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Antiretroviral Adherence Trajectories Among Black Americans Living with HIV

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Abstract

Black people living with HIV (BPLWH) are less likely to adhere to antiretroviral treatment than are members of other racial/ethnic groups. Data were combined from two studies of BPLWH (n = 239) to estimate adherence trajectories using a semiparametric, group-based modeling strategy over three time-points (spanning 6 months). Analyses identified three groups of individuals (high-stable, moderately low-stable, low-decreasing). Multinomial logistic regressions were used to predict trajectory membership with multiple levels of socio-ecological factors (structural, institutional/health system, community, interpersonal/network, individual). Older age was associated with being in the high-stable group, whereas substance use, lower perceived treatment effectiveness, and lower quality healthcare ratings were related to being in the moderately low-stable group. In sum, multiple socio-ecological factors contribute to adherence among BPLWH and thus could be targeted in future intervention efforts.

Keywords Black/African American · HIV · Antiretroviral therapy · Adherence · Trajectory analysis

Resumen

Los afroamericanos que viven con VIH tienen menos probabilidades de adherirse al tratamiento antirretroviral que los miembros de otros grupos raciales o étnicos. Los datos de dos estudios de afroamericanos viviendo con VIH (n = 239) se combinaron para estimar las trayectorias de adherencia utilizando una estrategia de modelado semiparamétrica basada en grupos de tres puntos de tiempo (en el lapso de 6 meses). Los análisis identificaron tres grupos de individuos (alto-estable, moderadamente bajo-estable, bajo-decreciente). Las regresiones logísticas multinomiales se usaron para predecir la afiliación de la trayectoria con múltiples niveles de factores socio-ecológicos (estructural, institucional/sistema de salud, comunidad, interpersonal/red, individual). Mayor edad se asoció con estar en el grupo alto-estable, mientras que el uso de sustancias, la menor efectividad del tratamiento percibido y las calificaciones de cuidado de salud de menor calidad se relacionaron con estar en el grupo de moderadamente-estable. En resumen, múltiples factores socio-ecológicos contribuyen a la adherencia entre los afroamericanos y, por lo tanto, podrían ser el objetivo en futuros esfuerzos de intervención.

Palabras claves Afroamericanos · VIH · Terapia antirretroviral · Adherencia · Análisis de trayectoria

Introduction

Black people living with HIV (BPLWH) in the United States are less likely to be diagnosed, to be engaged in care, to receive and adhere to antiretroviral treatment (ART), and to be virally suppressed than are members of other racial/ethnic groups [1–3]. Among men who have sex with men (MSM), Black MSM are the subgroup most disproportionately impacted by HIV. Similarly, Black heterosexual women and men have a higher incidence of new HIV infections than

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other heterosexuals [4, 5]. Use of ART prevents transmission of HIV between serodiscordant sex partners [6–9] and prolongs survival [10]. Therefore, access and adherence to ART are vital aspects of HIV prevention and care for BPLWH.

Kaufman and colleagues have suggested that the factors influencing HIV-related health behavior fall along multiple levels of a socio-ecological framework, made up of structural, institutional/healthcare system, community, interpersonal/network, and individual behavior change factors [11–13]. This multi-level model aids in the conceptualization and measurement of factors influencing HIV prevention and treatment. Kaufman et al. suggest that these levels run along a spectrum from the most macro or structural-level (e.g., poverty, access to care, cost of services), to the institutional and/or healthcare system-level (e.g., competent supportive providers, culturally congruent care). From the institutional and/or healthcare system-level, factors follow to the community-level (e.g., racism, HIV-related and other forms of stigma, homophobia), and then to the interpersonal or network-level (e.g., relationship factors, social support, social network configuration). Finally, factors flow down to the most micro or individual-level (e.g., mental health, substance use, internalized stigma, medical mistrust, physical health) [11].

Kaufman et al. suggests that many of the factors in this framework are not discrete but represent interrelated relationships among multiple socio-ecological levels and can thus represent multiple levels simultaneously [11]. Further these factors, and the complex relationships between them, are likely to fluctuate over time [11]. For example, substance use and sexual risk-taking are generally measured as individual-level factors but can, and often do, occur in interpersonal or network contexts [14–16]. Medical mistrust among BPLWH is often measured at the individual level, although this factor represents a historically complex and dynamic relationship reflecting tensions among institutions, health systems, medical providers, and Black patients.

