SCIENTIFIC CULTURE

www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 5.1, (2026), pp. 1199-1218
Open Access. Online & Print

10.5281/zenodo.22670633

PERFORMANCE OF HIV DRUG RESISTANCE EARLY WARNING INDICATORS AND ASSOCIATED PROGRAM FACTORS IN LESOTHO DURING THE DOLUTEGRAVIR ERA

Mosa Mabataung Monyake[1], Keletso Ntene[2], Anna Masheane-Moseneke[3], Morongoe Nyakane-Nkoko[4], Pakiso Makhoahle[5], Justen Manasa[6], Francis Mupeta[7], Mosa Selebalo[8], Tapiwa Tarumbiswa[9]

[1]Faculty of Health and Environmental Science, Centre for Quality of Health and Living, Central University of Technology Free State and Laboratory Services and Research Directorate, Ministry of Health, Maseru, Lesotho
[2]Disease Control Directorate, Ministry of Health, Maseru, Lesotho
[3]Disease Control Directorate, Ministry of Health, Maseru, Lesotho
[4]Disease Control Directorate, Ministry of Health, Maseru, Lesotho
[5]Faculty of Health and Environmental Science, Centre for Quality of Health and Living, Central University of Technology Free State and Laboratory Services
[6]Faculty of Medicine and Health Sciences, University of Zimbabwe, Harare, Zimbabwe
[7]Lusaka Apex Medical University, Faculty of Medicine, Lusaka, Zambia
[8]Disease Control Directorate, Ministry of Health, Maseru, Lesotho
[9]Disease Control Directorate, Ministry of Health, Maseru, Lesotho

Received: 15/04/2026
Accepted: 22/06/2026

Corresponding Author: Mosa Mabataung Monyake

ABSTRACT

HIV drug resistance (HIVDR) remains a major threat to the long-term effectiveness of antiretroviral therapy (ART) programs, particularly in settings where routine resistance testing is limited. Although dolutegravir (DTG)-based regimens have improved treatment durability, programmatic factors such as poor adherence, treatment interruptions, and inadequate monitoring continue to increase the risk of HIVDR. The World Health Organisation (WHO) recommends HIVDR Early Warning Indicators (EWIs) to monitor program performance and identify vulnerabilities associated with the emergence of HIVDR. This study assessed HIVDR EWI performance and examined facility-level factors associated with program performance in Lesotho during the DTG era. Methods: A cross-sectional assessment was conducted using routinely collected ART program data from 74 facilities across all ten districts of Lesotho during the 2023 reporting period. Four WHO HIVDR EWIs were assessed: total attrition from ART (ART.2), viral load suppression (ART.3), viral load testing coverage (ART.6), and on-time antiretroviral drug pick-up as an adherence proxy (ART.13). Descriptive analyses summarised facility performance, while multivariable linear regression models examined facility- and district-level factors associated with attrition and adherence outcomes. Results: On retention in care, 97% of facilities met the WHO target for attrition. For adherence performance, 88% of facilities did not meet the target for on-time antiretroviral drug pick-up. For viral load suppression, 55% of facilities met the WHO threshold, while only 5% achieved the target for viral load testing coverage. In addition, 45% of facilities could not be classified for viral load-related indicators because of missing viral load data. Multivariable regression analysis

identified significant district-level variation in adherence. Compared with facilities in Mokhotlong, facilities in Leribe, Mafeteng, Maseru, Qacha's Nek, Quthing, and Thaba-Tseka had lower adherence levels, with these differences statistically significant. Hospitals recorded higher adherence levels than clinics. Attrition showed limited associations with facility characteristics. Compared with facilities in Mokhotlong, facilities in Quthing and Thaba-Tseka had lower attrition rates. Conclusions: Lesotho's ART program demonstrated strong retention in care but important weaknesses in treatment continuity, viral load monitoring, and routine program information systems. The coexistence of high retention and poor adherence suggests that continued engagement in care does not necessarily translate into uninterrupted treatment exposure. Variation in performance across districts and facility types further indicates that local service delivery conditions influence program outcomes and HIVDR risk. Overall, the findings suggest that while ART scale-up has been successful, key systems required to sustain long-term treatment effectiveness have not strengthened at the same pace. Strengthening adherence support, improving monitoring systems, and integrating routine EWI monitoring with laboratory-based HIVDR surveillance should be prioritised to safeguard the effectiveness of ART in the DTG era.

KEYWORDS: HIV Drug Resistance, Early Warning Indicators, Antiretroviral Therapy, Dolutegravir, Adherence, Retention in Care, Viral Load Monitoring, Lesotho.

1. INTRODUCTION

The scale-up of antiretroviral therapy (ART) has transformed HIV infection into a manageable chronic condition and substantially reduced HIV-related morbidity, mortality, and transmission globally. By 2023, more than 30 million people were receiving ART worldwide, with the greatest expansion occurring in sub-Saharan Africa, the region most affected by the HIV epidemic. Despite these achievements, the long-term effectiveness of ART programs is increasingly threatened by HIV drug resistance (HIVDR), which compromises treatment outcomes, limits future therapeutic options, increases program costs, and threatens progress toward global HIV control targets.

Although HIVDR develops through viral mutations that reduce susceptibility to antiretroviral medicines, its emergence is strongly influenced by the performance of HIV treatment programs. Poor adherence, treatment interruptions, inadequate viral load monitoring, delayed identification of treatment failure, and weaknesses in drug supply systems can create conditions that favour the development and transmission of resistant HIV strains. Recognising these risks, the World Health Organisation (WHO) recommends a comprehensive HIVDR surveillance framework that includes pretreatment and acquired HIVDR surveys, together with routine monitoring of HIVDR Early Warning Indicators (EWIs). Unlike laboratory-based resistance surveillance, EWIs assess programmatic and health system factors associated with HIVDR risk using routinely collected program data, providing a practical approach for monitoring program performance in resource-limited settings.

Over the past decade, Lesotho has made substantial progress in expanding ART access through universal treatment policies, widespread adoption of dolutegravir (DTG)-based regimens, expanded viral load testing services, and the implementation of differentiated service delivery models. These interventions were intended to strengthen treatment continuity, improve adherence, increase viral suppression, and reduce the risk of HIVDR.

Despite these advances, routine HIVDR surveillance remains limited in Lesotho. The most recent nationally coordinated HIVDR Early Warning Indicator assessment was conducted in 2014, prior to the introduction of DTG-based regimens and several major HIV program reforms. Since then, substantial changes in treatment policies, service delivery models, and monitoring systems have fundamentally altered the HIV treatment landscape. However, it remains unclear whether the systems required to sustain long-term treatment effectiveness have strengthened at the same pace as ART expansion.

This study assessed performance on selected WHO HIVDR Early Warning Indicators across ART facilities in Lesotho during the DTG era and examined facility-level factors associated with variation in attrition and adherence outcomes. By evaluating key dimensions of program performance associated with HIVDR risk, the study sought to determine whether HIV program strengthening has kept pace with ART scale-up and to identify vulnerabilities that may threaten the long-term effectiveness of ART in Lesotho.

2. METHODS

2.1. Study Design and Setting

This cross-sectional facility-based assessment evaluated programmatic factors associated with HIV drug resistance (HIVDR) using World Health Organisation (WHO) HIVDR Early Warning Indicators (EWIs). The study was conducted using routinely collected data from the antiretroviral therapy (ART) program for the 2023 reporting period.

The study was implemented across ART facilities distributed throughout all ten districts of Lesotho. ART services are delivered through a decentralised health system comprising facilities operated by the Government of Lesotho, the Christian Health Association of Lesotho (CHAL), private providers, and non-governmental organisations. Data were obtained from routine ART program records, including ART registers, pharmacy dispensing records, viral load monitoring systems, and electronic medical records where available.

2.2. HIV Drug Resistance Early Warning Indicators

The study assessed four WHO-revised HIVDR Early Warning Indicators: total attrition from ART (ART.2), viral load suppression (ART.3), viral load testing coverage (ART.6), and on-time antiretroviral drug pick-up as an adherence proxy (ART.13). These indicators monitor key programmatic factors associated with treatment effectiveness and HIVDR risk.

Although seven WHO-revised EWIs were initially selected, only four indicators had sufficient and reliable routine data to support formal analysis. Three indicators (ART.8, ART.12, and ART.14) were excluded because of incomplete or unavailable data. Indicator definitions, calculation methods, and performance thresholds followed WHO guidance

and are summarised in Table 1.

Table 1: Revised WHO EWI For HIVDR And Corresponding Performance Thresholds.

