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Determinants of HIV viral load suppression rates in Amhara region, Ethiopia with a large number of internally displaced people

Gizachew Yismaw [a], Muluken Azage Yenesew [b], Tegegn Kebebaw [c], Leslie Hinyard [d], Asaminew Gizaw [c], Alemitu Mequanint [e], Christian Hendrix [f], Getahun Abate [f,*]

[a] Amhara public health institute, Bahir Dar, Ethiopia
[b] School of Public Health, Bahir Dar University, Ethiopia
[c] BahirDar Institute of Technology, Bahir Dar University, Ethiopia
[d] Advanced Health Data Research Institute, Saint Louis University, USA
[e] Addis Ababa Science and Technology University, Ethiopia
[f] Division of Infectious Diseases, Saint Louis University, USA

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ABSTRACT

Background: The Amhara region in Ethiopia has been affected by a war that led to displacement of millions of people. This study was conducted with the objectives of evaluating HIV viral suppression rates, assessing viral load (VL) testing turnaround time (TAT) and pilot testing of a new webapp to make VL results available in real time while the health system is affected by large numbers of internally displaced people (IDP).
Methods: Data was obtained from 7 HIV VL testing centers that serve 378 anti-retroviral treatment centers. Viral load (VL) suppression rates and VL result turnaround time (TAT) were used as markers of effectiveness of HIV control.
Findings: A total of 98,957 records were analyzed. Patients at three of the seven VL testing sites including Debre-Birehan Referral Hospital (aOR 1.87, 95 CI [1.63–2.14]), Debre-Markos Referral Hospital (aOR 1.76, 95 CI [1.61–1.93]) and University of Gonder (aOR 2.28, 95 CI [2.07–2.51]) had increased risk of virologic failure. TAT between the time VL results were available to the time results were mailed to treatment centers was $\leq$ 1 week for 61,148 (63.4%) and 2 weeks for 25,172 (26.1%) tests. TAT vary among the 7 VL testing centers.
Interpretation: In a region with large numbers of IDP, virologic failure is more common in older age groups. VL and TAT vary by testing centers which could be reflective of ART default and delay in courier mail driven by internal displacement.

Introduction

Expanded access to routine viral load (VL) testing is considered a game-changer in the global response to AIDS. It improves treatment quality and individual health outcomes for people living with HIV, contributes to prevention, and potentially reduces resources needed for costly second- and third-line HIV medicines (UNAIDS, 2016). VL testing is cost-effective for monitoring treatment success and the results help reduce frequency of health care visits for patients who are virally suppressed (Working Group on Modelling of Antiretroviral Therapy Monitoring Strategies in Sub-Saharan et al., 2015). Sustaining an undetectable VL breaks the transmission of HIV and therefore, VL test results are useful indicators that control programs follow (Cohen et al., 2011; Bavinton et al., 2018). In fact, this concept of "Undetectable=Untransmittable" has been endorsed by UNAIDS (UNAIDS, 2018). Therefore, increased HIV VL testing is a global priority (Joint United Nations Programme on HIV/AIDS, 2014; World Health Organization, 2013). However, VL testing to have meaningful impacts, VL result turnaround time (TAT) must be acceptable. Long turnaround time may negatively impact HIV control programs (Lubega et al., 2022).

Ethiopia, one of the sub-Saharan countries and one of the hotspots for HIV, has been engulfed in internal ethnic and political conflicts since November 2020. The number of internally displaced people (IDP) may fluctuate but will continue to be a challenge for disease control efforts in Ethiopia. The Amhara region, one of the 12 administrative regions located in the northwestern part of Ethiopia, has 31% (or 190,930) of

* Corresponding author at: 1100 South Grand Blvd, Doisy Research Center, Division of Infectious Diseases, Saint Louis University, 63104, USA.
E-mail address: getahun.abate@health.slu.edu (G. Abate).

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estimated total of 616,105 people living with HIV (PEPFAR) and is one of the regions most affected by internal displacement. It is estimated that conflict and violence triggered more than 5 million new displacements in Ethiopia in 2021 alone, three times the number in 2020 and the highest annual figure ever recorded for a single country (NRC, 2021). In the Amhara region, there were about 156,000 IDP living in 15 camps, with more than 2.1 million living in host communities in 2021. Similarly, there were about 132,000 IDP living in camps and more than 967, 000 living in host communities in 2022. War among different ethnic groups or political parties is the main cause of internal displacement in Ethiopia. It is expected that massive IDP numbers threaten HIV control efforts in this region. Therefore, this study was done with the objectives of i) comparing HIV VL suppression rates among testing centers and according to patient characteristics, ii) assessing VL testing TAT and iii) pilot testing of a new webapp to make VL results available in real-time in Amhara region.

