, which further disrupt consistent drug intake.

Collectively, these pathways highlight how OIs not only emerge as sequelae of poor viral suppression but can also create barriers to sustained treatment success, thus perpetuating a cycle of virologic failure and immunological decline. These findings highlight the importance of early diagnosis, prevention, and management of opportunistic infections as part of comprehensive HIV care.

Alcohol consumption also emerged as a significant predictor of virologic failure. Our findings are in

agreement with Sithole et al., (2018), who reported a ninefold increase in virologic failure among PLWHIV who are alcohol consumers [26]. Alcohol impairs adherence by increasing forgetfulness and interacts negatively with antiretroviral drugs via the cytochrome P450 pathway, thereby reducing efficacy and increasing toxicity [36]. Furthermore, alcohol-induced damage to the blood-brain barrier can enhance viral replication in the central nervous system, where ART is less effective [37]. Incorporating interventions to address alcohol use disorders within ART programs is therefore essential.

### Study limitations

Our study had considerable limitations. The study employed an unmatched case-control design, which may introduce selection bias due to differences in baseline characteristics between cases and controls. Furthermore, the study relied on secondary data, which may be prone to inaccuracies and missing information. Despite efforts to validate data across multiple facility records, the potential for information bias remains. Nevertheless, these limitations do not diminish the importance of the findings, which offer valuable insights into the predictors of virologic failure among adults on first-line ART.

## Conclusions

This study identified that rural residence, non-disclosure of HIV status, alcohol consumption, poor adherence to ART and a history of opportunistic infections were significantly associated with virologic failure. Conversely, formal education and self-employment were protective against virologic failure. Health authorities in the municipality should strengthen adherence support through peer networks, disclosure counseling, and stigma reduction interventions. Expansion of differentiated service delivery models, including multi-month dispensing and community ART distribution, is needed to reduce rural-urban disparities in treatment access. Additionally, integration of interventions targeting alcohol use and opportunistic infections within ART services will improve treatment outcomes.

### What is Already Known About this Topic

- Poor ART adherence and low education levels are key predictors of virologic failure in HIV-positive individuals residence can hinder access to HIV care and reduce treatment effectiveness
- Non-disclosure of HIV status often leads to lower adherence due to lack of social support

**What This Study Adds**

- Identifies non-disclosure, rural residence, alcohol consumption, and poor adherence as strong predictors of virologic failure in Sunyani Municipality, Ghana
- Demonstrates that self-employment and formal education significantly reduce the risk of virologic failure the need for targeted interventions focusing on education, adherence, and rural healthcare access

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**Authors' Contributions**

MAA, BS and EA conceived and designed the study. MAA and MK collected the data. MAA and CLN performed the statistical analysis and data visualization. MAA, MK and CLN wrote the first draft. BS and EK provided technical guidance in the design of the study and in the revision of the manuscript. All authors read and approved the final manuscript.

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**Conflict of Interest Statement**

The authors of this work declare no competing interests.

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