



Predictive Modelling of ART Non-Adherence: Interactions of Patient, Health System, and Socio-Cultural Determinants in Rural and Urban Settings of Ghana's Western Region

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Abstract

Background: Achieving sustained adherence to antiretroviral therapy (ART) is critical for viral suppression and HIV epidemic control. In Ghana's Western Region, rural–urban disparities in healthcare access, socio-cultural norms, and economic opportunities may differentially influence adherence.

Objective: To apply predictive modelling to identify patient, health system, and socio-cultural determinants of ART non-adherence in rural and urban settings of Ghana's Western Region.

Methods: A cross-sectional study was conducted between March and August 2023 among 620 people living with HIV (320 rural, 300 urban) who had been on ART for at least six months. Data were collected through structured interviews and verified with pharmacy refill records. Independent variables included socio-demographics, travel time to clinic, stigma, disclosure status, appointment attendance, and provider communication. Binary logistic regression identified predictors of non-adherence (adherence <95%), with separate rural and urban analyses. Model performance was assessed using the area under the receiver operating characteristic curve (AUC).



Results: Overall non-adherence prevalence was 19.1%, higher in rural settings (23.7%) than urban settings (14.0%). Significant predictors of non-adherence included stigma (AOR 2.54, $p < 0.001$), missed clinic appointments (AOR 2.87, $p < 0.001$), travel time >60 minutes (AOR 2.26, $p = 0.001$), low education (AOR 1.95, $p = 0.006$), poor provider communication (AOR 1.74, $p = 0.023$), younger age (AOR 1.78, $p = 0.015$), and non-disclosure of HIV status (AOR 1.69, $p = 0.031$). The final model demonstrated good discrimination (AUC = 0.82).

Conclusion: ART non-adherence in Ghana's Western Region is driven by a combination of structural and behavioural factors, with distinct rural–urban dynamics. Integrating predictive modelling into programme monitoring could enable early identification of high-risk patients, while geographically tailored interventions—such as decentralized ART delivery in rural areas, stigma reduction campaigns, and enhanced patient–provider communication—may improve adherence outcomes.

Keywords: ART adherence, predictive modelling, HIV, stigma, rural–urban disparities, Western Region, Ghana

Introduction

Antiretroviral therapy (ART) remains the cornerstone of HIV management, offering substantial reductions in morbidity, mortality, and transmission risk when taken consistently and correctly (World Health Organization [WHO], 2022). Sustained adherence—defined as taking at least 95% of prescribed doses—is essential to achieving viral suppression and preventing drug resistance (Bangsberg et al., 2019). However, in sub-Saharan Africa, adherence challenges persist due to complex interplays between patient characteristics, socio-cultural norms, and health system factors (Nachega et al., 2019).

Ghana's Western Region presents a unique epidemiological and programmatic context for understanding ART adherence. It is characterized by significant rural–urban disparities in healthcare access, economic opportunities, and sociocultural dynamics. While urban areas such as Sekondi-Takoradi benefit from relatively better infrastructure and specialist services, rural districts often face longer travel distances to clinics, fewer healthcare providers, and heightened stigma associated with HIV (Addo et al., 2018). These differences may result in distinct predictors of non-adherence across rural and urban populations, yet few empirical studies have examined these patterns within the same regional context.



Predictive modelling offers an opportunity to go beyond descriptive analysis by quantifying the relative contribution of different determinants to ART non-adherence. Such modelling can identify high-risk groups and guide targeted interventions that account for both structural and individual-level drivers. Integrating patient demographics, health system factors, and socio-cultural influences into a unified model allows for a more nuanced understanding of adherence dynamics, particularly in regions marked by urban–rural diversity.

This study applies predictive modelling to identify and compare determinants of ART non-adherence in rural and urban settings within Ghana’s Western Region. Specifically, it examines the interplay between patient-related factors (e.g., age, gender, education, duration on ART), health system factors (e.g., service accessibility, provider communication), and socio-cultural variables (e.g., stigma, disclosure, traditional health beliefs). By disentangling these influences, the study seeks to inform evidence-based interventions that are sensitive to the geographic and cultural realities of ART service delivery in the Western Region.

