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ORIGINAL PAPER

# Multilevel Factors Associated with a Lack of Viral Suppression Among Persons Living with HIV in a Federally Funded Housing Program

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**Abstract**
Persons with HIV who are receiving housing services often have high rates of engagement in care, yet many are not virally suppressed. We linked data from the New York City Housing Opportunities for Persons with AIDS (HOPWA) program to electronically reported laboratory tests from the HIV surveillance registry to examine factors associated with a lack of viral suppression. Of 1491 HOPWA consumers, 523 (35.1%) were not durably suppressed, and 253 (17.0%) were unsuppressed at their last viral load test. Substance use, age < 27 years, and emergency housing all independently predicted lack of durable viral suppression and lack of viral suppression at last viral load test.

**Keywords** Housing · HIV/AIDS · HIV viral suppression

**Resumen**
Personas con VIH que reciben servicios de vivienda tienen alto índices de participación en su cuidado médico. Sin embargo, muchos no han logrado la supresión viral. Vinculamos los datos del Programa de Vivienda para Personas con VIH/SIDA (HOPWA) de la Ciudad de Nueva York con pruebas de laboratorio reportadas electrónicamente en el registro de vigilancia del VIH, con el fin de evaluar los factores asociados con la falta de la supresión viral. De 1491 participantes, 523 (35.1%) no lograron supresión viral de forma duradera, y 253 (17.0%) no lograron supresión viral de acuerdo a su última prueba de carga viral. El uso de sustancias, la edad menor de 27 años, y el alojamiento en una vivienda de emergencia, independientemente predijeron la falta de supresión viral duradera y la falta de supresión viral en la última prueba de carga viral.

## Introduction

Unstable or insufficient housing is associated with poor health outcomes for persons living with HIV (PLWH) [1]. PLWH who are unstably housed or homeless are less likely to be engaged in medical care and maintain HIV viral load suppression ("viral suppression") than those who are stably housed [2, 3]. To improve housing stability, the U.S. Department of Housing and Urban Development's (HUD) Housing Opportunities for Persons with AIDS (HOPWA) program assists low-income individuals with a history of unstable housing in locating and retaining stable residences, while also providing related supportive services. In New York City (NYC), the largest HOPWA jurisdiction in the country, HOPWA consumers are more likely to be engaged in care, defined as one or more primary care visits in a twelve month period, than other New Yorkers living with HIV, but not more likely to achieve or maintain viral suppression [4].

Substance use [5], mental illness (particularly depression) [6, 7], younger age [8, 9], and poverty have all been linked to a lack of viral suppression. Although homelessness, housing instability, and poor housing conditions are understood in and of themselves as potential contributors to non-suppression, little research has been done on factors associated with a lack of viral suppression among persons who have a history of or are currently experiencing unstable housing [1, 10].

In NYC, HOPWA services are provided by community-based organizations (CBOs) while the overall HOPWA program is administered by the NYC Department of Health and

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Mental Hygiene (DOHMH). NYC HOPWA consumers are almost universally engaged in care and receive services such as substance use treatment, mental health counseling, and subsidized or no-cost permanent, stable housing to address individual and structural barriers to viral suppression. However, some consumers struggle to achieve and maintain viral suppression. To assist HOPWA providers in improving viral suppression outcomes, we set out to examine factors associated with a lack of HIV viral suppression by linking HIV surveillance outcomes with routine HOPWA program assessments.

## Methods

### Data Sources

#### HOPWA Program Data

The CBOs providing HOPWA services in NYC complete detailed housing, medical, and psychosocial assessments with NYC HOPWA consumers at intake and a minimum of every 90 days thereafter. Data from these assessments, along with services provided to consumers, are entered into a secure, web-based system (eCOMPAS), then extracted by DOHMH research and evaluation staff. We used these sources to populate the demographic, housing, and behavioral variables included in our analysis.