Ref. No.	Indicator	Definition	Performance Thresholds
ART.2	Total attrition from ART	Percentage of people living with HIV (PLHIV) who were on ART at the start of the reporting period (including newly initiated) and are no longer on ART at the end of the reporting period (including death, loss to follow-up, or treatment interruption)	Green: <15% Amber: 15–25% Red:>25%
ART.3	Viral load suppression	Percentage of PLHIV on ART for ≥6 months who have a suppressed viral load (VL <1000 copies/mL) among those with a documented VL result	Green: ≥90% Amber: 80–<90% Red:<80%
ART.6	Viral load testing coverage	Percentage of PLHIV on ART for ≥6 months who have a documented VL test result during the reporting period	Green: ≥95% Amber: 85–<95% Red:<85%
ART.13	On-time ARV drug pick-up (adherence proxy)	Percentage of PLHIV on ART who collect their prescribed ARV medication on time (defined as no more than 2 days late from the scheduled appointment date at first refill after baseline)	Green: ≥90% Amber: 80–<90% Red:<80%

2.3. Sampling Strategy and Data Collection

The sampling frame was derived from the national ART facility master list and stratified by district, geographic location, and ownership. Facilities included in the previous national HIVDR EWI survey were purposively retained, while additional facilities were selected from the national ART facility network to achieve broad national representation, resulting in a total sample of 90 facilities.

All age groups of patients receiving ART at selected facilities during the reporting period were eligible for inclusion. Patient records were sampled according to WHO-defined indicator-specific eligibility criteria. Facilities that were closed, inaccessible during data collection, or had insufficient records to support reliable EWI calculation were excluded from analysis. Facilities with incomplete data for specific indicators remained eligible for inclusion but were classified as unscorable (grey) for the affected indicator in accordance with WHO guidance.

Data were retrospectively abstracted from routine ART program records covering the period 1 January to 31 December 2023. Trained data collectors used standardised WHO EWI abstraction tools and underwent structured training and pilot testing prior to data collection.

Data quality assurance focused on reliability, completeness, and consistency. Facility-level data were cross-checked across ART registers, pharmacy records, viral load registers, and electronic systems where available. Facilities with less than 70% completeness of required data elements were classified as unscorable. Additional quality checks included verification of reporting periods, identification of duplicate records, and validation of indicator calculations using WHO definitions and thresholds.

All data were de-identified before analysis and managed in accordance with WHO-recommended procedures for HIVDR EWI surveys. Access to study datasets was restricted to authorised study personnel.

2.4. Statistical Analysis

Early Warning Indicator outcomes were calculated using the WHO HIVDR EWI Aggregator Tool and classified according to WHO performance thresholds. Descriptive analyses were used to summarise facility performance across indicators and to examine variation by district and facility characteristics. Indicator performance was presented as proportions and percentages.

To assess factors associated with variation in program performance, multivariable ordinary least squares (OLS) regression models were fitted using facility-level attrition (ART.2) and adherence (ART.13) outcomes. Explanatory variables included district, facility type, ownership, service volume (Tx Curr ≥ 2000), and previous participation in the national EWI survey. Mokhotlong district, clinics, and CHAL-owned facilities served as reference categories.

Robust standard errors were used for all regression models. Statistical significance was assessed at the 10%, 5%, and 1% levels. Regression

coefficients were interpreted as the average difference in outcome measures relative to the corresponding reference category. The attrition analysis included 74 facilities, while the adherence analysis included 73 facilities because one facility had missing adherence data. All analyses were conducted using Stata version 17.

2.5. Ethical Considerations

Ethical approval for the study was obtained from the relevant national ethics review authorities. The survey utilised routinely collected program data and did not involve direct patient contact, clinical intervention, or specimen collection.

All data were de-identified prior to analysis to protect patient confidentiality. Facility-level results were reported in aggregate, and no individual patient identifiers were collected or retained.

The study was conducted in accordance with national ethical requirements and the principles outlined in the Declaration of Helsinki.

3. RESULTS

3.1. Facility Sample and Participation

A total of 90 ART facilities were selected from the national ART program across all ten districts of Lesotho. Of these, 74 facilities (82%) met minimum data quality requirements and were included in the final analysis, while 16 facilities (18%) were excluded. Ten facilities were excluded because routine records were insufficient to support reliable EWI calculation, and six facilities were inaccessible during the data collection period. The final analytic sample included facilities representing all districts, ownership categories, and levels of service delivery.

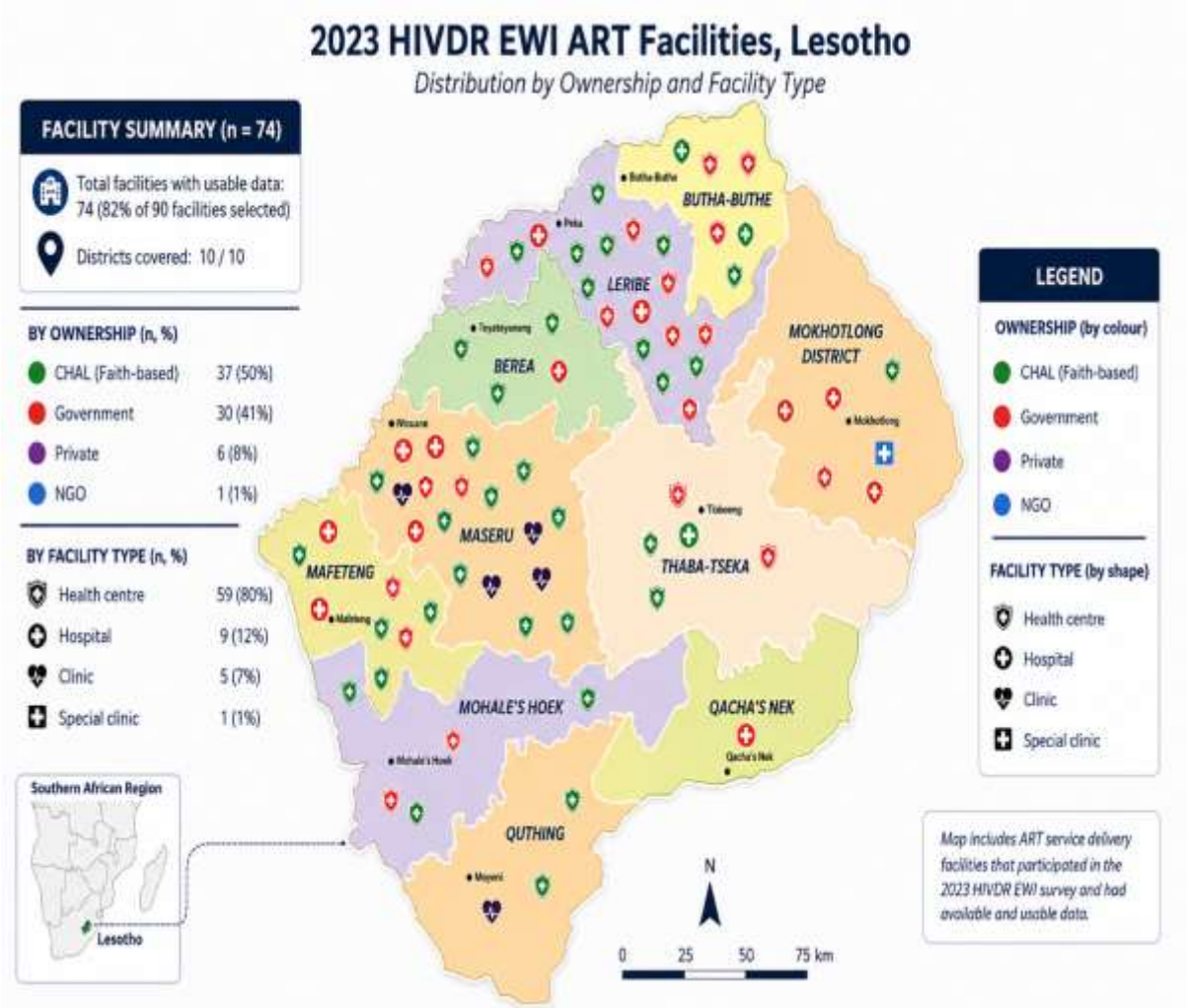

Figure 1: Geographic Distribution and Characteristics of ART Facilities Included in the 2023 HIVDR EWI Survey, Lesotho.

Figure 1 illustrates the geographic distribution, ownership, and facility types of the 74 ART facilities included in the 2023 HIVDR EWI survey. Facilities were distributed across all ten districts, providing

national representation across both lowland and highland regions.