Materials and methods

Study design and setting

This study was a one-year retrospective study of viral suppression rates and VL testing TAT at 7 HIV VL testing sites in the Amhara region that provide service to 378 anti-retroviral treatment (ART) centers. Fig. 1 shows the location of the Amhara region in Ethiopia and the distribution of the 7 VL testing centers: Amhara Public Health Institute at Bahir Dar (APHI-BD), APHI-Dessie, Debre Birhan Referral Hospital (DBRH), Debre Markos Referral Hospital (DMRH), Debre Tabor Referral Hospital (DTRH), University of Gondar (UoG) and Woldiya Referral Hospital (WRH). VL test requests are currently made by completing and mailing a standard form along with a clinical sample to a testing center. Similarly, VL test results are communicated via mail.

Data source

HIV VL testing paper reports over 1 year from March 30, 2021 to March 29, 2022 was obtained from all 7 HIV VL testing sites. The unit of observation was the patient. The data we obtained contained duplicate results from some patients who had two tests in a year. We do not have the exact number of duplicates as the data we have was deidentified, but these are usually patients with VL >1000 and requiring change in ART regimen.

The numbers of IDP in different parts of Amhara region in 2021 and 2022 were obtained from regional health bureau and are shown in supplement Table 1.

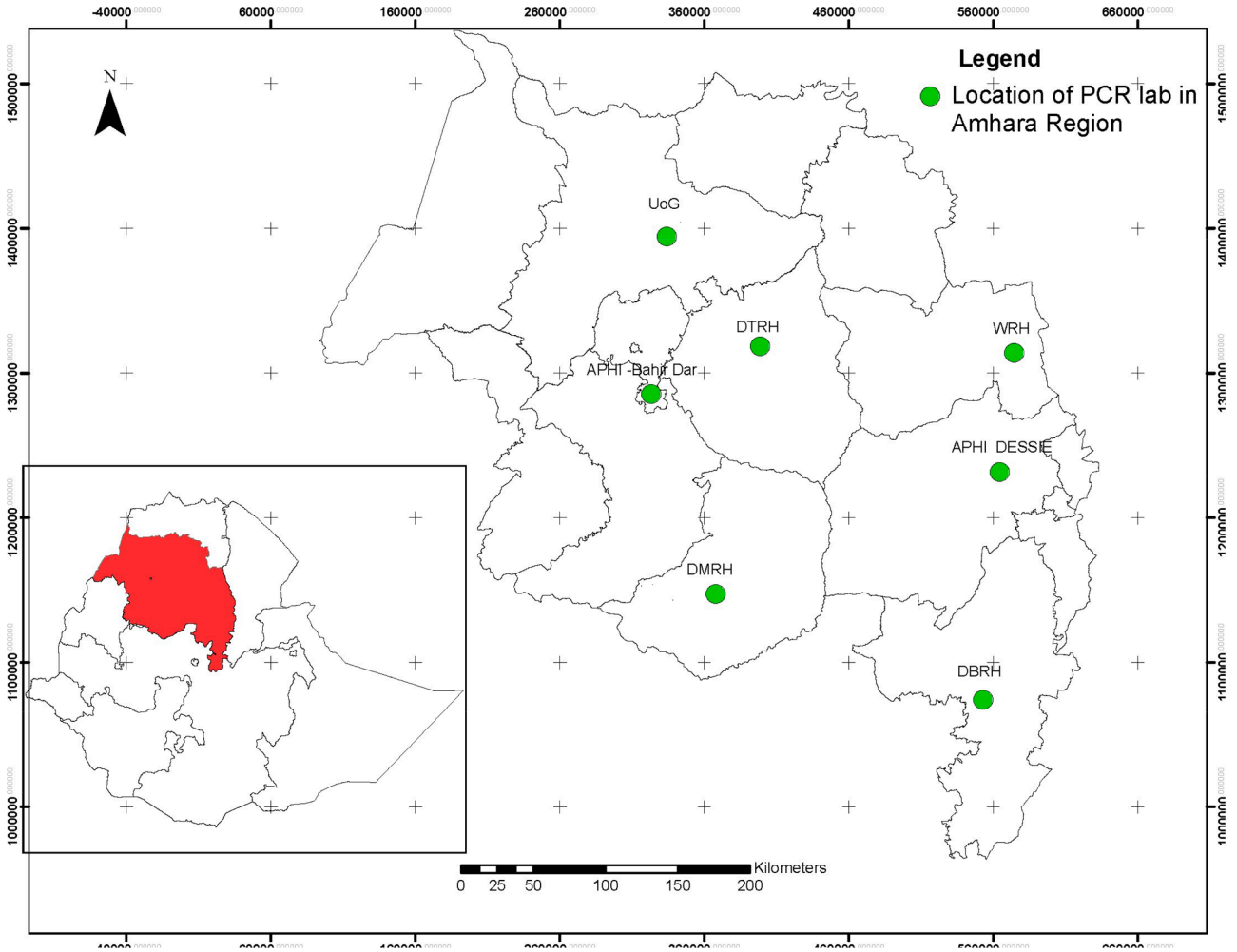

Fig. 1. HIV specialized laboratories and IDP in Amhara region, Ethiopia. Locations of 7 VL testing centers that serve a total of 378 health institutes with estimated annual HIV VL request of more than 95,000. UoG, University of Gondar; DTRH, Debre Tabor Referral Hospital; DMRH, Debre Markos Referral Hospital; DBRH, Debre Birhan Referral Hospital; WRH, Woldiya Referral Hospital; APHI-Bahir Dar, Amhara Public Health Institute, Bahir Dar branch; APHI-Dessie, Amhara Public Health Institute, Dessie branch.

Table 1
Demographic characteristics of patients who had VL testing.

Demographic	N (%)
Sex	
Female	63,839 (64.5)
Male	33,297 (33.7)
Unknown	1778 (1.8)
Age	
<5	190 (0.2)
5–17	5573 (5.6)
18–49	74.113 (74.9)