#### Electronically Reported Clinical Data

Clinical variables, including the primary outcomes of durable viral suppression and viral suppression at last viral load test, were extracted from the NYC DOHMH HIV Surveillance Registry (the Registry). All HIV-related laboratory tests for PLWH receiving care in NYC are electronically reported to the NYC DOHMH, as mandated by New York State law.

#### Record Linkage

HOPWA consumers are matched to the Registry quarterly, using a deterministic algorithm incorporating multiple identifiers and a three-tiered human review of indeterminate matches [11]. Using the results of this matching process, we linked HOPWA program data to electronically reported clinical data to create our analytic dataset.

### Eligibility Criteria and Analysis Design

HOPWA consumers were considered for eligibility in this analysis if they had at least 1 day of enrollment and at least one service entered into eCOMPAS in calendar year 2015 (n = 1773). Participants were then followed for 365 days after that initial day, regardless of continued enrollment in HOPWA. As a result, all participants had exactly 1 year of follow-up (observation period) in which to assess their viral suppression outcomes, with the start point of that year ranging from January 1, 2015, to December 31, 2015. Further inclusion criteria were having two or more quantitative viral load tests and at least one valid housing assessment with valid zip code information within the observation period. Consumers who passed away prior to the end of their observation period were excluded from the final analysis.

### Primary Outcomes

This analysis had two outcomes of interest. The first, lack of durable viral suppression (LDVS), was defined as any HIV viral load test reported to the Registry during the observation period being greater than 200 copies/mL. The second, lack of viral suppression (LVS) at last viral load test, was defined as a viral load of greater than 200 copies/mL at the last viral load test within the observation period. The last viral load in a given time period is used in HUD reporting and guidelines and is recommended as an indicator of viral suppression for the general population of PLWH in the United States [12]. However, durable viral suppression may be more appropriate as a measure for particularly vulnerable populations, and its use is increasing in analyses in a variety of contexts [13]. We included both outcomes, reported as a percent of the given population achieving each.

### Predictor Variables

Predictor variables were selected based on previous research and feedback from DOHMH programmatic staff and staff members from community-based organizations providing NYC HOPWA services in the community [1, 14]. Continuous predictors were transformed into categorical variables for ease of interpretation. Cutoffs for predictor variables were selected based on programmatic knowledge and research hypotheses and are described below.

Demographic variables included age ($\leq 26$, 27–54, $\geq 55$), gender (cisgender male, cisgender female, transgender), and race/ethnicity (Hispanic/Latino, Black, White, another race). Our cutoffs for the categorical age variable were chosen because NYC HOPWA has several contracts specifically targeting younger (age 26 or less) and older (age 55 or greater) PLWH. For race/ethnicity, anyone reporting Hispanic/Latino ethnicity was characterized as Hispanic/Latino. Anyone identifying solely as non-Hispanic Black or non-Hispanic White was reported as such, while all other consumers were categorized as "another race" for the purposes of this analysis.

Clinical variables included clinical status (HIV non-AIDS, AIDS diagnosis) and time since HIV diagnosis prior to the start of the observation period (< 1 year, 1– < 5 years, 5– < 10 years, 10– < 20 years, ≥ 20 years). Socioeconomic, programmatic, and behavioral variables included HIV risk factor (MSM, heterosexual, IDU, other/unknown), housing status (continuous stable, suboptimal, emergency/homeless), mental health history (no diagnosis, diagnosed, psychiatric hospitalization), recent substance use (none, "soft" [tobacco, alcohol, and/or marijuana use], "hard" [cocaine, opioid, and/or amphetamine use]), and time enrolled in NYC HOPWA prior to the start of the observation period (> 180 days, 1–180 days, newly enrolled).

For housing status, participants were considered stably housed if they resided in supportive housing or an apartment or home that they owned/rented in *all* housing assessments that were completed during the study period. Those who reported living on the street, in a homeless shelter, or in an emergency single-room occupancy (SRO) hotel in *any* housing assessment during the study period were classified with a "homeless/emergency" housing status. All other participants were considered sub-optimally housed and included those who were living temporarily with friends or family, or in transitional housing, in at least one housing assessment during the study period.