With respect to the most macro or structural-level factors influencing HIV-related health behavior, incarceration, poverty, and homelessness disproportionately affect Black communities [17–19]. Patients who are low income, uninsured (or Medicaid insured), and have unstable housing are less likely to be retained in care and are less likely to be adherent to ART [17, 18, 20–22]. Moreover, institutional and healthcare system factors that include the quality of healthcare and cultural competency of providers may contribute to levels of medical mistrust among Black Americans at the individual-level [23–26]; mistrust of HIV treatment efficacy and the healthcare system has been associated with lower ART adherence among BPLWH [27–31]. Many Black Americans report beliefs that the US health system is discriminatory and mistrust of medical information about HIV medication efficacy [32–37] and HIV's origins (i.e., HIV

"conspiracy beliefs" that the government created HIV as a form of genocide), which in turn are related to worse ART adherence [28, 29].

In terms of community and interpersonal factors, BPLWH experience high levels of discrimination based on their multiple identities, including serostatus, sexual orientation (for MSM), and race/ethnicity [38–43], and these experiences with discrimination are strongly related to both medical mistrust and ART nonadherence [44–46]. These factors are generally measured at the individual-level but are reflective of a dynamic relationship among multiple socio-ecological levels. In addition, stigma at the community-level and experienced from within social networks may be reflected in individual-level internalized stigma around HIV, an established correlate of ART nonadherence [47]. Conversely, social support is a strong correlate of better adherence [48], and may serve as a buffer against HIV stigma in the social networks of BPLWH [30].

Depression and use of specific substances such as stimulants (e.g., cocaine, crack, and methamphetamine) are generally measured at the individual-level and serve as major drivers of suboptimal ART adherence [49–53]. Use of crack-cocaine and methamphetamine negatively impacts ART adherence and is associated with lower CD4 cell counts and elevated viral load [54–60]. Although substance use rates among Black Americans may not differ significantly from those among White Americans, the health, legal, and social consequences of drug use may be significantly greater for racial/ethnic minorities [61]. Black Americans report the highest levels of discrimination due to race/ethnicity, poverty, and substance use [62, 63]. Risk for substance abuse is high when individuals report negative affect due to multiple types of discrimination reflecting the complex, multi-level interplay between community-level factors, substance use, and mood [64]. These discriminatory experiences are likely to increase Black people's risk for non-adherence by influencing individual-level risk factors such as substance use, as well as through societal and contextual factors that influence the internalization of homonegative attitudes among Black MSM [43, 65–67].

Adherence is thought to be a dynamic process involving a complex interplay among myriad factors over time, some of which may be located at a single socio-ecological level, others representing relationships among multiple levels. The measurement of this dynamic process of adherence over time has been termed adherence trajectory analysis, and although previous work has assessed factors associated with multiple trajectories of adherence [68–73], to date research has not fully elucidated the multiple levels of factors that contribute to different adherence trajectories among BPLWH. The Swiss Cohort Study [73] found four trajectories of self-reported adherence: good, worsening, improving, and poor. Younger age, less education, a change in living

conditions, injection drug use initiation, increased alcohol use, depression, greater time since diagnosis, lipodystrophy, and changing care providers were found to be associated with worsening adherence while having a simplified regimen, changed ART class, less time on ART, started another medication (e.g., for opportunistic infections) were found to be associated with improving adherence. Further, a longitudinal analysis of ART adherence found that young Black MSM with high adherence were less likely to report alcohol and/or marijuana use and had higher family acceptance and self-efficacy [74]. The current analysis seeks to expand upon these previous adherence trajectory analyses by analyzing factors at multiple levels of a socio-ecological model to better understand the complex and dynamic relationships predicting ART adherence group membership among BPLWH.

Method

Participants

To increase statistical power, we combined two longitudinal (6-month) datasets of HIV-positive African American adults recruited in community settings in Los Angeles, CA (from 2010 to 2015). Specifically, we included data from 246 participants in Project Mednet [75], a longitudinal study of social networks of BPLWH conducted from August 2010 to September 2013, and 108 participants in Project Rise [76], a randomized controlled trial of a culturally congruent adherence intervention for BPLWH conducted from April 2012 to September 2015. Only data from participants in the control group were used from Rise in order to remove from the analysis any intervention effects on adherence trajectories. The dataset omitted 33 duplicate participants who were in both studies, as well as 82 participants missing electronically monitored adherence data at any time point (the main analysis outcome, described below), yielding a final sample size of 239. Participants in both studies conducted a baseline audio computer-assisted self-interview.

Measures

Individual-Level Factors

Socio-demographic Factors Participants were asked to self-report their age at the time of the baseline interview, their current gender identity, their current sexual orientation, and the date of their HIV diagnosis (from which we derived a variable representing length of time since diagnosis). Participant socio-demographic and psychosocial variables are presented in Table 1.