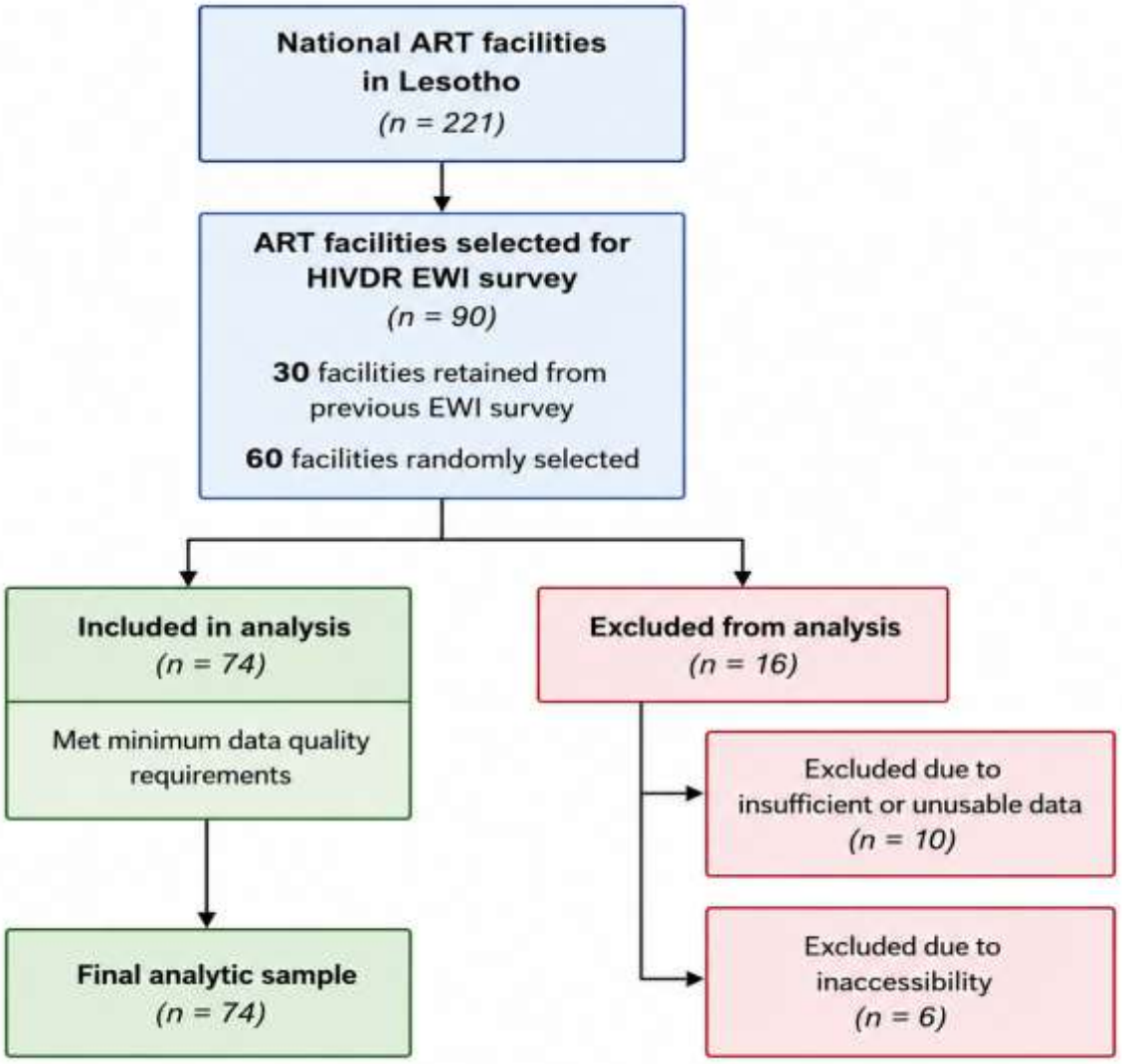

Figure 2: Selection And Inclusion of ART Facilities for the HIVDR EWI Survey, Lesotho, 2023.

Figure 2 summarises facility selection and inclusion in the survey. Of the 90 facilities selected, 74 were included in the final analysis after assessment of accessibility and data quality.

3.2. Characteristics Of Participating Facilities

Among the 74 participating facilities, 47 (64%) were located in lowland districts and 27 (36%) in highland districts. Most facilities were health centres (59; 80%), followed by hospitals (9; 12%) and clinics or special clinics (6; 8%). Half of the facilities were operated by the Christian Health Association of Lesotho (CHAL) (37; 50%), while 30 (41%) were government-owned and 7 (9%) were privately or NGO-managed.

Twenty-three facilities (31%) were classified as high-volume sites (Tx Curr ≥ 2000), while 29 facilities (39%) had participated in the 2012 national EWI survey. Facility characteristics are summarised in Table 2.

Table 2: Characteristics Of Participating ART Facilities and Program Attributes, Lesotho, 2023 (N = 74).

Domain	Category	n	%
Facility ownership	CHAL (Faith-based)	37	50
	Government	30	41
	Private	6	8
	NGO	1	1
Facility type	Health centre	59	80

	Hospital	9	12
	Clinic/Special clinic	6	8
Service volume	High-volume (Tx Curr ≥ 2000)	23	31
	Non-high volume (Tx Curr <2000)	51	69
Participation in 2012 EWI survey	Yes	29	39
	No	45	61
Geographic zone	Lowlands	47	64
	Highlands	27	36

3.3. National EWI Performance by Indicator

Facility-level EWI performance was classified using WHO performance strata: Green (good), Amber (fair), Red (poor), and Grey (unclassified due to missing data). Performance across indicators are shown in Table 3 and Figure 4.3. Total attrition from ART (ART.2), 72 out of 74 facilities (97%) achieved the WHO target. Adherence performance was measured using on-time antiretroviral drug pick-up (ART.13); only one facility (1%) met the WHO target, while 65 facilities (88%) did not.

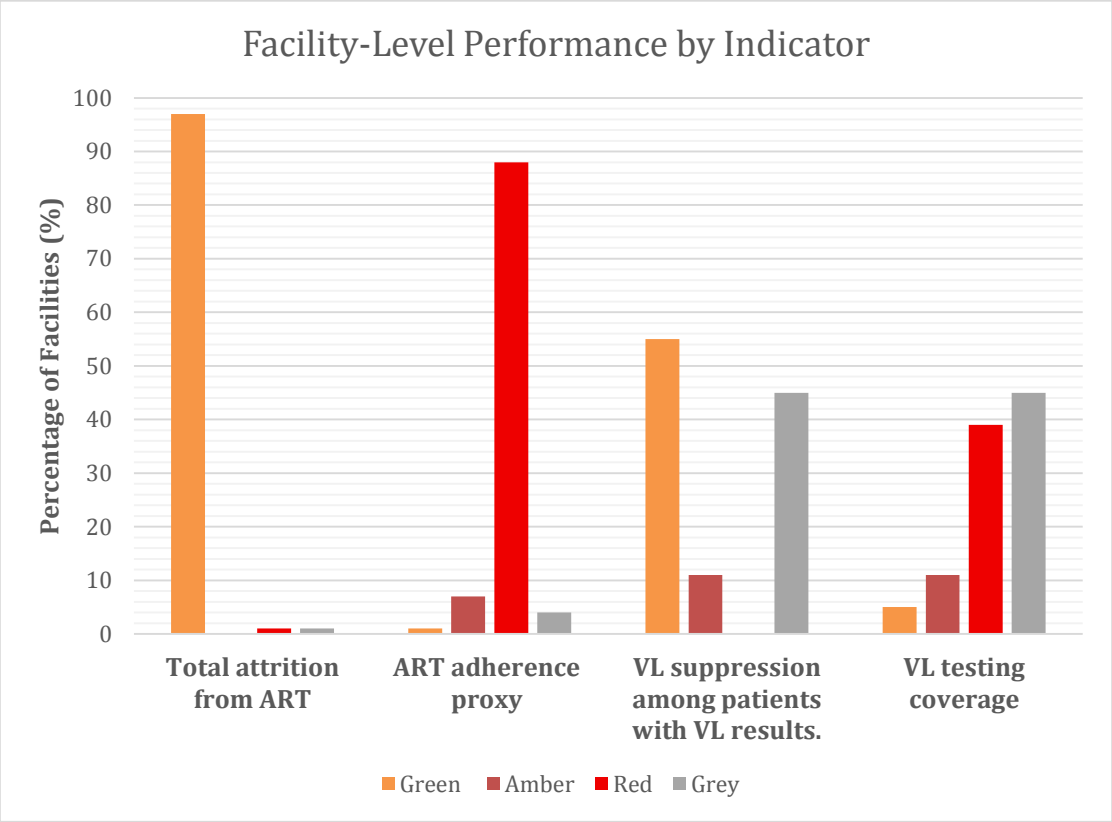

Figure 3: Facility Performance Across Selected HIVDR EWI, Lesotho, 2023.

Only 4 facilities (5%) achieved the WHO target for viral load testing coverage (ART.6), while 29 facilities (39%) failed to meet the recommended thresholds, and 33 facilities (45%) could not be classified due to insufficient data. Viral load suppression (ART.3) met WHO thresholds in 41 facilities (55%). The table provides an overview of the proportion of facilities that meet, approach, or fall below recommended performance standards.

Table 3: Distribution of EWI Performance Across Facilities in Lesotho (N = 74).