Neighborhood poverty was the only structural-level predictor variable included in our analysis. The last known zip code of residence during each individual observation period was converted into a zip code tabulation area (ZCTA), then American Community Survey 2011–2015 data was used to determine the percentage of a given ZCTA living below the poverty line. The variable was then transformed into "low" (< 10% of residents of the zip code living below the poverty line), "medium" (10% to < 20%), "high" (20%– < 30%), and "very high" (30% or more) categories.

### Statistical Analysis

Descriptive statistics were calculated for all participants. Univariate logistic regression was used to determine if a significant association existed between predictor variables and the two primary outcomes. Multilevel logistic regression was used to explore adjusted associations between predictor and outcome variables while also accounting for clustering by neighborhood of residence. The multivariable model was theory-based and did not exclude variables based on any statistical significance threshold in univariate analysis. Statistical significance level was set at 0.05 for all tests, and all analyses were run using SAS statistical software version 9.4 (SAS Institute Inc., Cary, NC, USA).

## Results

Of the 1491 individuals meeting the eligibility criteria and included in the final study sample, the majority were Black (54.5%), male (60.8%), and lived continuously in stable housing during the study period (59.5%). The median age was 47 years old (IQR 37–53). The median number of viral load tests per consumer during the study period was 4 (IQR 3–5), with a maximum of 22. The median CD4 count prior to the study period was 533.5 (IQR 341–756).

A total of 523 (35.1%) participants were not durably suppressed while 253 (17.0%) were unsuppressed as of their last viral load test. In our simple logistic regression models, statistically significant factors associated with both LDVS and LVS included: intravenous drug use as a risk factor for HIV compared to MSM (OR = 1.83, CI 1.32–2.5 for LDVS; OR = 1.66, CI 1.12–2.47 for LVS); emergency housing compared to continuous stable housing (OR = 2.01, CI 1.53–2.64 for LDVS; OR = 1.40, CI 1.00–1.97 for LVS); a history of psychiatric hospitalization compared to no history of mental health diagnoses (OR = 2.31, CI 1.72–3.10 for LDVS; OR = 1.76, CI 1.22–2.53 for LVS); and recent substance use involving cocaine, heroin, or other "hard" drugs compared to no recent substance use (OR = 4.00, CI 2.48–6.46 for LDVS; OR = 2.88, CI 1.71–4.86 for LVS). Compared to consumers less than 27 years old, consumers aged 27–54 (OR = 0.48, CI 0.32–0.73 for LDVS; OR = 0.43, CI 0.27–0.68 for LVS) and ≥ 55 years old (OR = 0.59, CI 0.38–0.93 for LDVS; OR = 0.58, CI 0.35–0.96 for LVS) had lower odds of LDVS and LVS. There were no significant associations between either LDVS or LVS and gender or race.

Approximately 3% of the variability in LDVS and LVS (intraclass correlation coefficient [ICC] = 0.025 and 0.034, respectively) was attributable to differences between zip codes. In the multivariable multilevel logistic regression model, "hard" substance use (AOR = 3.01, CI 1.86–5.17 for LDVS; AOR = 2.24, CI 1.26–3.96 for LVS), emergency housing status (AOR = 2.13, CI 1.53–2.97 for LDVS; AOR = 1.58, CI 1.04–2.39 for LVS), and age under 27 years (27–54 compared to < 27, AOR = 0.37, CI 0.23–0.59 for LDVS; AOR = 0.29, CI 0.17–0.51 for LVS) were the only three factors that remained independently associated with both LDVS and LVS. Full results of all analyses are described in Table 1.