CD4 Cell Count and Undetectable Viral Load Participants were asked to self-report their most recent CD4 cell count and whether the result of their most recent viral load test was undetectable. Participants were also asked to provide permission to collect their medical records data on these indicators. For this analysis we used the medical record measurement closest to their baseline assessment. If the medical record was not available, we used self-report of the most recent CD4 cell count and whether the result of their most recent viral load test was undetectable.

Perceived ART Efficacy Perceived ART medication efficacy was measured using 8 items adapted from the questions developed by the Patient Care Committee & Adherence Working Group of the Outcomes Committee of the Adult AIDS Clinical Trials Group [77]. Example items are: "taking HIV medication will keep me healthier longer," and "I am hopeful that the HIV medications will be effective for me." Items were scored on a 4-point scale ranging from "strongly disagree" to "strongly agree." The items displayed adequate internal consistency (Cronbach's Alpha = 0.75) and the average score was utilized for analysis.

Depression Depressive symptom severity during the past 2 weeks were measured using the 9-item Patient Health Questionnaire [78]. Items ask participants to rate the frequency of depressive symptoms such as "little interest or pleasure in doing things" or "feeling down, depressed, or hopeless." Items were scored on a 4-point scale ranging from "not at all" to "nearly every day." The items displayed good internal consistency (Cronbach's Alpha = 0.89). The 4-point scale for each item has range 0–3; these scores were then summed to create a variable with range 0–27. We dichotomized the depression variable according to the recommendation that subjects be considered depressed if the sum was equal to 10 or more [78].

Individual–Interpersonal/Network-Level Factors

Substance Use Illicit drug use over the past 30 days was measured by substance using specific items from the Addiction Severity Index [79]. Items assess the frequency with which participants used marijuana, heroin, cocaine, crack cocaine, amphetamine, and methamphetamine. For the purposes of the current analyses, stimulant substance use items (i.e., cocaine, crack cocaine, methamphetamine) were combined to form a single simulant substance use score, and both marijuana and stimulant use were dichotomized to indicate any use. All other illicit drug items (other than marijuana) were dropped from the final analyses due to low endorsement of these items among participants. Binge drinking was measured with the question "During the last year, have you

Table 1 Characteristics of study sample by adherence trajectory group

Variable	% or mean (SD)				Corresponding socio-ecological level(s)
	Overall (N=239)	High-stable (N=95)	Moderately low-stable (N=83)	Low-decreasing (N=61)	
Age (years)	47.7 (10.0)	49.7 (11.4)	47.7 (8.4)	44.7 (8.9)	Individual
Gender identity					Individual
Female (non-transgender)	21	23	24	11	Individual
Male (non-transgender)	75	73	72	82	Individual
Transgender or other non-binary	5	4	4	7	Individual
Sexual orientation					Individual
Bisexual male	15	13	11	23	Individual
Bisexual female	<1	0	0	2	Individual
Gay male	48	46	48	49	Individual
Gay female	1	2	1	0	Individual
Straight	33	37	35	25	Individual
Not sure/other	3	2	5	2	Individual
Time since diagnosis (years)	14.3 (7.7)	14.8 (8.1)	13.3 (6.9)	14.8 (8.2)	Individual
Undetectable viral load	57	75	53	36	Individual
Most recent CD4 cell count (m/L)	580 (335)	633 (288)	587 (383)	467 (315)	Individual
Perceived ART efficacy rating	3.23 (0.58)	3.33 (0.55)	3.13 (0.64)	3.20 (0.51)	Individual
Depression (past 2 weeks)	20	19	21	21	Individual
Substance use (past 30 days)					Individual–interpersonal/network
Used marijuana	40	36	44	39	Individual–interpersonal/network
Used stimulant (cocaine/crack/methamphetamine)	23	15	30	25	Individual–interpersonal/network
Had sex while high	21	12	28	26	Individual–interpersonal/network
Had sex while drunk	20	16	23	21	Individual–interpersonal/network
Had 5 or more drinks in sitting	26	22	29	29	Individual–interpersonal/network
Condomless sex (any with serodiscordant last 3 months)	20	14	25	21	Individual–interpersonal/network
Medical mistrust, racial/ethnic subscale	2.28 (0.66)	2.20 (0.63)	2.39 (0.65)	2.26 (0.70)	Individual–institutional/health system
Care rating	8.74 (1.79)	9.09 (1.44)	8.29 (2.17)	8.82 (1.61)	Individual–institutional/health system
Doctor rating	8.87 (1.89)	9.08 (1.80)	8.54 (2.07)	9.00 (1.72)	Individual–institutional/health system
Internalized HIV stigma	2.65 (1.16)	2.67 (1.22)	2.64 (1.09)	2.64 (1.19)	Individual–community
Relationship status					Interpersonal/network
Single	72	72	72	74	Interpersonal/network
Steady relationship, not married/other	18	20	14	18	Interpersonal/network
Married/domestic partnership	10	8	13	8	Interpersonal/network
Social support	3.31 (1.12)	3.41 (1.19)	3.17 (1.06)	3.36 (1.08)	Interpersonal/network
HIV-related discrimination	1.29 (2.08)	1.20 (2.01)	1.27 (2.02)	1.46 (2.28)	Community
Income < $10,000 annually	32	34	30	31	Individual–structural
Currently stably housed	74	75	73	74	Individual–structural
Incarcerated past 3 months	8	5	6	13	Individual–structural
Education level completed					Individual–structural
< High school	17	18	16	16	Individual–structural
High school diploma or GED	36	35	37	38	Individual–structural
Some college	32	29	36	30	Individual–structural
College degree or more	15	18	11	16	Individual–structural
Current employment status					Individual–structural