Indicator Level	Indicator	Aggregated Facility Performance n (%)			
		Green	Amber	Red	Grey
Patient	ART.2 Total attrition from ART	72(97%)	0	1(1%)	1(1%)
	ART.13 Adherence proxy	1 (1%)	5 (7%)	65(88%)	3(4%)
Facility	ART.6 Viral load testing coverage	4 (5%)	8 (11%)	29(39)	33 (45%)
ART Program	ART.3 Viral load suppression	41 (55%)	0	0	33 (45%)

Percentages are calculated based on 74 facilities. Values may not sum to exactly 100% due to rounding.

3.4 Geographic and Facility-Level Patterns in Attrition

3.4.1. Geographic And Facility-Level Patterns in Patient Attrition

Mean attrition rates remained below the WHO threshold of 15% across all districts and facility categories (Figure 4). District-level attrition ranged from 1.0% in Qacha's Nek to 7.2% in Mohale's Hoek. Attrition in high-volume and non-high-volume facilities was 3.5% and 3.7%, respectively, and in facilities located in highland and lowland districts, 3.5% and 3.7%, respectively.

Clinics recorded a mean attrition rate of 5.4%, while special clinics recorded 1.0%. Overall, attrition remained well below WHO performance thresholds across all strata.

Figure 4: Distribution Of Facility-Level Attrition Rates Across Program Characteristics, Lesotho, 2023

3.4.2. Geographic and Facility-Level Patterns in Adherence

The mean adherence rate was 15.1% in Leribe, 16.7% in Quthing, and 17.4% in Mohale's Hoek. The mean adherence level in Thaba-Tseka was 19.4%, in Mafeteng 20.8%, and in Maseru 21.3%, while Qacha's Nek recorded a mean adherence rate of 23.0%, Butha-Buthe 26.5%, Berea 27.5%, and Mokhotlong 31.8%.

When stratified by facility volume, high-volume facilities had a mean adherence of 19.7%, and non-high-volume facilities had 21.1%. Across facility types, clinics had a mean adherence of 19.0%, while health centres had 19.6%. Hospitals had a mean adherence rate of 29.6%, and special clinics had 37.0%.

When stratified by facility ownership, NGO-managed facilities recorded a mean adherence of 16.0%, private facilities 19.6%, CHAL facilities 20.6%, and government facilities 21.5%. By geographic zone, facilities in the lowlands had a mean adherence of 20.3%, and those in the highlands had 22.4%. Facilities that had previously participated in a survey recorded a mean adherence of 21.8%, while those that

had not recorded 20.3%.

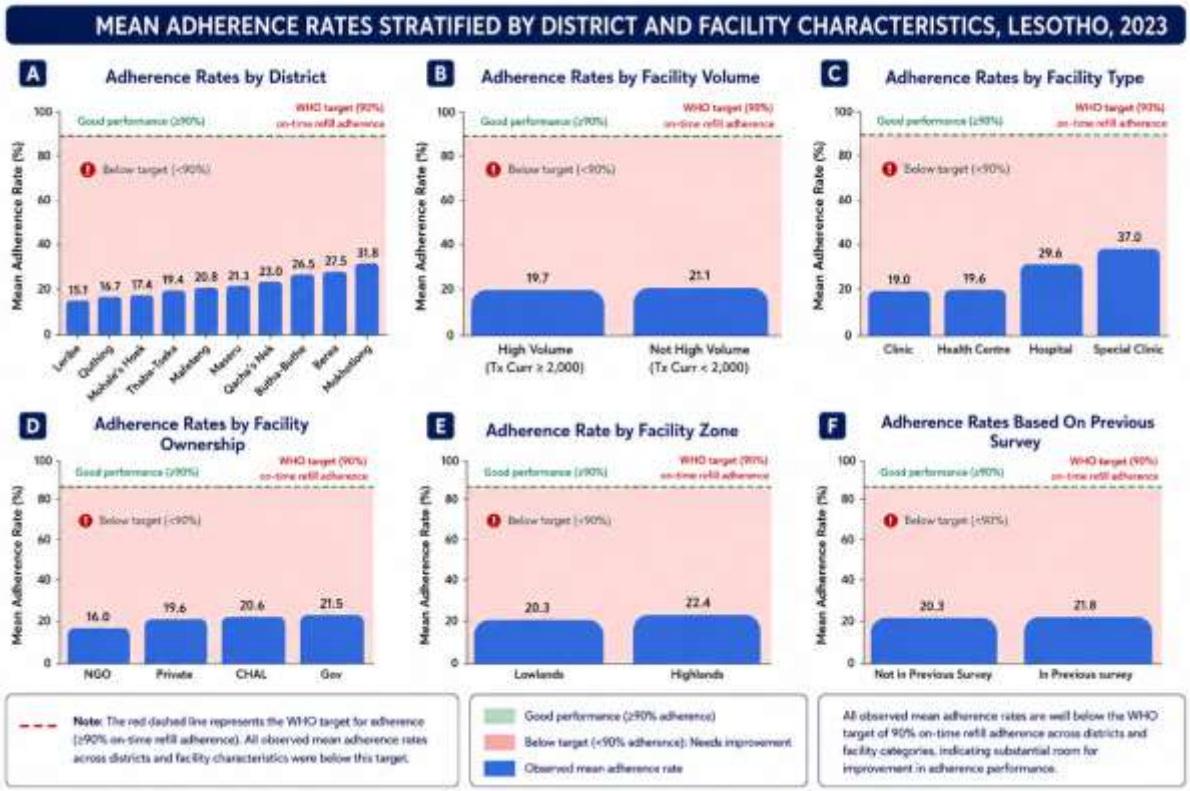

Figure 5: Distribution Of Mean Adherence Rates Across Facilities by District, Facility Characteristics, And Program Factors in Lesotho.

3.5. Multivariable Regression Results

3.5.1. Determinants of Attrition

Multivariable regression analysis was conducted to examine associations between district-, facility-, and program-level characteristics and facility-level attrition. Across all model specifications, district-level variation in attrition was observed. Compared with facilities in Mokhotlong, facilities in Quthing and Thaba-Tseka consistently demonstrated lower attrition rates, and these associations remained significant in the fully adjusted model.

Although hospitals and special clinics generally exhibited lower attrition rates than clinics in the unadjusted and partially adjusted models, these associations were attenuated after adjustment for facility ownership and other covariates. Facility ownership was not significantly associated with attrition, although government- and privately owned facilities tended to demonstrate slightly higher attrition rates than CHAL-owned facilities.

Neither high-volume facility status nor previous participation in the 2012 EWI survey was significantly associated with attrition. Overall, the findings suggest that district-level factors were the primary determinants of variation in attrition, while facility type, ownership, and program characteristics contributed little to explaining differences in attrition performance across facilities.

3.5.2. Determinants of Adherence

Multivariable regression analysis was conducted to assess associations between district-, facility-, and program-level characteristics and facility-level adherence. Across all model specifications, substantial geographic variation in adherence was observed. Compared with facilities in Mokhotlong, facilities in several districts consistently demonstrated lower adherence levels, with the largest reductions observed in Leribe, Qacha's Nek, and Quthing.

These district-level disparities remained significant after adjustment for facility type, ownership, service volume, and previous participation in the 2012 EWI survey, indicating persistent geographic differences in program performance. Facility type was also associated with adherence, with hospitals consistently demonstrating higher adherence levels than clinics across all models.

Facility ownership contributed to variation in adherence outcomes. NGO-managed facilities

exhibited significantly lower adherence than CHAL-owned facilities, while adherence among government-owned and privately owned facilities did not differ significantly from CHAL facilities. In contrast, neither high-volume facility status nor previous participation in the 2012 EWI survey was significantly associated with adherence.

Overall, the findings suggest that district-level factors were the strongest determinants of adherence performance, while facility ownership and, to a lesser extent, facility type also contributed to variation in adherence outcomes across facilities.

4. DISCUSSION AND CONCLUSION

4.1. Discussion of Key Findings

4.1.1. Program Strengths: Retention In Care

Retention in care emerged as the strongest-performing HIVDR Early Warning Indicator in this assessment. Nearly all participating facilities (97%) met the WHO attrition target, indicating that most patients remained engaged in HIV care and treatment services throughout the reporting period. Mean attrition rates remained well below the WHO threshold across all districts and facility categories, demonstrating consistently strong performance throughout the national ART program.

These findings suggest that Lesotho has achieved substantial success in maintaining continuity of care despite the challenges associated with delivering HIV services in a geographically dispersed setting. The observed retention outcomes likely reflect the cumulative impact of investments in ART scale-up, decentralisation of HIV services, differentiated service delivery models, and expansion of treatment access over the past decade.

Strong retention has also been reported in several ART programs across sub-Saharan Africa following the introduction of universal treatment policies and DTG-based regimens (Fox & Rosen, 2015; Siedner et al., 2013). From an HIVDR perspective, sustained engagement in care is important because it supports ongoing treatment exposure, routine monitoring, and timely clinical management, all of which contribute to reducing the risk of treatment failure and drug resistance.