50+	16,361 (16.5)
Missing	2677 (2.7)
Test Reason Even More Collapsed	
Not indicated on Form	1029 (1.0)
Routine (pregnant and not)	96.439 (97.5)
Targeted (confirmatory & suspected fail)	1446 (1.5)
Testing Site	
APHI	31,779 (32.1)
APHI Dessie Branch	21,743 (22.0)
DBRH	8180 (8.3)
DMRH	17,413 (17.6)
UoG	14,831 (15.0)
DTRH	3505 (3.5)
WRH	1463 (1.5)
Treatment	
Missing	8220 (8.3)
First Line	87,524 (88.5)
Second Line	3095 (3.1)
Third Line	75 (0.1)
Time to Dispatch (from final result)	
≤1 week	62,660 (63.3)
2 weeks	25,884 (26.2)
3 weeks	6098 (6.2)
4 weeks	2343 (2.4)
5 weeks	405 (0.4)
≥ 6 weeks	1524 (1.5)

Data collection procedure and quality assurance

Data was extracted from the regional HIV VL database and checked for completeness. Variables such as socio-demographic (age, sex), VL testing profile, pregnant, breast feeding, WHO HIV/AIDS stage, adherence, test reason, VL copy per milliliter (mL), and type of treatment were extracted from the database. The regional HIV VL results were used to cross-check the validity of data records at each VL testing center.

Definitions

TAT was defined as the number of days between sample collection for VL testing and result availability at HIV treatment center. TAT could be divided into different timepoints. TAT-1 was defined as the number of days between specimen collection at HIV treatment facilities and subsequent receipt by the corresponding VL testing center. TAT-2 was defined as the number of days between the time samples were delivered to the laboratory until the VL results were available for dispatch. TAT-3 was defined as the number of days between the time the VL results were available in the laboratory until the time results were mailed. TAT-4 was defined as the number of days VL results being mailed by the laboratory until results were received by the ART center.

In addition to TAT, VL suppression was evaluated. VL suppression was defined as a VL that is undetectable or ≤ 50 copies per mL of blood (UNAIDS, 2018; WHO, 2021). Low level viremia was defined as VL results >50 but ≤ 1000 copies/ml. Virologic failure was defined as a VL >1000 copies/ml (WHO, 2021).