Table 1 (continued)

Variable	% or mean (SD)				Corresponding socio-ecological level(s)
	Overall (N = 239)	High-stable (N = 95)	Moderately low-stable (N = 83)	Low-decreasing (N = 61)	
Full-time (40 or more hours/week)	5	4	7	3	Individual–structural
Part-time (< 40 h/week)	3	4	2	3	Individual–structural
Unemployed	66	62	65	74	Individual–structural
Retired	12	20	7	5	Individual–structural
Other	14	9	18	15	Individual–structural
Adherence (% doses per MEMS)					Outcome
Time 1	64.8 (33.9)	92.6 (9.9)	63.5 (24.8)	23.2 (23.8)	Outcome
Time 2	65.7 (32.8)	92.4 (10.4)	60.2 (24.7)	26.8 (26.4)	Outcome
Time 3	62.2 (34.1)	89.9 (13.7)	58.4 (23.9)	16.3 (20.5)	Outcome

had 5 or more drinks on at least one occasion?" This item was also dichotomized to indicate any binge drinking.

Sexual Risk Combined substance use and sexual behavior was assessed with two items from the Addiction Severity Index [79]: "In the last 30 days, how many times have you had sex when you were high on drugs?," and "In the last 30 days how many times have you had sex when you were drunk on alcohol?" Number of times participants have had condomless sex with a serodiscordant (HIV-negative) partner in the past 3 months was assessed for both receptive and penetrative anal and vaginal sex. These items were then combined into one condomless sex with serodiscordant partner item in the final analyses. Because the majority of participants (80%) did not report that they had engaged in these condomless behaviors, they were dichotomized (none vs any).

Individual–Institutional/Health System-Level Factors

Medical Mistrust Mistrust of health care organizations on issues related to race-ethnicity was assessed using 4 items from the Medical Mistrust Index [80]. Items included questions such as "racial discrimination in a doctor's office is common," and "in most hospitals, African Americans and Whites receive the same kind of care as everyone else" (reversed for analysis). Participants rated the extent to which they agreed with these statements on 4-point scale ranging from "strongly agree" to "strongly disagree." The items displayed adequate internal consistency (Cronbach's Alpha = 0.76) and the average score was utilized for analysis.

Healthcare and Doctor Ratings Two items were used from the Consumer Assessment of Health Plans Study [81]: participants were asked to rate the quality of their HIV medical care for the past 12 months on a scale ranging from 0 (worst medical care possible) to 10 (best medical care possible).

Participants were also asked to rate the quality of the HIV doctor they saw most often during the past 12 months on a scale ranging from 0 (worst doctor possible) to 10 (best doctor possible). The healthcare rating item and the doctor rating item were treated separately as single items for analytic purposes.

Individual–Community-Level Factors

Internalized HIV Stigma The extent to which participants experienced internalized HIV stigma was measured with 6 items adapted from the AIDS-Related Stigmas Scale [82]. Example items include "Being HIV positive makes me feel dirty," and "I am ashamed that I am HIV positive." Participants were asked to rate the extent to which they agree with the statement on a 5-point scale with items ranging from "strongly agree" to "strongly disagree." The items displayed good internal consistency (Cronbach's Alpha = 0.88) and the average score was utilized for analysis.

Interpersonal/Network-Level Factors

Relationship Status Participants were also asked whether they were currently single, in a steady relationship but not married, or currently married or in a domestic partnership. Relationship status was treated as single item for analytic purposes.