## Discussion

After adjusting for demographic, clinical, and neighborhood characteristics, and clustering within neighborhoods, substance use, younger age, and time spent in emergency

**Table 1** Factors associated with a lack of durable viral suppression and a lack of viral suppression at last viral load test, NYC HOPWA program

| Characteristic | Total | | Lacking durable viral suppression[a] (LDVS) | | | | Lacking viral suppression[a] at last viral load test (LVS) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | Col (%) | N | Row (%) | OR (95% CI) | AOR (95% CI) | N | Row (%) | OR (95% CI) | AOR (95% CI) |
| Age | | | | | | | | | | |
| ≤ 26 | 99 | 6.6 | 50 | 50.5 | – | – | 29 | 29.3 | – | – |
| 27–54 | 1060 | 71.1 | 348 | 32.8 | **0.48 (0.32–0.73)** | **0.37 (0.23–0.59)** | 160 | 15.1 | **0.43 (0.27–0.68)** | **0.29 (0.17–0.51)** |
| ≥ 55 | 332 | 22.3 | 125 | 37.7 | **0.59 (0.38–0.93)** | **0.41 (0.24–0.70)** | 64 | 19.3 | **0.58 (0.35–0.96)** | **0.35 (0.19–0.65)** |
| Gender | | | | | | | | | | |
| Cisgender male | 906 | 60.8 | 307 | 33.9 | – | – | 146 | 16.1 | – | – |
| Cisgender female | 551 | 37.0 | 201 | 36.5 | 1.12 (0.90–1.40) | 1.03 (0.76–1.41) | 100 | 18.2 | 1.15 (0.87–1.53) | 1.11 (0.75–1.64) |
| Transgender | 34 | 2.3 | 15 | 44.1 | 1.54 (0.77–3.07) | 1.65 (0.78–3.47) | 7 | 20.6 | 1.35 (0.58–3.16) | 1.39 (0.56–3.43) |
| Race/ethnicity | | | | | | | | | | |
| Hispanic/latino | 579 | 38.8 | 202 | 34.9 | – | – | 97 | 16.8 | – | – |
| Black | 813 | 54.5 | 295 | 36.3 | 1.06 (0.85–1.33) | 0.93 (0.73–1.19) | 144 | 17.7 | 1.07 (0.81–1.42) | 0.96 (0.70–1.30) |
| White | 52 | 3.5 | 16 | 30.8 | 0.83 (0.45–1.53) | 0.81 (0.42–1.56) | 8 | 15.4 | 0.90 (0.41–1.98) | 0.93 (0.41–2.11) |
| Another race[b] | 47 | 3.2 | 10 | 21.3 | 0.50 (0.25–1.04) | 0.52 (0.25–1.10) | 4 | 8.5 | 0.46 (0.16–1.32) | 0.47 (0.16–1.37) |
| HIV risk category | | | | | | | | | | |
| MSM | 522 | 35.0 | 163 | 31.2 | – | – | 80 | 15.3 | – | – |
| Heterosexual | 441 | 29.6 | 150 | 34.0 | 1.13 (0.87–1.49) | 1.23 (0.84–1.80) | 70 | 15.9 | 1.04 (0.74–1.48) | 1.04 (0.64–1.69) |
| IDU | 216 | 14.5 | 98 | 45.4 | **1.83 (1.32–2.53)** | 1.40 (0.93–2.09) | 50 | 23.2 | **1.67 (1.12–2.47)** | 1.26 (0.77–2.05) |
| Other/unknown | 312 | 20.9 | 112 | 35.9 | 1.23 (0.92–1.66) | 1.32 (0.93-1.87) | 53 | 17.0 | 1.13 (0.77–1.65) | 1.09 (0.70–1.69) |
| Clinical status | | | | | | | | | | |
| HIV non–AIDS | 608 | 40.8 | 189 | 31.1 | – | – | 94 | 15.5 | – | – |
| AIDS | 883 | 59.2 | 334 | 37.8 | **1.35 (1.08–1.68)** | **1.33 (1.03–1.71)** | 159 | 18.0 | 1.20 (0.91–1.59) | 1.16 (0.84–1.59) |
| Time since diagnosis | | | | | | | | | | |
| < 1 year | 63 | 4.2 | 18 | 28.6 | – | – | 7 | 11.1 | – | – |
| 1–< 5 years | 240 | 16.1 | 68 | 28.3 | 0.99 (0.54–1.83) | 0.85 (0.44–1.64) | 28 | 11.7 | 1.06 (0.44–2.55) | 0.96 (0.38–2.44) |
| 5–< 10 years | 339 | 22.7 | 120 | 35.4 | 1.37 (0.76–2.47) | 1.31 (0.69–2.50) | 59 | 17.4 | 1.69 (0.73–3.88) | 1.88 (0.75–4.67) |
| 10–< 20 years | 638 | 42.8 | 222 | 34.8 | 1.33 (0.75–2.36) | 1.13 (0.60–2.14) | 112 | 17.6 | 1.70 (0.76–3.84) | 1.83 (0.74–4.54) |
| ≥ 20 years | 211 | 14.2 | 95 | 45.0 | **2.05 (1.11–3.77)** | 1.47 (0.74–2.93) | 47 | 22.3 | 2.29 (0.98–5.36) | 2.11 (0.81–5.53) |
| Housing status | | | | | | | | | | |
| Continuous stable | 887 | 59.5 | 273 | 30.8 | – | – | 140 | 15.8 | – | – |
| Suboptimal | 316 | 21.2 | 114 | 36.1 | 1.27 (0.97–1.66) | **1.52 (1.10–2.11)** | 53 | 16.8 | 1.08 (0.76–1.52) | 1.31 (0.87–1.98) |
| Emergency/homeless | 288 | 19.3 | 136 | 47.2 | **2.01 (1.53–2.64)** | **2.13 (1.53–2.97)** | 60 | 20.8 | **1.40 (1.00–1.97)** | **1.58 (1.04–2.39)** |
| Mental health history | | | | | | | | | | |
| No diagnosis | 719 | 48.2 | 216 | 30.0 | – | – | 102 | 14.2 | – | – |
| Diagnosed | 523 | 35.1 | 183 | 35.0 | 1.25 (0.99–1.59) | 1.17 (0.90–1.51) | 95 | 18.2 | 1.34 (0.99—1.82) | 1.18 (0.85–1.65) |
| Psyc. hospitalization | 249 | 16.7 | 124 | 49.8 | **2.31 (1.72–3.10)** | **1.81 (1.30–2.53)** | 56 | 22.5 | **1.76 (1.22–2.53)** | 1.32 (0.86–1.98) |