Development and pilot testing of a new VL result reporting system

A viral load test management system (ViLTMS), a new mobile and web app, which will be useful for real-time reporting of HIV VL results that targets TAT-3 and TAT-4 was developed. In addition to potential shortening of TAT-3 and TAT-4, ViLTMS supports HIV care providers in selecting treatment regimens based on VL results. The app was developed using iterative software development methodology, following the human-centered design principle which embraces human factors in the design of interactive systems to suit the needs and value of end users (Committee, 2019). The prototype was evaluated by a beta-testing and User Version of the Mobile Application Rating scale (uMARS). In the beta-testing, 6 participants were asked to navigate ViLTMS at their own pace and in the order they chose, and this was followed by an interview about their experience with the system. We conducted an initial evaluation with six participants through after-use interviews. Data were analyzed using interpretative phenomenological analysis (IPA) (Pietkiewicz, 2014; Smith and Larkin, 2009). IPA assumes that people are always interpreting the world around them through a lens built upon previous experiences, personal beliefs, and current environment. IPA provides an opportunity to deeply explore personal experiences of ViLTMS use with a heterogeneous and small size of participants. uMARS provides a 20-item measure that includes 4 objective quality subcategories: engagement (entertainment, customization), functionality (ease of use, navigation), aesthetics (layout, graphics, visual appeal), and information (quality, quantity) (Stoyanov et al., 2016). uMARS was assessed on 8 lab personnel from 2 VL testing centers using standard questionnaire (supplementary Table 2). Pilot testing with a small number of samples was guided by previous studies on similar applications (Stoyanov et al., 2016; Bakogiannis et al., 2021). The scores were collected after 30 mins, one day (i.e., 2- 4 h) and one week (1–2 h per day for 5 days) of using the ViLTMS for five hypothetical patient records.

Data analysis

We used different methods of analysis based on the nature of data. Bivariate comparisons were made using chi-square tests for categorical variables for continuous variables. One-way ANOVA testing was used to compare mean TATs of VL testing centers. Factors associated with long TAT. VL TAT between PCR centers were compared using *t*-tests (for comparison of two centers) or ANOVA (for comparison of more than two centers). Regression analyses, binary and multivariable logistic regression, were used to identify factors associated the VL suppression failure as binary outcome (VL>1000="1″, VL ≤1000="0″). The assumption of normal distribution (TAT-3 which is number of days between the time the VL results are mailed by the laboratory until the results are received by the ART center) as outcome variable was checked. The data is not normally distributed. The relationship between PCR centers and TAT-3 was estimated using negative binomial regression to account for overdispersion in the data. A Kendall's Tau test was used to measure the strength and direction of the association between number of VL and IDP at zonal level. This test is particularly useful for small sample sizes and is less sensitive to outliers compared to Spearman's correlation since number of IDP in-campus and host community are only available at Zonal level of the region which are 15 (Supplement 1). A $p < 0.05$ was considered statistically significant

Ethical considerations

Ethical approvals from Amhara Public Health Institute and Saint Louis University's institutional review board were obtained. All personal identifiers were removed. The data storage and analysis did not include personal identifier information.

Results

Type of specimen and indications for VL testing

In total, there were 98,957 VL records from 7 VL testing centers in the Amhara region. A total of 98,863/98,957 (99.9%) specimens were

plasma, 33 were dried blood and 61 samples were whole blood. All specimens were acceptable for VL testing. Specific indications for testing out of total results were analyzed and routine follow up after initiation or modification of HIV treatment is the major reason, contributing to 96,170/98,957 (97.2%) of VL tests. Routine follow up during pregnancy, targeted testing for previous VL>1000 copies/mL or suspected treatment failure, and diagnosis of HIV in infants contributed to 312/98,957 (0.3 %), 446/98,957, (1.5%) and 5/98,957 tests, respectively. In addition, 63,839 (64.5%) samples were from females and 96,998 (98.1%) were patients followed in Amhara region whereas the remaining patents were from adjoining regions including Afar, Benishangul Gumuz, and Oromia. Table 1 shows detailed demographic characteristics.

There was a statistically significant difference in sex, age, testing site and current ART regimen among patients tested for routine VL follow up, targeted follow up and patients with missing data for testing reason ($P < 0.001$, Table 2). In Table 2, data for pregnant women and patients with routine VL follow up were combined.

VL suppression rates and predictors of virologic failure

In patients tested for a routine follow up after initiation or modification of HIV treatment, pregnant women and patients tested for suspected treatment failure, VL suppression was achieved in 87,147/96,170 (90.6 %), 265/312 (84.9%) and 849/1446 (58.7%), respectively. Supplementary Table 3 shows the VL results and treatment regimens by VL testing center. Using VL of children under 5 years of age (i.e., taking ART with the help of parents or guardians) as a control, a logistic regression analysis (Fig. 2) showed that older age groups were associated with worse VL or increased virologic failure with adjusted OR (aOR) of 0.35 (95% CI 0.23–0.53) for age groups 5–17, 0.17 (95% CI 0.12–0.25) for 18–49-year age group, 0.13 (95% CI 0.09–0.20) for the age group ≥ 50 years. Similar findings were obtained using VL of children under 17 years old as a control.