However, retention alone does not guarantee optimal treatment outcomes. The coexistence of strong retention and poor adherence observed in this study highlights the need to assess multiple dimensions of program performance when evaluating HIVDR risk.

4.1.2. ART Program Gaps: Adherence, Monitoring, And Data Systems

Despite strong retention outcomes, important weaknesses were identified in treatment continuity, viral load monitoring, and routine program information systems. Adherence performance was poor across almost all facilities, with most failing to achieve the WHO target for on-time ARV drug pick-up. This finding is concerning because adherence is a critical determinant of sustained viral suppression and HIVDR prevention. The coexistence of strong retention and poor adherence suggests that continued engagement in care does not necessarily translate into uninterrupted treatment exposure, with patients potentially remaining enrolled in care while experiencing delayed medication collection or treatment interruptions.

Similar patterns have been reported elsewhere in sub-Saharan Africa, where treatment interruptions and inconsistent adherence remain important drivers of virological failure and HIV drug resistance despite favourable retention outcomes (Nichols et al., 2020; Moyo et al., 2022; Manasa et al., 2023; Chimukangara et al., 2019). These findings reinforce the importance of assessing multiple program indicators rather than relying on retention alone as a measure of program success.

Major weaknesses were also identified in viral load monitoring. Only a small proportion of facilities met WHO targets for viral load testing coverage, while nearly half could not be classified due to missing or incomplete data. Although national program reports indicated approximately 95% viral load coverage during the same period, this apparent discrepancy reflects important methodological differences between routine program reporting and EWI measurement.

Unlike routine program indicators, EWI viral load coverage is time-bound and assesses whether viral load testing was performed within the recommended monitoring interval. Tests conducted outside the recommended timeframe are classified as not meeting the indicator because delayed testing may postpone identification of treatment failure and increase the risk of HIV drug resistance development.

In addition, this EWI assessment relied on paper-based documentation available at the facility level. Consequently, viral load tests that were performed but not recorded in facility records were classified as missing for EWI purposes. The findings therefore suggest that weaknesses in documentation, laboratory-clinical data linkage, and health information systems may substantially affect the accurate measurement of facility-level viral load

coverage. Similar challenges have been reported across sub-Saharan Africa, where fragmented information systems and poor interoperability between clinical and laboratory databases undermine routine monitoring and evaluation (Muthee et al., 2018; Odhiambo et al., 2020; Nichols et al., 2020).

Similar challenges have been documented across sub-Saharan Africa, where fragmented information systems and poor interoperability between clinical and laboratory databases undermine routine monitoring and evaluation (Muthee et al., 2018; Huerga et al., 2017; Nichols et al., 2020).

The inability to assess several WHO-recommended indicators further highlights weaknesses in routine program information systems. Indicators related to ARV stock-outs, follow-up viral load testing, and treatment switching could not be evaluated consistently because of incomplete data. As EWI surveillance depends on the quality and completeness of routine program records, these gaps limit the ability to comprehensively monitor program performance and identify emerging HIVDR risks (Bertagnolio et al., 2012).

Collectively, these findings suggest that weaknesses in treatment continuity, monitoring systems, and data integration may delay identification of treatment failure and create conditions that facilitate the emergence of HIV drug resistance.

4.2. Determinants of Program Performance

Important variation in program performance was observed across districts and facility characteristics, particularly for adherence outcomes. District-level differences remained significant after adjustment for facility characteristics, suggesting that local service delivery contexts influence treatment continuity and program effectiveness. Similar geographic variation has been reported across sub-Saharan Africa, where factors such as access to care, population mobility, transport availability, and socioeconomic conditions influence retention and adherence outcomes (Nichols et al., 2020; Moyo et al., 2022; Siedner et al., 2013).

An unexpected finding was the comparatively stronger adherence performance observed among facilities in Mokhotlong. Although the study was not designed to identify the underlying causes of district-level differences, the findings suggest that local program implementation practices or patient support mechanisms may contribute to treatment continuity. Understanding the factors associated with stronger performance in this district may provide useful lessons for program improvement elsewhere.

Facility type was also associated with program performance. Hospitals generally demonstrated better adherence outcomes than clinics, suggesting that stronger clinical capacity, more stable staffing, enhanced patient follow-up systems, and better integration of clinical and laboratory services may support treatment continuity. In contrast, facility ownership, service volume, and previous participation in the 2012 EWI survey showed limited or inconsistent associations with program performance.

The relatively weak associations observed for attrition likely reflect the uniformly strong retention performance across facilities. With nearly all facilities meeting WHO attrition targets, there was limited variation available to be explained by facility characteristics. In contrast, adherence demonstrated substantial variability across districts and facility types, making contextual differences more readily detectable.

Collectively, these findings suggest that HIVDR risk is influenced by a combination of district-level factors, facility service capacity, and program organisation rather than by facility size alone. This interpretation aligns with systems-based frameworks of HIV drug resistance, which emphasise the interaction between structural, clinical, and behavioural determinants of program performance (Bertagnolio et al., 2012; Kiekens et al., 2022).

4.3. Conclusion

This national assessment of HIVDR Early Warning Indicators demonstrates that while Lesotho has achieved strong patient retention and generally favourable viral suppression outcomes, important gaps remain in adherence, viral load monitoring, and routine program information systems. Performance varied across districts and facility types, suggesting that local service delivery conditions influence treatment continuity and HIVDR risk. Together, these findings indicate that despite significant progress in ART scale-up, key systems required to sustain long-term treatment effectiveness and prevent HIV drug resistance require further strengthening.

Overall, the findings suggest that HIV program strengthening has not fully kept pace with ART scale-up in Lesotho. While the national ART programme has achieved substantial success in expanding treatment access, retaining patients in care, and maintaining favourable viral suppression among facilities with assessible data, important systems

required to sustain long-term treatment effectiveness remain underdeveloped. Poor adherence performance, low coverage of viral load monitoring, substantial data gaps, and persistent district-level variation indicate that some program components have not strengthened at the same pace as treatment access.

Taken together, these findings suggest that ART scale-up in Lesotho has progressed faster than the broader system-strengthening efforts required to support long-term HIVDR prevention. As HIV programmes continue to transition into the DTG-based treatment, strengthening adherence support, viral load monitoring, and program information systems should be prioritised to safeguard treatment effectiveness and prevent HIV drug resistance.

4.4. Study Limitations

This study has several limitations. First, the analysis relied on routinely collected program data, which were incomplete for some indicators, resulting in a substantial proportion of facilities being classified as unscorable and preventing assessment of several WHO-recommended EWIs. Second, only 74 of the 90 selected facilities were included in the final analysis because of data quality limitations and accessibility challenges.

Third, the use of aggregated facility-level data precluded assessment of patient-level determinants of adherence, treatment outcomes, and HIVDR risk. Finally, the cross-sectional design provides a snapshot of program performance and does not permit assessment of temporal trends or causal relationships. Despite these limitations, the study provides a nationally representative assessment of HIVDR Early Warning Indicator performance in Lesotho during the DTG era and offers important insights into program factors associated with HIVDR risk

DECLARATIONS

Ethics Approval and Consent to Participate: Ethical approval for this study was obtained from the Ministry of Health National Health Research and Ethics Committee of Lesotho. The study utilised routinely collected program data and did not involve direct patient contact, clinical intervention, or specimen collection. A waiver of informed consent was granted because only de-identified retrospective program data were used.

Availability of Data and Materials: The datasets analysed during the current study are not publicly available because they contain program data owned by the Ministry of Health, Lesotho. Data may be made available from the corresponding author upon request and with permission from the Ministry of Health.

Competing Interests: The authors declare that they have no competing interests.

Funding: This work was supported through the Ministry of Health, Lesotho, with technical support from the World Health Organisation and funding from the Global Fund. The funders had no role in study design, data analysis, interpretation of findings, or manuscript preparation.

Authors' Contributions: Mosa Mabataung Monyake conducted the data analysis, interpreted the findings, and led the drafting and revision of the manuscript. Pakiso Makhoahle and Justen Manasa provided scientific supervision, advised on data analysis and interpretation, and critically reviewed the manuscript. Francis Mupeta provided technical guidance on study implementation, data analysis, and interpretation of findings and critically reviewed the manuscript. All authors reviewed and approved the final manuscript.

Acknowledgements: The authors acknowledge the Ministry of Health, Lesotho; the District Health Management Teams; the participating ART facilities; and the healthcare workers who supported the implementation of the HIV Drug Resistance Early Warning Indicator (EWI) survey.
Special appreciation is extended to the Ministry of Health HIV Programme for its leadership and support in data abstraction and data collection for the survey.
The authors further acknowledge the technical support provided by the World Health Organisation (WHO), the financial support provided through the Global Fund, and the continued support of the U.S. Centres for Disease Control and Prevention (CDC) in strengthening HIV services in Lesotho. We also thank collaborating partners for their contributions to survey planning, implementation, and data review.