**Table 1** (continued)

| Characteristic | Total | | Lacking durable viral suppression[a] (LDVS) | | | | Lacking viral suppression[a] at last viral load test (LVS) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | Col (%) | N | Row (%) | OR (95% CI) | AOR (95% CI) | N | Row (%) | OR (95% CI) | AOR (95% CI) |
| Recent substance use | | | | | | | | | | |
| None | 767 | 51.4 | 214 | 27.9 | – | – | 101 | 13.2 | – | – |
| Soft[c] | 645 | 43.3 | 261 | 40.5 | **1.76 (1.41–2.20)** | **1.57 (1.23–2.00)** | 128 | 19.8 | **1.63 (1.23–2.17)** | **1.46 (1.07–1.99)** |
| Hard[d] | 79 | 5.3 | 48 | 60.8 | **4.00 (2.48–6.46)** | **3.10 (1.86–5.17)** | 24 | 30.4 | **2.88 (1.71–4.86)** | **2.24 (1.26–3.96)** |
| HOPWA enrollment[e] | | | | | | | | | | |
| > 180 days | 803 | 53.9 | 273 | 34.0 | – | – | 143 | 17.8 | – | – |
| 1–180 days | 197 | 13.2 | 73 | 37.1 | 1.14 (0.83–1.58) | 0.89 (0.61–1.28) | 27 | 13.7 | 0.73 (0.47–1.14) | 0.61 (0.38–1.00) |
| Newly enrolled | 491 | 32.9 | 177 | 36.1 | 1.10 (0.87–1.38) | 0.80 (0.59–1.08) | 83 | 16.9 | 0.94 (0.70–1.26) | 0.78 (0.54–1.14) |
| Neighborhood poverty[f] | | | | | | | | | | |
| Low | 61 | 4.1 | 22 | 36.1 | – | – | 14 | 23.0 | – | – |
| Medium | 356 | 23.9 | 118 | 33.2 | 0.88 (0.50–1.55) | 0.84 (0.46–1.54) | 57 | 16.0 | 0.64 (0.33–1.24) | 0.61 (0.30–1.25) |
| High | 385 | 25.8 | 118 | 30.7 | 0.78 (0.46–1.38) | 0.68 (0.37–1.24) | 51 | 13.3 | **0.51 (0.26–1.00)** | **0.44 (0.21–0.92)** |
| Very high | 689 | 46.2 | 265 | 38.5 | 1.11 (0.64–1.91) | 0.96 (0.53–1.71) | 131 | 19.0 | 0.79 (0.42–1.47) | 0.71 (0.36–1.41) |
| Total | 1491 | 100.0 | 523 | 35.1 | | | 253 | 17.0 | | |