Social Support Social support was assessed on multiple dimensions using the 19-item Medical Outcomes Study Social Support Survey [83]. Items ask participants how often various kinds of support are available to them on a 5-point scale with answers ranging from "none of the time" to "all of the time". Sample items include "how often is… someone you can count on to listen to you when you talk… available to you?" and "how often is… someone to take you to the doctor of you need it… available to you?" The items displayed excellent internal consistency (Cronbach's

Alpha = 0.97) and the average score was utilized for analysis.

Community-Level Factors

HIV-Related Discrimination The extent to which participants experienced HIV-related discrimination was measured with the 10 HIV-related items from the Multiple Discrimination Scale [44]. Example items include "in the past year, were you ignored, excluded, or avoided by people close to you because you are HIV-positive?" and "In the past year, were you treated with hostility or coldness by strangers because you are HIV-positive?" Participants were asked to answer the questions with either "yes" or "no." The items displayed good internal consistency (Cronbach's Alpha = 0.86) and the sum score was utilized for analysis.

Individual–Structural-Level Factors

Several socio-demographic items were measured at the individual-level, but used as proxies for structural-level factors: income (dichotomized as less than $10,000 vs greater than or equal to $10,000 annually), stable housing (with stable housing coded as "rent or own home/apartment" or "publicly subsidized housing" versus unstable housing coded as "residential drug, alcohol or other treatment facility," "a friend or relative's home or apartment," "temporary or transitional housing," or "homeless: sleeping in a shelter or on the street"); recent incarceration (in the last 3 months); level of education completed (dichotomized as less than high school/GED vs high school degree/GED or more), and current employment status (dichotomized as unemployed, not working, or retired, vs working full-time or part-time).

Outcome Variable

Adherence Adherence was electronically monitored with the Medication Event Monitoring System (MEMS; AARDEX, Inc.), which measures each time the medication bottle is opened. In both studies, data were downloaded at 3 time-points, although the timing differed slightly across studies. In Mednet, MEMS data were downloaded at 2, 4, and 6 months post-baseline and in Rise, MEMS was measured at 1.5, 4.5, and 6 months post-baseline. We used MEMS software to calculate the percentage of doses taken in the past 2-weeks at each of these time-point. In addition, MEMS data were adjusted to account for participants' self-reported use of the cap not as intended in the past 2 weeks (e.g., bottle opened without removing a dose). These self-report responses were then used to adjust estimates of the percentage of doses taken [84].

Statistical Analysis

Descriptive statistics were first computed for all variables. A procedure written for SAS software (Proc TRAJ) was then used to identify clusters of individuals with similar progressions of adherence over time, by forming developmental trajectories estimated from the longitudinal data based on a semiparametric, group-based modeling strategy, and then assessing membership probabilities estimated in each group for every participant [85]. The Bayesian Information Criterion (BIC) was relied on for model selection as described by Jones and Nagin [86]. We then developed bivariate and multivariate multinomial logistic regression models to predict trajectory membership with the structural, institutional/health system, community, interpersonal/network, and individual-level factors. We compared pairs of trajectories for each predictor variable and developed a final multivariate model from predictors found to be significantly associated (p < 0.05) with membership in any pair of trajectories. To avoid issues with multicollinearity, we dropped any predictors correlated with others at r > 0.50, retaining the item with the stronger bivariate associations [87, 88]. Adherence was measured as percentage of doses taken (of those prescribed) per MEMS cap reading. Undetectable viral load and most recent CD4 count were associated with trajectory group membership but were dropped from the final multivariate model as these outcomes are highly associated with adherence.

Results

Adherence Modeling

Trajectory Analysis

Adherence progressions fit a three-group model over the three time-points (see Fig. 1). As shown in Table 1, 40.0% (n = 95) of participants were classified as having "high-stable adherence," with an average of 92.6% (SD 9.9) of doses taken at Time 1, 92.4% (SD 10.4) of doses taken at Time 2, and 89.9% (SD 13.7) of doses taken at Time 3. A total of 35.0% (n = 83) of participants were classified as "moderate-low-stable adherence," with an average of 63.5% (SD 24.8) of doses taken at Time 1, 60.2% (SD 24.7) of doses taken at Time 2, and 58.4% (SD 23.9) of doses taken at Time 3. The remaining 25.0% (n = 61) of participants were classified as "low-decreasing adherence," with 23.2% (SD 23.8) of doses taken at Time 1, 26.8% (SD 26.4) of doses taken at Time 2, and 16.3% (SD 20.5) of doses taken at Time 3.
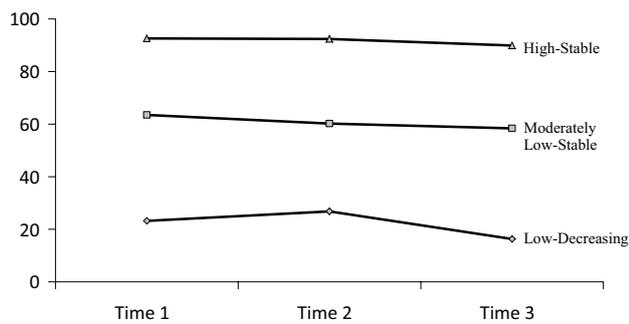
Fig. 1 Adherence trajectories by time