REFERENCES

Bertagnolio, S., Jordan, M.R., Hong, S.Y., Rakhmanina, N., Benkeser, D., Penazzato, M., et al. (2012). Early warning indicators for HIV drug resistance in low- and middle-income countries: status, challenges, and progress. AIDS Reviews, 14(4), 245–253.

Chimukangara, B., Lessells, R.J., Rhee, S.Y., Giandhari, J., Kharsany, A.B.M., Naidoo, K., et al. (2019). Trends in pretreatment HIV-1 drug resistance in antiretroviral therapy-naive adults in South Africa, 2000–2016: a pooled sequence analysis. EClinicalMedicine, 9, 26–34.

Fatti, G., Shaikh, N., Eley, B., et al. (2014). Adherence to antiretroviral therapy in South Africa. South African Medical Journal, 104(3), 192–197.

Fox, M.P. and Rosen, S. (2015). Retention of adult patients on antiretroviral therapy in low- and middle-income countries. Journal of Acquired Immune Deficiency Syndromes, 69(1), 98–108.

Huerga, H., Shiferie, F., Greig, J., et al. (2017). Retention and attrition in HIV care. Journal of the International AIDS Society, 20(1), 21688.

Kiekens, A., De Casterlé, B.D., Ferreyra, C., et al. (2022). Exploring mechanisms behind HIV drug resistance in sub-Saharan Africa. BMC Public Health, 22, 532.

Kredo, T., Adeniyi, F.B., Bateganya, M. and Pienaar, E.D. (2013). Task shifting from doctors to non-doctors for initiation and maintenance of antiretroviral therapy. Cochrane Database of Systematic Reviews, 7, CD007331.

Loosli, T., Hossmann, S., Ingle, S.M., et al. (2023). HIV-1 drug resistance in people on dolutegravir-based ART. The Lancet HIV, 10(11), e733–e744.

Manasa, J., Katzenstein, D., Cassol, S., et al. (2013). HIV-1 drug resistance and treatment outcomes. Journal of Infectious Diseases, 207(Suppl. 2), S73–S80.

Ministry of Health, Lesotho. (2012). HIV Drug Resistance Early Warning Indicators Survey Report. Maseru: Government of Lesotho.

Ministry of Health, Lesotho. (2022). National HIV and AIDS Strategic Plan / ART Program Report. Maseru: Ministry of Health.

Ministry of Health, Lesotho. (2023). Annual HIV Program Report 2023. Maseru: Ministry of Health.

Moyo, S., Hunt, G., Zuma, K., Zungu, M., Marinda, E., Mabaso, M., et al. (2020). HIV drug resistance profile in South Africa: Findings and implications from the 2017 national HIV household survey. PLOS ONE, 15(11), e0241071.

Muthee, V., Bochner, A.F., Liku, N., et al. (2018). Integration of HIV services and data systems. BMC Health Services Research, 18, 158.

National AIDS Commission Lesotho. (2024). National HIV Estimates Report 2024. Maseru: National AIDS Commission.

Nichols, B.E., Sigaloff, K.C.E., Kityo, C., et al. (2020). Monitoring HIV drug resistance using early warning indicators. Current Opinion in HIV and AIDS, 15(1), 63–70.

Odhiambo, J., Kizito, W., Njoroge, A., et al. (2020). Strengthening HIV data systems in sub-Saharan Africa. BMC Public Health, 20, 1023.

Siedner, M.J., Ng, C.K., Bassett, I.V., et al. (2013). Trends in retention in HIV care. Clinical Infectious Diseases, 56(7), 1013–1020.

UNAIDS. (2023). The Path That Ends AIDS: UNAIDS Global AIDS Update 2023. Geneva: Joint United Nations Programme on HIV/AIDS.

World Health Organization (WHO). (2011). Manual for HIV Drug Resistance Monitoring Using Early Warning Indicators at HIV Care and Treatment Sites. Geneva: World Health Organization.

World Health Organization (WHO). (2019). Update of Recommendations on First- and Second-Line Antiretroviral Regimens. Geneva: World Health Organization.

World Health Organization (WHO). (2021). HIV Drug Resistance Report 2021. Geneva: World Health Organization.

World Health Organization (WHO). (2022). Consolidated Guidelines on Person-Centred HIV Strategic Information. Geneva: World Health Organization.

ANNEXURES

Annexure A: WHO Early Warning Indicator Definitions For HIV Drug Resistance

Indicator	Description/What It Measures	Numerator	Denominator	Disaggregation

ART.2 – Total Attrition from ART	Measures loss from ART care during a reporting period, including patients who died, stopped treatment, or were lost to follow-up. Reflects programme performance in retaining patients on ART.	Number of patients on ART at end of previous period plus those newly initiated during reporting period who were not on ART at the end of the reporting period.	Total number of patients on ART at end of previous period plus new ART initiations during reporting period.	Gender; Age groups; Key populations; Treatment outcome category (died, stopped treatment, LTFU).
ART.3 – Viral Load Suppression	Measures treatment effectiveness and programme success in achieving viral suppression among patients on ART. Represents progress toward the third UNAIDS 95 target.	Number of patients on ART ≥6 months with viral load <1000 copies/mL during reporting period.	Number of patients on ART ≥6 months with at least one viral load test result during reporting period.	Gender; Age groups; Key populations.
ART.6 – Viral Load Testing Coverage	Assesses availability and utilization of viral load testing among patients receiving ART. Indicates the capacity of the health system to monitor treatment outcomes.	Number of ART patients with at least one viral load test result during reporting period.	Number of ART patients on treatment ≥6 months.	Gender; Age groups; Key populations; Priority populations.
ART.8 – Appropriate Second Viral Load Test	Measures timely follow-up testing after an unsuppressed viral load result, indicating effectiveness of clinical monitoring and adherence support.	Number of patients with VL ≥1000 copies/mL who received a follow-up VL test within recommended time frame.	Number of patients on ART with VL ≥1000 copies/mL during reporting period.	Gender; Age groups; Key populations; ART regimen; Receipt of adherence counselling.
ART.12 – ARV Medicine Stock-Outs	Measures continuity of ARV drug supply and identifies supply chain interruptions that may lead to treatment interruptions.	Number of months in which no ARV stock-outs occurred at the facility during the reporting period.	Total number of months in the reporting period.	Facility-level only (no patient-level disaggregation).
ART.13 – On-Time Drug Pick-Up (Adherence Proxy)	Measures timeliness of ART refills and serves as a proxy indicator for patient adherence to treatment.	Number of patients who picked up ART drugs on time at first refill after initiation.	Number of patients expected to pick up ART drugs during the reporting period.	Gender; Age groups; Key populations.
ART.14 – Appropriate Switch to Second-Line Regimen	Measures timely clinical management of treatment failure by assessing switching to second-line ART after confirmed virologic failure.	Number of patients with confirmed treatment failure who were appropriately switched to second-line regimen.	Number of patients eligible for switching following confirmed treatment failure.	Gender; Age groups; ART regimen category.

Annexure B: Detailed Definition of Indicators

ART.2 Total attrition from ART

Number and percentage of people living with HIV reported on ART at the end of the last reporting period and/or newly initiating ART during the current reporting period who were not on ART at the end of the reporting period.

What it measures

This indicator measures progress towards promoting retention on ART and mitigating loss, that is, ART attrition. This indicator is central to understanding total attrition (loss) from ART during a reporting period and to understanding net progress towards reaching the second 95 target.

Numerator

Number of people living with HIV reported on ART at the end of the last reporting period who were not on treatment at the end of the current reporting period (including those who died, stopped treatment and were lost to follow-up).

plus

Number of people living with HIV newly initiated on ART during the current reporting period who were not on treatment at the end of the current reporting period (including those who died, stopped treatment or were lost to follow-up).

Denominator (for calculation of total attrition rate)

Number of people reported on ART at the end of the last reporting period plus new on ART during the current reporting period.

This indicator will be segregated by;

Disaggregation

1. Gender (male, female, transgender)

2. Age (0–4, 5–9, 10–14, 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50+)
3. Key populations (men who have sex with men, people living in prisons and other closed settings, people who inject drugs, sex workers, transgender people)
4. Treatment outcome category (died, stopped treatment, lost to follow-up) WHO,2022)

ART. 3 People living with HIV who have suppressed VL.

Percentage of people living with HIV on ART (for at least 6 months) who have virological suppression.

What it measures

This indicator measures clinical outcomes of patients on ART regardless of initiation date. Viral load suppression (VLS) represents the expected outcome of ART programme services (that is, the third 95). VLS is also the best available measure of patient adherence to ART.

Numerator

Number of people living with HIV on ART for at least 6 months and with at least one routine VL test result who have virological suppression (<1000 copies/mL) during the reporting period.