To compare VL testing centers for viral load suppression, we used APHI-BD that has the most resources by being in the capital city as a control. DBRH (aOR 1.87, 95% CI [1.63–2.14]), DMRH (aOR 1.76, 95% CI [1.61–1.93]) and UoG (aOR 2.28, 95% CI [2.07–2.51]) had higher risks of virologic failure whereas DTRH had a lower risk of virologic failure (aOR 0.77, 95% CI [0.61–0.96]), indicating that the VL testing centers in Amhara region have significantly different VL suppression rates ($P < 0.0001$).

The association between number of IDP with Kendall's Tau test (Kendall's score $=-3$, $p = 0.9212$ in 2021 and Kendall's score $=-7$, $p = 0.7665$ in 2022) did not show statistically significance difference with VL suppression rates.

TAT and factors associated with long TAT

TAT-1, TAT-2 and TAT-3 for all tested patients ($n = 98,957$) were 1.78 ± 11.22 (Mean ± SD), 14.06 ± 17.79, 8.2 ± 17.99, respectively. TAT-2 is affected by adequacy of manpower and workload at the testing centers. TAT-1 and TAT-4 measure the efficiency of the carrier system in the area. TAT-3 is the most amenable for improvement. Among patients with routine VL testing, TAT-3 was ≤ 1 week in 61,148 (63.4%) and 2 weeks in 25,172 (26.1%). Among patients with targeted VL testing, TAT-3 was ≤ 1 week in 938 (64.9%) and 2 weeks in 368 (25.4%). In patients who had VL testing for unknown reason, 574 (55.8%) had TAT-3 of ≤ 1 week and 344 (33.4%) had TAT-3 of 2 weeks, and these values were significantly different compared to corresponding values for other groups with known indications for VL testing ($P < 0.001$, Table 2).

The 7 testing centers, APHI-Bahir Dar, APHI-Dessie, DBRH, DMRH, DTRH, UoG and WRH had a TAT-3 (Mean ± SD) of 11.2 ± 28.2, 7.5 ± 9.2, 7.7 ± 12.2, 5.7 ± 3.9, 6.6 ± 14.9, 3.9 ± 4.1, and 28.1 ± 27.3 days, respectively ($P < 0001$). The results showed there was significant variation between and within PCR centers ($P < 0.001$). However, TAT-3 did not show statistically significance difference between APHI and DBRH ($p = 0.666$). Post hoc analysis with Bonferroni adjustment for multiple comparisons showed there was significant variation among VL testing centers ($P < 0.001$) except between APHI and DBRH ($p = 0.666$). Fig. 3 shows TAT-3 of VL results from seven VL testing centers. APHI-Bahir Dar, APHI-Dessie and WRH had TAT-3 of >1 week for 54.9%, 41.8% and 70.3% of tests, respectively. DBRH, DMRH, DTRG and UoG had TAT-3 < 1 week for 73%, 79%, 90%, and 84% of tests, respectively. Fig. 4 shows that exponentiated coefficients with 95% CI for association of different variables with longer TAT-3 in a negative binomial model. Using APHI-BD as a control, significantly lower TAT-3 with Exp (B) of 0.67 (95% CI 0.66–0.68), 0.69 (95% CI 0.67–0.71), 0.5 (95% CI 0.49–0.51), 0.58 (0.56–0.61), and 0.34 (95% CI 0.33–0.35) was obtained for APHI-Dessie, DBRH, DMRH, DTRH and UoG. One site, WRH,

Table 2
Results stratified by reasons for viral load testing.

Demographics	Routine N (%)	Targeted N (%)	Missing (Not indicated on form) N (%)	p-value
Sex				
Female	62,310 (64.6)	840 (58.1)	689 (67.0)	< 0.001
Male	32,449 (33.6)	567 (39.2)	281 (27.3)	
Unknown	1680 (1.7)	39 (2.7)	59 (5.7)	
Age				
1–4	176 (0.2)	12 (0.8)	2 (0.2)	< 0.001
5–17	5334 (5.5)	189 (13.1)	50 (4.9)	
18–49	72,305 (75.0)	1022 (70.7)	786 (76.4)	
50+	16,051 (16.6)	178 (12.3)	132 (12.8)	
Missing	2573 (2.7)	45 (3.1)	59 (5.7)	
Testing Site				
APHI	30,830 (32.0)	416 (28.8)	533 (51.8)	< 0.001
APHI-Dessie Branch	21,397 (22.2)	144 (10.0)	202 (19.6)	
DBRH	7919 (8.2)	152 (10.5)	109 (10.6)	
DMRH	16,899 (17.5)	514 (35.5)	0 (0.0)	
UoG	14,661 (15.2)	131 (9.1)	39 (3.8)	
DTRH	3286 (3.4)	79 (5.5)	140 (13.6)	
WRH	1477 (1.5)	10 (0.7)	6 (0.6)	
Treatment				
Missing	8004 (8.3)	111 (7.7)	105 (10.2)	< 0.001
First Line	85,582 (88.7)	1053 (72.8)	889 (86.4)	
Second Line	2780 (2.9)	281 (19.4)	34 (3.3)	
Third Line	73 (0.1)	1 (0.1)	1 (0.1)	
Time to Dispatch (from final result)				
≤1 week	61,148 (63.4)	938 (64.9)	574 (55.8)	< 0.001
2 weeks	25,172 (26.1)	368 (25.4)	344 (33.4)	
3 weeks	5959 (6.2)	66 (4.6)	73 (7.1)	
4 weeks	2283 (2.4)	41 (2.8)	19 (1.8)	
5 weeks	391 (0.4)	11 (0.8)	3 (0.3)	
≥ 6 weeks	1486 (1.5)	22 (1.5)	16 (1.6)	