Bivariate Analysis

A separate bivariate model was run for each possible comparison group (Table 2). Bivariate results are presented by model below.

High-Stable Versus Low-Decreasing Adherence Groups

In terms of individual-level factors, the results of the bivariate analyses indicated significant differences in age between the high-stable and low-decreasing adherence groups (OR 1.05, 95% CI 1.02–1.09, p < 0.01) with younger participants significantly more likely to be in the low-decreasing group than in the high-stable group. Having an undetectable viral load was significantly associated with being in the high-stable adherence group over the low-decreasing group (OR 5.31, CI 2.63–10.70, p < 0.001). Having a higher most recent CD4 cell count (m/10 L) was significantly associated with being in the high-stable adherence group over the low-decreasing group (OR 1.02, CI 1.00–1.03, p < 0.001).

In terms of individual–interpersonal/network level factors, those who reported having recently had sex while high were less likely to be in the high-stable group than in the low-decreasing adherence (OR 0.36, CI 0.15–0.85, p < 0.05).

Moderately Low-Stable Versus Low-Decreasing Adherence Groups

One individual-level factor, having an undetectable viral load, was more highly associated with being in the moderately low-stable group than the low-decreasing group (OR 2.06, CI 1.04–4.08, p < 0.05).

High-Stable Versus Moderately Low-Stable Adherence Groups

In terms of individual-level factors, having an undetectable viral load had a greater association with being in the

high-stable group than the moderately low-stable group (OR 2.57, CI 1.36–4.85, p < 0.01). Higher ratings of ART efficacy were also associated with being in the high-stable adherence group over the moderately low-stable group (OR 1.85, 1.09–3.15, p < 0.05).

With respect to individual–interpersonal/network level factors, those who reported having recently used stimulants (e.g., cocaine, crack, methamphetamine) were less likely to be in the high-stable and more likely to be in the moderately low-stable adherence group (OR 0.41, CI 0.20–0.86, p < 0.05). Those who reported having recently had sex while high were less likely to be in the high-stable group than in the moderately low-stable adherence group (OR 0.36, CI 0.16–0.80, p < 0.05).

In terms of individual–institutional/health system factors, participants who rated their healthcare as worse overall were more likely to be in moderately low-stable adherence group than in the high-stable adherence (OR 1.32, CI 1.09–1.59, p < 0.01) group.

Multivariate Analysis

Based on the bivariate results, we built a multivariate binary logistic model including the predictor variables found to be significantly (p < 0.05) related to adherence group membership (see Table 3). Although significantly associated with adherence group membership, undetectable viral load and CD4 cell count were not included as these were viewed as individual-level outcomes rather than predictors of adherence. A significant model was achieved (Wald $\chi^2(10) = 28.56$, $p = 0.002$) with significant individual-level, individual–interpersonal/network-level, and individual-institutional/health system-level factors. Specifically, being older was related to a higher probability of being in the high-stable group than in the low-decreasing adherence group (OR 1.05, CI 1.02–1.09, p < 0.01). Higher ART efficacy perceptions were related to a higher probability of being in the high-stable adherence group than in the moderately low-stable group (OR 1.81, CI 1.04–3.13, p < 0.05). Using stimulants was related to a lower probability of being in the high-stable group than in the moderately low-stable adherence group (OR 0.39, CI 0.18–0.83, p < 0.05). Higher overall healthcare ratings were related to a higher probability of being in the high-stable than in the moderately low-stable group (OR 1.30, CI 1.07–1.56, p < 0.01) and a higher probability of being in the moderately low-stable group than in the low-decreasing adherence group (OR 0.82, CI 0.67–1.00, p < 0.05).