Denominator

Number of people living with HIV on ART at least 6 months with at least one routine VL result in a medical or lab record during the reporting period.

Disaggregation

1. Gender (male, female, transgender)

2. Age 0–4, 5–9, 10–14, 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50+)

Key populations (men who have sex with men, people living in prisons and other closed settings, people who inject drugs, sex workers, transgender people) (WHO,2022).

ART.6. Viral load testing coverage

Percentage of people on ART (for at least 6 months) with viral load test results

What it measures

This indicator assesses the extent to which VL testing is available in the country and enables appropriate interpretation of VL testing data. This indicator was not measured in the previous EWIs. This indicator is critical to decide whether VL suppression as measured through routine data is likely to be representative of all patients on ART.

Numerator

Number of ART patients with at least one routine VL test result during the reporting period

Denominator

Number of ART patients on ART at least 6 months

Disaggregation

1. Gender (male, female, transgender)
2. Age (0–4, 5–9, 10–14, 15–19, 20–24, 25–49, 50+)
3. Key populations (men who have sex with men, people living in prisons and other closed settings, people who inject drugs, sex workers, transgender people)
4. Other specific priority populations.

ART.8. Appropriate second VL test

Percentage of people receiving ART with VL ≥1000 copies/mL who received a follow-up VL test within 3 months after enhanced adherence counselling, per national guidelines.

What it measures

This indicator measures the extent to which people living with HIV with non-suppressed VL receive appropriate follow-up VL testing to check virologic suppression. Virologic suppression is essential to the 95–95–95-related impact goals, including HIV elimination.

Numerator: Number of people living with HIV on ART who received a follow-up VL test within 6 months after a VL test result of ≥1000 copies/ml during the reporting period.

Denominator: Number of people living with HIV on ART with VL ≥1000 copies/ml during the reporting period.

Disaggregation

1. Gender (male, female, transgender)
2. Age (0–4, 5–9, 10–14, 15–19, 20–24, 25–49, 50+)
3. Key populations (men who have sex with men, people living in prisons and other closed settings, people who inject drugs, sex workers, transgender people)
4. ART regimen

5. Receipt of enhanced adherence counselling (yes/no/unknown) (WHO,2022).

Annexure C: Who Performance Thresholds

Indicator Code	Indicator Name	Definition	Green (Good Performance)	Amber (Fair Performance)	Red (Poor Performance)
ART.2	Retention in care (Attrition)	% of patients lost to follow-up, died, or stopped ART within 12 months	≤10%	10–20%	>20%
ART.3	Viral load suppression	% of patients on ART with viral load <1000 copies/mL	≥90%	75–89%	<75%
ART.6	Viral load testing coverage	% of eligible patients receiving viral load test	≥90%	80–89%	<80%
ART.8	Follow-up viral load testing	% of patients with high VL receiving repeat VL within recommended time	≥80%	70–79%	<70%
ART.12	ARV drug stock-outs	% of months with no ARV stock-outs	100% (no stock-outs)	—	Any stock-out
ART.13	On-time drug pick-up (Adherence proxy)	% of patients collecting ART on time	≥90%	80–89%	<80%
ART.14	Appropriate switch to second-line ART	% of patients with confirmed failure switched appropriately	≥80%	60–79%	<60%

Annexure D: Data Quality Assessment Checklist for HIVDR EWI Data, Lesotho, 2023

A structured data quality assessment checklist was developed based on WHO guidance on HIV drug resistance Early Warning Indicator data management and validation procedures (World Health Organization, 2021; World Health Organization, 2022).

Domain	Assessment Item	Description	Response (Yes/No)	Comments
Data Completeness	Availability of required data fields	All required variables for EWI calculation were present (numerators, denominators, dates)		
	Missing data assessment	Proportion of missing data assessed for each indicator		
	Inclusion criteria met	Facility met minimum data requirements for inclusion in analysis (≥70% completeness)		
Data Accuracy	Consistency between registers and reports	Data verified against source documents (ART registers, VL registers, pharmacy records)		
	Logical consistency	No impossible or inconsistent values (e.g. VL result without test date)		
	Correct classification	Indicator calculations correctly classified according to WHO thresholds		
Data Timeliness	Reporting period completeness	Data covered full reporting period (January–December 2023)		

Annexure E: Detailed Characteristics of ART Facilities and Indicator Results Tables

ID	District	Zone	Ownership	Type	ART.2	ART.3	ART.6	ART.8	ART.12	ART.13	ART.14
F01	Maseru	Lowland	Private	Clinic	Green	Grey	Grey	N/A	Red	Red	N/A
F02	Maseru	Lowland	Gov	Hospital	Green	Green	Red	N/A	Red	Red	N/A
F03	Maseru	Lowland	Gov	Hospital	Green	Green	Red	N/A	Green	Red	N/A
F04	Maseru	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A

F05	Maseru	Lowland	CHAL	Health Centre	Green	Green	Red	N/A	Green	Red	N/A
F06	Maseru	Lowland	CHAL	Health Centre	Green	Green	Amber	N/A	Green	Red	N/A
F07	Maseru	Lowland	Gov	Health Centre	Green	Grey	Grey	N/A	Green	Red	N/A
F08	Maseru	Lowland	Gov	Health Centre	Green	Green	Red	N/A	Red	Red	N/A
F09	Maseru	Lowland	Private	Clinic	Green	Green	Red	N/A	Red	Red	N/A
F10	Maseru	Lowland	Private	Clinic	Green	Grey	Grey	N/A	Red	Red	N/A
F11	Maseru	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F12	Maseru	Lowland	Gov	Clinic	Green	Green	Red	N/A	Red	Red	N/A
F13	Maseru	Lowland	CHAL	Health Centre	Green	Green	Red	N/A	Red	Red	N/A
F14	Maseru	Lowland	Private	Clinic	Red	Grey	Grey	N/A	Green	Red	N/A
F15	Maseru	Lowland	CHAL	Health Centre	Green	Green	Red	N/A	Red	Red	N/A
F16	Maseru	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	Green	Red	N/A
F17	Maseru	Lowland	CHAL	Health Centre	Green	Green	Green	N/A	Red	Red	N/A
F18	Maseru	Lowland	CHAL	Health Centre	Green	Green	Red	N/A	Green	Red	N/A
F19	Mafeteng	Lowland	Gov	Hospital	Green	Green	Red	N/A	Red	Red	N/A
F20	Mafeteng	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F21	Mafeteng	Lowland	Gov	Hospital	Green	Green	Red	N/A	Red	Red	N/A
F22	Mafeteng	Lowland	Gov	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F23	Mafeteng	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F24	Mafeteng	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F25	Mafeteng	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F26	Mafeteng	Lowland	Gov	Health Centre	Green	Green	Red	N/A	Red	Red	N/A
F27	Mohale's Hoek	Highland	Gov	Health Centre	Green	Green	Red	N/A	Green	Red	N/A
F28	Mohale's Hoek	Highland	CHAL	Health Centre	Green	Green	Red	N/A	Green	Amber	N/A
F29	Mohale's Hoek	Highland	Gov	Health Centre	Green	Green	Green	N/A	Green	Red	N/A
F30	Mohale's Hoek	Highland	CHAL	Health Centre	Green	Grey	Grey	N/A	Green	Red	N/A
F31	Mohale's Hoek	Highland	CHAL	Health Centre	Green	Grey	Grey	N/A	Green	Red	N/A
F32	Quthing	Highland	Private	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F33	Quthing	Highland	CHAL	Health Centre	Green	Green	Red	N/A	Red	Red	N/A
F34	Quthing	Highland	CHAL	Health Centre	Green	Green	Amber	N/A	Green	Red	N/A
F35	Qacha's Nek	Highland	Gov	Hospital	Green	Green	Red	N/A	Red	Red	N/A
F36	Thaba-Tseka	Highland	CHAL	Hospital	Green	Green	Red	N/A	Red	Red	N/A
F37	Thaba-Tseka	Highland	Gov	Health Centre	Green	Green	Red	N/A	Red	Red	N/A
F38	Thaba-Tseka	Highland	CHAL	Health Centre	Green	Green	Red	N/A	Red	Red	N/A
F39	Thaba-Tseka	Highland	CHAL	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F40	Thaba-Tseka	Highland	Gov	Health Centre	Green	Green	Red	N/A	Red	Red	N/A
F41	Berea	Lowland	CHAL	Health Centre	Green	Green	Red	N/A	Red	Red	N/A