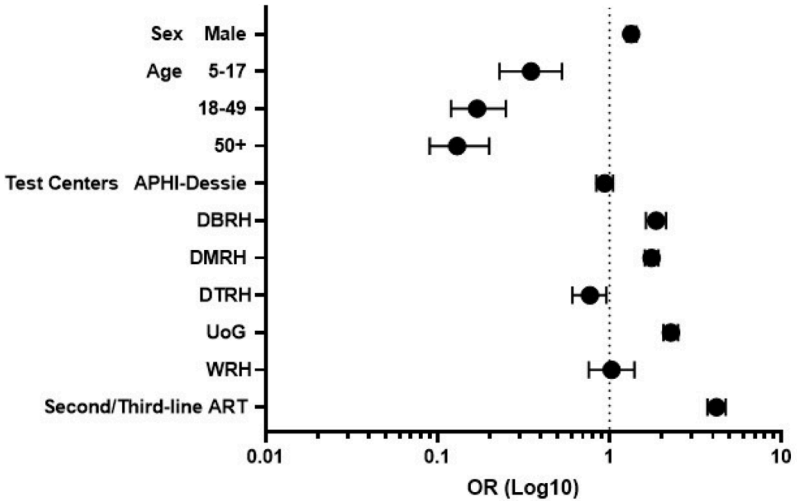

Fig. 2. Predictors of VL suppression. The forest plot shows odds ratio (aOR) and 95% CI from logistic regression analysis of factors that may be associated with VL level. Male sex (aOR 1.34, 95 CI [1.26–1.44]), testing at three VL testing centers such as DBRH (aOR 1.87, 95 CI [1.63–2.14]), DMRH (aOR 1.76, 95 CI [1.61–1.93]) and UoG (aOR 2.28, 95 CI [2.07–2.51]), and second- or third-line ART are associated with VL >1000. Compared to age under 5 years, age groups 5–17 years (aOR 0.35, 95 CI [0.23–0.53]), 18–49 (aOR 0.17, 95 CI [0.12–0.25]) and 50+ (aOR 0.13, 95 CI [0.09–0.20]) are associated with VL suppression.

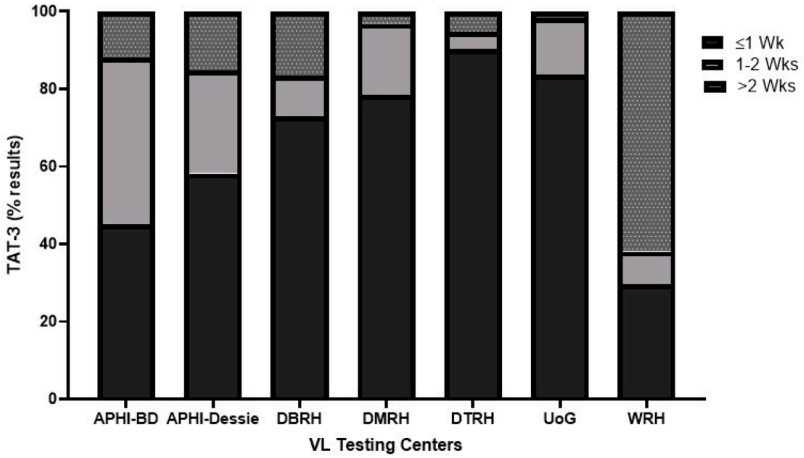

Fig. 3. TAT-3 of seven VL testing centers in Amhara region. Two sites, APHI-BD and WRH were able to have TAT-3 ≤ 1 week only for 45% (n = 37,181) and 29.7% (n = 1463) of patients. TAT-3 was more than 1 week for 54.9, 41.8%, 27.1%, 21.5%, 9.8%, 16.3%, and 70.3% of results from APHI-BD, APHI-Dessie, DBRH, DMRH, DTRH, UoG and WRH, respectively. APHI-BD, APHI-Dessie, and WRH benefit require a better strategy of reporting VL test results. APHI-BD, APHI-Bahir Dar.