Table 2 Bivariate analyses of predictors by adherence trajectory group

Variable	Odds ratio (95% confidence interval)			Corresponding socio-ecological level
	High-stable vs low-decreasing	Moderately low-stable vs low-decreasing	High-stable vs moderately low-stable	
Age (years)	1.05 (1.02–1.09)**	1.03 (1.00–1.06)+	1.02 (0.99–1.06)	Individual
Female (biological and MTF transgender)	1.70 (0.77–3.76)	1.72 (0.76–3.89)	0.99 (0.51–1.91)	Individual
Heterosexual orientation	1.76 (0.86–3.61)	1.61 (0.77–3.37)	1.09 (0.59–2.03)	Individual
Time since diagnosis (years)	1.00 (0.96–1.05)	0.98 (0.93–1.02)	1.03 (0.99–1.07)	Individual
Undetectable viral load	5.31 (2.63–10.70)***	2.06 (1.04–4.08)*	2.57 (1.36–4.85)**	Individual
Most recent CD4 cell count (m/10 L)	1.02 (1.00–1.03)***	1.01 (1.00–1.02)+	1.00 (0.99–1.01)	Individual
Perceived ART efficacy rating	1.54 (0.85–2.78)	0.83 (0.48–1.46)	1.85 (1.09–3.15)*	Individual
Depression (past 2 weeks)	0.90 (0.40–2.01)	0.99 (0.43–2.24)	0.91 (0.44–1.91)	Individual
Substance use (past 30 days)				Individual–interpersonal/network
Used marijuana	0.85 (0.44–1.66)	1.21 (0.61–2.38)	0.70 (0.38–1.30)	Individual–interpersonal/network
Used stimulant (cocaine/crack/ methamphetamine)	0.53 (0.24–1.21)	1.31 (0.61–2.79)	0.41 (0.20–0.86)*	Individual–interpersonal/network
Had sex while high	0.36 (0.15–0.85)*	1.00 (0.47–2.15)	0.36 (0.16–0.80)*	Individual–interpersonal/network
Had sex while drunk	0.68 (0.30–1.57)	1.05 (0.47–2.36)	0.65 (0.30–1.39)	Individual–interpersonal/network
Had 5 or more drinks in sitting	0.67 (0.31–1.43)	1.02 (0.48–2.16)	0.66 (0.33–1.33)	Individual–interpersonal/network
Condomless sex (any with sero-discordant last 3 months)	0.58 (0.21–1.58)	1.22 (0.48–3.11)	0.48 (0.19–1.17)	Individual–interpersonal/network
Medical mistrust, racial/ethnic subscale	0.86 (0.52–1.41)	1.34 (0.80–2.24)	0.64 (0.40–1.02)+	Individual–institutional/health system
Care rating	1.11 (0.89–1.37)	0.84 (0.69–1.01)+	1.32 (1.09–1.59)**	Individual–institutional/health system
Doctor rating	1.01 (0.84–1.23)	0.86 (0.72–1.03)	1.18 (1.00–1.39)+	Individual–institutional/health system
Internalized HIV stigma	1.02 (0.77–1.34)	1.00 (0.75–1.33)	1.02 (0.79–1.32)	Individual–community
Married/domestic partnership	1.02 (0.32–3.28)	1.69 (0.55–5.16)	0.60 (0.23–1.58)	Interpersonal/network
Social support	1.04 (0.78–1.40)	0.86 (0.64–1.16)	1.22 (0.93–1.59)	Interpersonal/network
HIV-related discrimination	0.95 (0.81–1.11)	0.97 (0.83–1.13)	0.98 (0.85–1.14)	Community
Income < $10,000 annually	0.98 (0.49–1.93)	1.21 (0.60–2.47)	0.80 (0.43–1.51)	Individual–structural
Currently stably housed	1.01 (0.48–2.12)	0.93 (0.44–1.99)	1.09 (0.55–2.14)	Individual–structural
Incarcerated past 3 months	0.37 (0.11–1.18)+	0.42 (0.13–1.35)	0.88 (0.25–3.17)	Individual–structural
Education < high school	1.06 (0.45–2.52)	0.88 (0.36–2.19)	1.20 (0.54–2.66)	Individual–structural
Employed (full-time or part-time)	1.27 (0.36–4.43)	1.45 (0.41–5.09)	0.87 (0.31–2.45)	Individual–structural
Adherence (% doses per MEMS)				Outcome
Time 1	1.17 (1.13–1.21)***	1.07 (1.05–1.09)***	1.09 (1.06–1.12)***	Outcome
Time 2	1.14 (1.10–1.17)***	1.04 (1.02–1.06)***	1.09 (1.07–1.12)***	Outcome
Time 3	1.13 (1.10–1.16)***	1.05 (1.03–1.06)***	1.08 (1.06–1.11)***	Outcome