All odds ratios and adjusted odds ratios in bold are statistically significant at the 0.05 level

[a]Viral suppression defined as viral load ≤ 200 copies/mL

[b]Asian, American Indian, those who reported "other," and multiple selections

[c]Any tobacco, alcohol, and/or marijuana use within the previous 3 months

[d]Any cocaine, opioid, and/or amphetamine use within the previous 3 months

[e]Days enrolled prior to 12-month observation period

[f]Neighborhood poverty is based on last known zip code during observation period and is classified as follows:

-Low: < 10% of population living below federal poverty level

-Medium: 10%–< 20% of population living below federal poverty level

-High: 20%–< 30% of population living below federal poverty level

-Very high: ≥ 30% of population living below federal poverty level

housing were the only independent predictors of both LDVS and LVS. Individuals less than 27 years old and those reporting recent cocaine, heroin, and/or methamphetamine use were the only groups included in this analysis with more than half of participants lacking durable viral suppression. These findings are consistent with other research on PLWH with histories of unstable housing and the general population of PLWH [1, 6, 8, 9, 15–17]. The results underscore the need to target interventions focused on viral suppression for these particular subgroups.

We did not find any association between race/ethnicity and lack of viral suppression by either of the outcome measures used in this analysis. Although those identifying as Black and Hispanic were more likely to be LDVS and LVS than those identifying as White or other/multiracial, those differences were not statistically significant. These results contradict the well-established evidence base showing disparities in viral suppression outcomes for persons of color compared to White PLWH [14, 18, 19]. We hypothesize that this inconsistency is due to a combination of: (1) small sample size for the White and other subgroups (93% of our population identified as either Black or Hispanic), and; (2) the role of HOPWA or other housing services, particularly the provision of stable, permanent housing, in moderating the racial disparities in outcomes traditionally seen in the general population of PLWH in the United States [20].

Similar to other studies, we found inconsistent evidence of the relationship between neighborhood poverty and lack of viral suppression [21]. NYC HOPWA consumers living in high-poverty zip codes had the best outcomes in terms of LDVS and LVS, followed by those in medium-poverty zip codes. Consumers living in very high-poverty zip codes had the highest proportion of LDVS, although this association (compared to low-poverty zip codes) was not significant in our adjusted or unadjusted models. Counterintuitively, those living in low-poverty zip codes were the least likely to be virally suppressed at their last viral load test; in our adjusted model for LVS, the relationship between low- and high- (but not very-high-) poverty neighborhoods remained statistically significant. The unexpectedly poor outcomes in low-poverty zip codes are surprising: evidence does not suggest that such neighborhoods have a lack of social support [22] nor a disproportionate presence of SROs and other emergency housing [23]. One explanation may be the additive effects of HIV and poverty-related stigma. Studies have shown that HIV-related stigma may be a barrier to ART adherence and that poverty may further exacerbate this effect [24]. Housing consumers living in low-poverty neighborhoods may feel dually isolated by their status as HIV positive as well as low-income in a low poverty neighborhood. The relationship between HIV-related stigma and poverty is not clearly understood, and researchers have called for it to be investigated further [25, 26].