had higher TAT-3 with Exp (b) of 2.5 (95% CI 2.4–2.6). The same model showed that patients on third-line ART regimen had longer TAT-3 compared to patients on first-line regimen (Exp (B) of 1.54, 95% CI [1.21–1.97]).

Development and pilot testing of ViLTMS that targets TAT-3 and TAT-4

ViLTMS, in addition to the VL test request and reporting options, incorporated a management algorithm based on national guidelines which include enhanced adherence counselling and alternative treatment regimens for patients with virologic failure. The steps in developing and evaluating ViLTMS are shown in supplementary figure 1. In the beta testing, we identified the following two main themes. First, participants appreciated the idea of pervasive electronic medical record (EMR) through a mobile app, accessible anywhere and anytime. Comparing it with traditional EMRs which are largely desktop-based applications, participants highlighted that ViLTMS is more appropriate considering low access to personal computers and frequent power interruptions. Second, ViLTMS was perceived by participants as easy-to-use with clear navigation and user-friendly interfaces. Moreover, participants mentioned that, on ViLTMS, there is a clear separation of roles between web administrators (e.g., information technology officers) and healthcare professionals. In some settings where an EMR(s) is adopted, everything is maintained exclusively by IT officers with minimal use by healthcare professionals. Table 3 shows the uMARS of ViLTMS after one-week of usage by eight health professionals working at the three tested centers in the Amhara region. Engagement, functionality, aesthetics and information had mean scores of 4.47, 4.00, 4.54, and 4.31, respectively with the overall mean uMARS score of 4.33 out of 5.00. Detailed questionnaire and results from individual participants are shown in supplement Table 2 and 4.

Discussion

This is the first study on HIV control efforts in a resource limited setting with massive number of IDP. VL suppression was high at all VL testing centers with only 2.3% - 6.3% of patients having VL >1000 copies/ml, indicating good HIV control efforts despite high number of IDP. However, the war and therefore, the number of IDP may have affected the courier system. It takes more than 1 week (TAT-3) for the VL

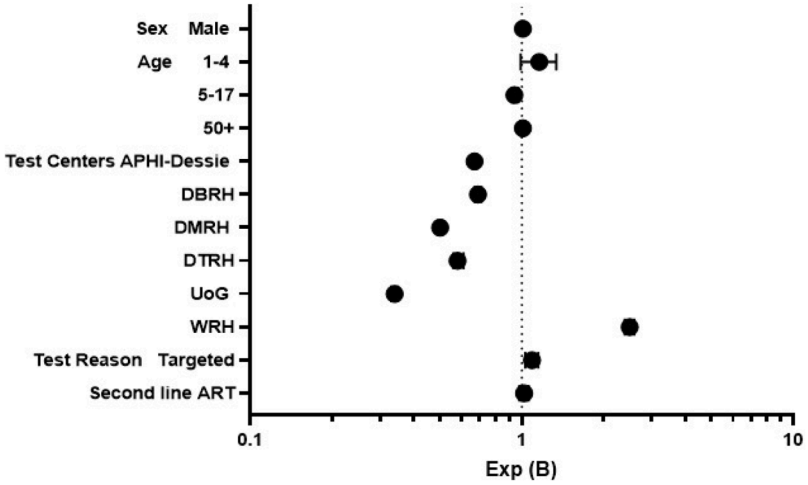

Fig. 4. Possible predictors TAT-3 length. The forest plot shows exponentiated coefficients [exp (β)] from negative binomial regression analysis of variables that may potentially affect TAT-3. Using APHI- Bahir Dar as a control, five VL testing centers such as DBRH (OR 0.69, 95 CI [0.67–0.71]), DMRH (OR 0.50, 95 CI [0.49–0.51]), DTRH (OR 0.58, 95% CI 0.56–0.61)] and UoG (OR 0.34, 95% CI [0.33–0.35]) had significantly lower TAT-3 whereas WRH (OR 2.5, 95% CI [2.4–2.6]) had significantly higher TAT-3. Sex, Age and ART regimen did not affect TAT-3.

Table 3
Overall uMARS scores by users of ViLTMS ($n = 8$).