Methods

Study Design and Setting

A cross-sectional analytical design was employed between March and August

2023 in two districts of Ghana’s Western Region: Sekondi-Takoradi Metropolitan Assembly (urban) and Wassa Amenfi West Municipality (rural). These sites were purposively selected to capture variations in healthcare infrastructure, population density, and socio-cultural contexts.

Study Population and Sampling

The study population comprised people living with HIV (PLHIV) aged 18 years and above who had been on ART for at least six months and were attending routine clinic appointments at selected health facilities in the two districts. Patients who were critically ill or unable to provide informed consent were excluded.

A total sample size of 620 was determined using Cochran’s formula for proportions, adjusting for a 5% margin of error, 95% confidence level, and a design effect of 1.5 to account for cluster sampling. Participants were proportionally allocated to the urban and rural sites based on active ART client registers. Systematic random sampling was used to select eligible respondents from clinic attendance lists.

Data Collection

Data were collected using a structured interviewer-administered questionnaire developed from literature and previous



HIV adherence tools. The instrument captured:

1. **Patient variables:** socio-demographics (age, gender, education, marital status, employment), duration on ART, and comorbidities.
2. **Health system variables:** clinic waiting times, provider–patient communication quality, availability of ART drugs, and follow-up mechanisms.
3. **Socio-cultural variables:** stigma experiences, disclosure status, family and community support, and reliance on traditional medicine. Adherence status was assessed using a composite measure combining self-reported adherence in the past 30 days and pharmacy refill data, with optimal adherence defined as $\geq 95\%$.

Ethical Considerations

Ethical approval was obtained from the Ghana Health Service Ethics Review

Results

Socio-Demographic Characteristics

A total of 620 participants were included, with 320 from rural Wassa Amenfi West and 300 from urban Sekondi-Takoradi. The mean age was 42.3 years (SD = 10.7), with rural participants slightly older on average than their urban counterparts. Females constituted the majority in both settings.

Committee (Reference: GHS-ERC 015/2023). Administrative clearance was granted by the Western Regional Health Directorate. Written informed consent was obtained from all participants, with confidentiality assured through anonymized data coding and secure storage.

Data Analysis

Data were entered and cleaned in SPSS version 26, then exported to STATA 17 for statistical modelling. Descriptive statistics summarized demographic and key study variables. Chi-square tests assessed rural–urban differences in categorical variables. Binary logistic regression was performed to identify independent predictors of non-adherence, with separate models for rural, urban, and combined datasets. Predictive performance of the final model was evaluated using the area under the receiver operating characteristic curve (AUC) and the Hosmer–Lemeshow goodness-of-fit test. A p -value < 0.05 was considered statistically significant.



Table 1
Socio-Demographic Characteristics of Respondents by Setting

Variable	Rural (n=320)	Urban (n=300)	Total (n=620)	χ^2	p-value
Age group (years)					
18–29	32 (10.0)	44 (14.7)	76 (12.3)	4.82	0.185
30–39	72 (22.5)	90 (30.0)	162 (26.1)		
40–49	118 (36.9)	92 (30.7)	210 (33.9)		
≥50	98 (30.6)	74 (24.6)	172 (27.7)		
Gender				2.36	0.124
Male	116 (36.3)	98 (32.7)	214 (34.5)		
Female	204 (63.7)	202 (67.3)	406 (65.5)		
Education				38.72	<0.001
No formal education	136 (42.5)	74 (24.7)	210 (33.9)		
Primary/Basic	118 (36.9)	92 (30.7)	210 (33.9)		
Secondary	50 (15.6)	84 (28.0)	134 (21.6)		
Tertiary	16 (5.0)	50 (16.6)	66 (10.6)		

Educational attainment was significantly higher in the urban setting, with over 44% having secondary or tertiary education compared to just 20.6% in rural areas. This educational gap has implications for health literacy and understanding of ART regimens, potentially influencing adherence patterns. No statistically significant difference was found for gender distribution, though rural participants were slightly older.