F42	Berea	Lowland	Gov	Health Centre	Green	Green	Red	N/A	Red	Red	N/A
F43	Berea	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F44	Berea	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	Red	N/A	N/A
F45	Leribe	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	Green	Red	N/A
F46	Leribe	Lowland	CHAL	Health Centre	Green	Green	Red	N/A	Green	Red	N/A
F47	Leribe	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	Green	Red	N/A
F48	Leribe	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F49	Leribe	Lowland	Gov	Health Centre	Green	Green	Red	N/A	Red	Red	N/A
F50	Leribe	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F51	Leribe	Lowland	Gov	Health Centre	Green	Green	Amber	N/A	Green	Red	N/A
F52	Leribe	Lowland	Gov	Health Centre	Green	Green	Red	N/A	Red	Red	N/A
F53	Leribe	Lowland	Gov	Health Centre	Green	Green	Green	N/A	Green	Green	N/A
F54	Leribe	Lowland	Gov	Health Centre	Green	Grey	Grey	N/A	Green	Red	N/A
F55	Leribe	Lowland	Gov	Hospital	Green	Grey	Grey	N/A	Green	Red	N/A
F56	Leribe	Lowland	Gov	Health Centre	N/A	Green	Red	N/A	Green	Red	N/A
F57	Leribe	Lowland	Gov	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F58	Leribe	Lowland	Gov	Health Centre	Green	Green	Red	N/A	Green	Red	N/A
F59	Leribe	Lowland	CHAL	Health Centre	Green	Green	Amber	N/A	Red	Red	N/A
F60	Leribe	Lowland	CHAL	Health Centre	Green	Green	Red	N/A	Green	Red	N/A
F61	Leribe	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	N/A	N/A	N/A
F62	Leribe	Lowland	CHAL	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F63	Butha-Buthe	Lowland	Gov	Health Centre	Green	Green	Green	N/A	Green	Red	N/A
F64	Butha-Buthe	Lowland	Gov	Health Centre	Green	Green	Amber	N/A	N/A	Red	N/A
F65	Butha-Buthe	Lowland	CHAL	Hospital	Green	Grey	Grey	N/A	N/A	Amber	N/A
F66	Butha-Buthe	Lowland	Gov	Health Centre	Green	Green	Red	N/A	N/A	Amber	N/A
F67	Butha-Buthe	Lowland	CHAL	Health Centre	Green	Green	Amber	N/A	Green	Red	N/A
F68	Butha-Buthe	Lowland	CHAL	Health Centre	Green	Green	Amber	N/A	Green	Red	N/A
F69	Mokhotlong	Highland	Gov	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F70	Mokhotlong	Highland	CHAL	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F71	Mokhotlong	Highland	Gov	Special Clinic	Green	Green	Amber	N/A	Red	Amber	Grey
F72	Mokhotlong	Highland	Gov	Health Centre	Green	Grey	Grey	N/A	Red	Red	N/A
F73	Mokhotlong	Highland	Gov	Health Centre	Green	Grey	Grey	N/A	Green	Amber	Grey
F74	Mokhotlong	Highland	Red Cross	Health Centre	Green	Grey	Grey	N/A	Green	Red	N/A

Annexure F: Regression Output Tables

Determinants of Attrition Rates

VARIABLES	(1)	(2)	(3)	(4)	(5)
District (Base: Mokhotlong)					
Berea	1.1667	0.6000	0.3348	0.2137	0.2405
	(1.9355)	(2.1214)	(2.5686)	(2.6195)	(2.2727)
Butha-Buthe	0.1667	-0.2987	-0.6929	-0.6831	-0.3633
	(2.0447)	(2.2757)	(2.5890)	(2.6185)	(2.5454)
Leribe	-0.8333	-1.3662	-1.7860	-1.8334	-1.8578
	(1.5606)	(1.7717)	(2.1829)	(2.1799)	(1.9366)
Mafeteng	0.6667	0.2520	-0.1230	-0.1935	0.0528
	(1.8519)	(2.1132)	(2.4392)	(2.4883)	(2.2878)
Maseru	-0.0556	-1.1526	-1.4210	-1.5378	-1.4710
	(1.5642)	(1.8385)	(2.1938)	(2.2400)	(2.0474)
Mohale's Hoek	3.3667	2.8000	2.4344	2.4142	2.6407
	(2.5564)	(2.7252)	(3.0656)	(3.0816)	(2.8908)
Qacha's nek	-2.8333**	-2.7921	-3.3292	-3.1699	-3.2816
	(1.3650)	(1.7745)	(2.2102)	(2.3394)	(2.1436)
Quthing	-2.5000*	-3.0667*	-4.2104*	-4.2431*	-3.8229*
	(1.3961)	(1.6171)	(2.3219)	(2.3321)	(2.1451)
Thaba-Tseka	-2.6333*	-3.0784*	-3.3980*	-3.4630*	-3.1047*
	(1.3799)	(1.6249)	(2.0656)	(2.0685)	(1.8616)
Facility type (Base: Clinic)					
Health Centre		-2.1526	0.3211	0.2109	-0.0759
		(1.5084)	(2.2609)	(2.3055)	(2.2872)
Hospital		-2.7605*	-0.5172	-0.7723	-1.3657
		(1.5292)	(2.3072)	(2.5275)	(2.6155)
Special Clinic		-5.5526**	-3.8463	-3.9422	-3.7491
		(2.1909)	(3.0301)	(3.0604)	(2.8500)
Ownership (Base: CHAL)					
Government			0.6696	0.6121	0.4894
			(0.8752)	(0.8929)	(0.9059)
Private			3.1380	3.1066	2.9172
			(2.0947)	(2.0974)	(2.0088)
NGO			-2.4978	-2.9102	-2.2008
			(2.0409)	(2.5486)	(2.5154)
High volume (=1 if yes)				0.3693	0.0170
				(1.4677)	(1.5217)
In previous survey (=1 if yes)					0.8981
					(0.9378)
Constant	3.8333***	6.5526***	4.1767	4.3300	4.2597
	(1.3650)	(2.1909)	(3.0418)	(3.0811)	(2.8956)
Observations	74	74	74	74	74
Number of facility name	64	64	64	64	64

Notes: Robust standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.

Determinants of Adherence Rates

VARIABLES	(1)	(2)	(3)	(4)	(5)
District (Base: Mokhotlong)					
Berea	-3.8732	-2.5165	-7.3354	-5.6404	-5.5501
	(7.0484)	(7.5493)	(6.5363)	(5.2375)	(5.1383)
Butha-Buthe	-3.2338	-3.9698	-8.6071*	-8.9657*	-8.6808*
	(5.8307)	(6.2091)	(4.7499)	(4.7195)	(5.1912)
Leribe	-16.7900***	-16.1739***	-20.7579***	-20.0491***	-19.9481***
	(4.6012)	(5.2958)	(3.2640)	(3.3790)	(3.7449)
Mafeteng	-12.1430**	-12.4475***	-17.1493***	-16.4334***	-16.2043***
	(4.7405)	(4.7790)	(2.2100)	(2.3993)	(3.1719)
Maseru	-9.4147**	-8.6925*	-13.5387***	-12.4688***	-12.3423***
	(4.3653)	(5.1552)	(2.9260)	(2.8791)	(3.0259)
Mohale's Hoek	-13.9732*	-12.6165	-17.3189***	-17.1278***	-16.9073**
	(7.2638)	(7.7608)	(6.5417)	(6.6354)	(7.0700)
Qacha's Nek	-8.3732**	-17.6404***	-22.1334***	-24.5191***	-24.4823***
	(3.6492)	(5.5235)	(3.5460)	(3.1460)	(3.1516)

Quthing	-14.7065**	-13.3499*	-19.4338***	-19.0948***	-18.7549***
	(6.7763)	(7.2831)	(5.3220)	(5.2532)	(5.8401)
Thaba-Tseka	-11.0295*	-12.2595**	-17.0504***	-16.0166***	-15.7204***
	(5.6537)	(5.2492)	(3.0295)	(3.5992)	(4.2448)
Facility type (Base: Clinic)					
Health Centre		2.3241	4.9056	5.9448	5.7721
		(4.4015)	(9.2068)	(9.0741)	(9.2401)
Hospital		12.9480***	15.7863*	18.9952**	18.6090*
		(4.6984)	(9.3826)	(9.2298)	(9.5872)
Special Clinic		9.3075	7.6529	8.4761	8.6808
		(6.1793)	(9.2246)	(9.0734)	(9.2985)
Ownership (Base: CHAL)					
Government			-0.7769	-0.0986	-0.1752
			(2.4504)	(2.3960)	(2.2812)
Private			3.2126	3.5826	3.4652
			(8.8670)	(8.7432)	(8.8815)
NGO			-19.0296***	-12.9583***	-12.4679**
			(1.7413)	(4.4027)	(6.2140)
High volume (=1 if yes)				-5.6090	-5.7986
				(3.9648)	(4.4329)
In previous survey (=1 if yes)					0.5541
					(3.3319)
Constant	31.3732***	27.6925***	30.1240***	28.6225***	28.4944***
	(3.6492)	(6.1793)	(9.4279)	(9.3028)	(9.5411)
Observations	73	73	73	73	73
Number of facilities	63	63	63	63	63

Base: Robust standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1