Category of Evaluation	Scores
Engagement Mean Score	4.47
Functionality Mean Score	4.00
Aesthetics Mean Score	4.54
Information Mean Score	4.31
ViLTMS quality Mean Score	4.33

test results of more than 35% of patients to be picked by a courier system and the system takes additional time (TAT-4) before the results are delivered to the treatment centers. These indicate an opportunity to improve the reporting system using our newly developed ViLTMS.

VL suppression in this study was highest (90.6%) in patients returning for routine follow up followed by pregnant women (84.9%). A lower VL suppression rate in pregnant women compared to other patients tested for routine follow up is concerning because VL suppression during pregnancy is important in reducing mother-to-child transmission, decreasing maternal morbidity and mortality, and sustaining long-term health of children and families (Myer et al., 2017). Our findings on patients tested for routine follow-up are similar to results obtained in other regions of Africa. In studies from Uganda, South Africa, and Rwanda, 81% - 94.5% of patients who were tested as a routine follow up had VL suppression.

Only 58.7% of patients with suspected treatment failure had VL suppression. In this patient group, lack of treatment adherence and drug-resistance could be potential reasons for low VL suppression (Bessong et al., 2021; Tchouwa et al., 2018). A meta-analysis of studies in Africa showed that enhanced adherence counselling without change of treatment regimen led to resuppression of VL in more than 40% of patients (Ford et al., 2019). However, longer use of a failing regimen is associated with a lower likelihood of resuppression and potential spread of drug-resistant virus, indicating the negative impact of long TAT (Nasuuna et al., 2018).

More than 35% of patients in this study had TAT-3 of more than 1 week and a total TAT exceeding 3 weeks. A similarly long TAT was seen in other low-income countries. In Zambia, where a mail-based VL reporting system was used, a test including two laboratories and ART facilities showed a post-test and total (i.e., pre-and post-test) turnaround time of 51 days and 67 days, respectively (Mbiva et al., 2021). In Kenya where a courier system was used for VL test request and reporting, the median (IQR) time from sample collection to dispatch of results was 21 (24) days (Mwau et al., 2018). A similarly long TAT of 28 days was reported from South Sudan (Chun et al., 2022). These long TATs in African settings indicate the need for a better system of reporting VL test results. Key informant interviews of health facility managers in Uganda showed that long TAT of VL test results was perceived as a barrier to adherence to guidelines (Lubega et al., 2022). One approach that has been proposed as a possible solution to decrease TAT was a point of care test (Ndoye et al., 2022; Mariani et al., 2020). However, point of care VL testing increases cost and requires resources including trained manpower at ART centers and may not be a solution by itself (Yee et al., 2021; Roberts et al., 2016). Another possible solution is the development and use of new web/mobile application that can work in places even with limited internet connection as a way to manage VL requests and reports.

ViLTMS, has been tested on a limited number of users at one HIV treatment center and the corresponding VL testing centers. We limited the analysis to uMARS because uMARS score was used for initial evaluation of new web applications in studies with small sample size (Stoyanov et al., 2016; LeBeau et al., 2019). Our uMARS results are promising and will be used to further improve the system. ViLTMS has to be tested systematically in a large-scale clinical trial and compared with current standard of care before it is widely implemented. In addition, in Amhara region which suffers from long TAT of other important tests such as multidrug-resistant (MDR)-tuberculosis (TB) reporting, the same application could be applied (Shiferaw and Yismaw, 2019).

The study has the following limitation: 1) Some patients particularly patients with VL>1000 and requiring changes in ART regimen may have two tests in a year. These patients may be counted twice in the data analysis since we used deidentified data.

In conclusion, despite war and high level of IDP, the VL suppression rates in Amhara region in patients tested for routine follow up were high. Long TAT-3 may affect the management of pregnant women and patients suspected of having treatment failure where treatment modification may be needed. ViLTMS could be useful to shorten TAT for all patients and in utilization of national HIV management guidelines for management of patients with high VL.

CRediT authorship contribution statement

Gizachew Yismaw: Writing – review & editing, Methodology, Conceptualization. **Muluken Azage Yenesew:** Writing – review & editing, Supervision, Project administration, Methodology, Formal analysis, Conceptualization. **Tegegn Kebebaw:** Writing – review &

editing, Software, Methodology, Conceptualization. **Leslie Hinyard:** Writing – review & editing, Investigation. **Asaminew Gizaw:** Software, Methodology. **Alemitu Mequanint:** Writing – review & editing, Methodology. **Christian Hendrix:** Writing – review & editing. **Getahun Abate:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jmh.2025.100304.

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