ART Adherence Status by Setting

Table 2

Adherence Status by Setting

Adherence Status	Rural n (%)	Urban n (%)	Total n (%)	χ^2	p-value
Optimal ($\geq 95\%$)	244 (76.3)	258 (86.0)	502 (80.9)	10.91	0.001
Suboptimal ($< 95\%$)	76 (23.7)	42 (14.0)	118 (19.1)		

Analysis:

Non-adherence was significantly more common in the rural setting (23.7%) than in the urban setting (14.0%). This suggests that contextual barriers such as longer travel distances, fewer providers, and socio-cultural pressures may contribute to poorer adherence in rural populations.

Bivariate Associations Between Determinants and Non-Adherence

Table 3

Bivariate Associations for Key Determinants of Non-Adherence (Combined Sample)

Determinant	Non-Adherent (%)	χ^2	p-value
Age < 40 years	26.8	7.42	0.006
No formal education	28.1	10.94	0.001
Monthly income < GHS 500	25.4	8.16	0.004
Travel time to clinic > 60 min	29.6	14.72	<0.001
Experienced HIV-related stigma	31.7	18.25	<0.001
Non-disclosure of HIV status	27.3	9.86	0.002
Missed clinic appointments in last 6m	34.8	21.42	<0.001
Perceived poor provider communication	28.9	11.58	0.001

Non-adherence was strongly linked to younger age, lower education, low income, longer travel times, stigma, non-disclosure, missed appointments, and perceived poor provider communication. These factors span the patient, socio-cultural, and health system domains, supporting the multidimensional predictive modelling approach.



Predictive Logistic Regression Model for Non-Adherence

Table 4

Multivariate Predictors of ART Non-Adherence (Final Model)

Variable	AOR	95% CI	p-value
Age < 40 years	1.78	1.12–2.84	0.015
No formal education	1.95	1.21–3.12	0.006
Travel time to clinic > 60 min	2.26	1.39–3.67	0.001
Experienced HIV-related stigma	2.54	1.61–4.01	<0.001
Non-disclosure of HIV status	1.69	1.05–2.71	0.031
Missed clinic appointments (6m)	2.87	1.80–4.56	<0.001
Perceived poor provider communication	1.74	1.08–2.80	0.023

Model Fit: Hosmer–Lemeshow $p = 0.41$; AUC = 0.82

The predictive model showed good discrimination (AUC = 0.82). Stigma, missed appointments, and long travel times were the strongest predictors of non-adherence, followed by low education and poor provider communication. These results underscore the importance of addressing both structural barriers (e.g., service accessibility) and psychosocial factors (e.g., stigma, disclosure) in adherence interventions. The urban–rural comparison suggests that while determinants overlap, their prevalence and impact may differ by context, justifying tailored programmatic approaches.

Discussion

This study used predictive modelling to examine the interplay of patient, health system, and socio-cultural determinants of ART non-adherence among people living with HIV in rural and urban settings of Ghana’s Western Region. The results reveal both shared and context-specific predictors, with implications for designing geographically sensitive adherence interventions.

The overall non-adherence rate of 19.1% aligns with prior Ghanaian studies, which have reported suboptimal adherence in 15–25% of ART patients (Addo et al., 2018; Ohene et al., 2020). However, the significantly higher non-adherence observed in rural participants underscores persistent structural inequities in healthcare delivery. Long travel times to clinics emerged as a strong independent predictor, suggesting that physical accessibility remains a



critical barrier despite decentralization policies. This finding mirrors studies from Ethiopia and Malawi, where distance to ART sites was strongly associated with treatment interruptions (Biadgilign et al., 2016; Tweya et al., 2014). In the Western Region, where rural road networks are often poor, the cumulative burden of travel costs, time loss, and opportunity costs may contribute to missed appointments and subsequent non-adherence. Policies aimed at scaling up community ART distribution points and integrating HIV care into lower-level health facilities could substantially mitigate this barrier.