Conversely, the unexpectedly positive outcomes in the high-poverty neighborhoods may be indicative of high levels of social support (i.e., low-income NYC HOPWA consumers may be more likely to live in close proximity to family and friends in high-poverty neighborhoods) without the deleterious effects of extreme poverty seen in very-high-poverty zip codes [27]. However, this relationship is not clear-cut; researchers have found a complex interplay between poverty, social support and social integration [22, 27, 28]. More research is needed to understand the relationship between neighborhood and viral suppression, particularly in the context of programs that house individuals in living situations they may be otherwise unable to afford, or vis-à-vis the effects of social support.

One unique aspect of our analysis was the use of both longer-term (LDVS) and cross-sectional (LVS) outcome measures for viral suppression in a housing program for PLWH. In our multivariable models, consumers who lived in emergency housing at any point during their observation period were more than twice as likely to be LDVS, compared to those in continuous stable housing. The relationship between housing status and LVS after adjusting for other factors was also statistically significant, with a smaller effect size. These findings may indicate a critical link between achieving and maintaining stable housing and achieving and maintaining viral suppression for PLWH. Additionally, the odds of consumers with a history of psychiatric hospitalization to be LDVS were significantly higher than those with no diagnosis of mental illness, while the relationship was not significant for LVS. This discrepancy between outcome measures may be due to the higher likelihood of the cross-sectional measure (LVS) assessing viral suppression at the end of a cycle of non-adherence (of both HIV and psychotropic medications), psychiatric hospitalization, and subsequent return to adherence and viral suppression [29]. The greater use of outcome measures that can account for the inherent instability of particularly vulnerable populations (i.e., those with a history of severe mental illness and unstable housing) should be encouraged when evaluating programs targeting those populations. This is particularly relevant for the prevention of HIV transmission, given the likelihood that periods of unstable housing, non-suppression, and behaviors with a higher risk of HIV transmission may overlap.

There were several limitations in our analysis. New York City is exceptional in terms of its housing costs and the amount of services available to PLWH; hence generalizability to housing programs for PLWH in other jurisdictions may be limited. Data for the majority of our predictor variables were obtained from program assessments based on self-report. Social desirability bias may have influenced over- or under-reporting of certain behaviors, such as substance use [30]. Although we did incorporate longer-term outcomes for

one of our primary outcomes (LDVS), the exact temporal relationship between some predictors and outcomes could not be established. For example, we could only determine if a consumer's housing type changed from one assessment to the next, rather than accessing an exact move-in date. Therefore the associations observed in this analysis should not be construed as causal.

One of the strengths of this analysis and of the NYC HOPWA program in general is our ability to link routine programmatic data to electronically reported laboratory outcomes data. We were able to answer our research questions with no additional expense or further interaction with a study population that already completes quarterly assessments and receives monthly home visits from NYC HOPWA staff. Another strength of this analysis was the utilization of a multilevel model to account for clustering of health-related behaviors within communities, even if that effect was relatively small in this case. Finally, to the best of our knowledge, this is the first time a comparison between cross-sectional and longer-term viral suppression outcomes has been made in a housing program for PLWH.

## Conclusion

PLWH with a history of unstable housing are uniquely vulnerable; identifying the factors that contribute to poor health outcomes in this population is an important step in controlling the HIV/AIDS epidemic. Our analysis identified substance use, younger age, and time spent in emergency housing as the strongest predictors of a lack of viral suppression in the NYC HOPWA program. Our findings highlight the relationship between continuous, stable housing and continuous, stable viral suppression. HOPWA providers and other providers of housing for low-income PLWH can use this information to focus interventions for improving viral suppression on the groups with the highest need.

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### Compliance with Ethical Standards

**Conflicts of interest** The authors declare that they have no conflict of interest.

**Ethical Approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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