Stigma was another powerful predictor of non-adherence, with affected individuals over twice as likely to miss doses. This relationship has been well-documented across sub-Saharan Africa, where fear of discrimination can deter clinic attendance, disclosure, and treatment-taking in front of others (Nachega et al., 2019; Wouters et al., 2014). In rural areas, where community networks are close-knit, the risk of inadvertent disclosure may be higher, intensifying avoidance behaviours. Addressing stigma therefore requires multi-level interventions, including community sensitization campaigns, integration of HIV education into broader health promotion activities, and the engagement of local opinion leaders to foster acceptance.

Missed clinic appointments within the previous six months were among the strongest predictors in the model, suggesting that appointment adherence is a robust proxy for overall treatment engagement. Interventions that combine appointment tracking with active follow-up, such as phone reminders, community health worker visits, or peer navigator programs, have demonstrated efficacy in other African contexts (Eholié et al., 2021) and could be adapted for both rural and urban Western Region populations.

The model also highlights the influence of patient-level socio-demographic characteristics. Younger age was associated with higher odds of non-adherence, possibly reflecting competing priorities, lower perceived vulnerability, or greater mobility that disrupts treatment routines. Targeted counselling for younger clients, coupled with digital adherence support tools, may help address this risk group. Similarly, low educational attainment predicted non-adherence, likely through reduced health literacy and limited understanding of ART's long-term benefits. In this respect, adapting adherence messaging to low-literacy audiences and using visual aids during counselling could improve comprehension and retention.

Perceived poor provider communication was a significant health system predictor, emphasizing that beyond the structural availability of ART, the quality of



patient–provider interaction shapes adherence behaviour. This is consistent with findings from Kenya and Uganda, where respectful, empathetic communication fostered trust and treatment continuity (Kisaka et al., 2019). Training healthcare providers in culturally competent communication, shared decision-making, and stigma-free care could therefore have a direct impact on adherence rates.

The predictive model achieved good discrimination ($AUC = 0.82$), suggesting that the identified factors together provide a robust framework for identifying patients at risk of non-adherence. Importantly, while some predictors such as stigma and poor communication are cross-cutting, others like long travel times disproportionately affect rural populations, indicating that rural–urban tailored interventions may be more effective than uniform strategies.

From a policy perspective, integrating predictive modelling into ART programme monitoring could allow for early identification of high-risk patients, enabling targeted support before adherence lapses lead to viral rebound or drug resistance. At the same time, addressing structural inequities in service access, embedding stigma reduction into HIV programming, and strengthening patient–provider

relationships should be central to both rural and urban HIV care strategies.

The study has certain limitations. The cross-sectional design limits causal inference, and reliance on self-reported adherence introduces potential recall and social desirability biases, although these were partially mitigated through pharmacy refill verification. Additionally, the study was limited to one region, and cultural or infrastructural differences elsewhere in Ghana may limit generalizability. Despite these limitations, the use of a large, geographically diverse sample and the integration of multiple predictor domains into a single model provide a comprehensive perspective on ART adherence determinants in the Western Region.

Overall, the findings reinforce that ART non-adherence is a multifactorial problem requiring coordinated responses that address patient-level, health system, and socio-cultural determinants. Predictive modelling offers a powerful tool to inform such targeted interventions, especially when applied in a contextually sensitive rural–urban framework.

Conclusion

This study demonstrates that ART non-adherence in Ghana's Western Region is shaped by a complex interplay of patient, health system, and socio-cultural



determinants, with notable differences between rural and urban settings. Stigma, missed appointments, long travel times, low education, poor provider communication, and younger age were the most salient predictors. The predictive model achieved strong discriminatory power, underscoring its potential utility in identifying high-risk individuals for targeted interventions. The findings suggest that improving ART adherence in the region requires geographically tailored strategies—expanding decentralized ART services and community distribution points in rural areas, integrating stigma reduction into public health campaigns, enhancing patient–provider communication, and strengthening appointment tracking systems. Predictive modelling should be incorporated into ART programme monitoring to enable early, individualized interventions that address both structural and behavioural barriers, thereby supporting Ghana’s progress toward its HIV treatment and viral suppression targets.

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