+$p < 0.10$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Discussion

This study sought to delineate the longitudinal trajectories of ART adherence among BPLWH across three assessments that took place over 6 months, and to examine the multilevel socio-ecological factors associated with membership in each trajectory group. Participants fell into one of three ART adherence trajectory groups: high-stable, moderately low-stable, and low-decreasing, with the majority (75%) in either the high- or low- two stable adherence categories. Although prior research has examined adherence trajectories [68–73], this study extends previous work by examining

Table 3 Multivariate analyses of predictors by adherence trajectory group

Variable	Odds ratio (95% confidence interval)			Corresponding socio-ecological level
	High-stable vs low-decreasing	Moderately low-stable vs low-decreasing	High-stable vs moderately low-stable	
Age (years)	1.05 (1.02–1.09)**	1.03 (1.00–1.07)[+]	1.02 (0.99–1.05)	Individual
Perceived ART efficacy rating	1.66 (0.91–3.06)	0.92 (0.52–1.65)	1.81 (1.04–3.13)*	Individual
Used stimulant past 30 days (cocaine/crack/methamphetamine)	0.55 (0.24–1.27)	1.41 (0.65–3.05)	0.39 (0.18–0.83)*	Individual–interpersonal/network
Care rating	1.06 (0.85–1.32)	0.82 (0.67–1.00)*	1.30 (1.07–1.56)**	Individual-institutional/health system

[+]$p < 0.10$, *$p < 0.05$, **$p < 0.01$

such trajectories among BPLWH who generally show low adherence and viral suppression rates [89], using electronically monitored adherence data.

Trajectories were generally flat, suggesting that there is a tendency towards consistency within different adherence groups irrespective of particular group membership. However, this finding should be interpreted with caution, as participants were only followed for a 6-month period of time. Factors at multiple socio-ecological levels were associated with ART adherence. In particular, individual-level factors associated with suboptimal adherence included being of younger age and perceiving ART to be less efficacious. These findings suggest that increasing trust in the efficacy of ART should be a focus of future adherence interventions and that interventions should be specifically developed for younger BPLWH.

With regard to an individual-interpersonal/network-level factor, use of stimulants was predictive of trajectory group membership. Previous work has shown that the use of stimulants is highly associated with decreased odds of ART adherence and persistence, elevated viral load, and elevated risk for HIV transmission [60, 90, 91]. The BPLWH in the current study were significantly more likely to be in the low adherence group if they reported stimulant use. Recent research has shown evidence that cognitive behavioral therapy (CBT) and combined CBT plus medication assisted treatment (MAT) may be effective in treating stimulant use and improving ART adherence among people living with HIV [90, 92, 93]. Future research efforts could tailor and evaluate these treatments for BPLWH stimulant users specifically.

An individual-institutional/health system-level factor, overall perceptions of healthcare, was also significantly predictive of trajectory group membership. Previous negative encounters with healthcare institutions and providers have helped to explain the poorer outcomes of HIV care among BPLWH [94]. The quality of relationships with healthcare providers has also been shown to affect ART adherence

[95–97]. These findings underscore the need for BPLWH to have access to high quality HIV services and providers who can foster strong relationships and provide a safe space where BPLWH can receive culturally competent, non-judgmental HIV care services.

The current study has several limitations. The sample size was relatively small and there was a limited number of assessments for a trajectory analysis, and thus some variables may not have been significant due to a lack of statistical power. In addition, some important structural and healthcare variables such as access to care were not measured and may be barriers to adherence. Although methods and research staff were mostly consistent, data points were combined over two different studies over a 5-year timespan, and the length of time between assessment time-points varied slightly. Given the idiosyncrasies in these data as well as the need to drop certain predictors due to multicollinearity, the reproducibility of these findings is uncertain. Future work should involve the replication and extension of these findings with a larger sample size, with a greater number of assessment points over a longer time-span, and include additional social-ecological predictors [11].

Overall, findings from the current study suggest that there are several key factors located within and across multiple socio-ecological levels that contribute to ART adherence group membership among BPLWH. Several interventions have shown promise of increasing engagement in HIV care and improving ART adherence [76, 98–100]. However, most interventions have not been tailored to address the specific needs of BPLWH, for example, by addressing key factors such as perceptions of HIV medication efficacy and mistrust of HIV-related healthcare services, interventions may further improve overall adherence rates among BPLWH. Further, given our findings regarding the effect of stimulant use on adherence trajectory group membership, cognitive behavioral and other evidence-based approaches that focus on increasing coping skills, regulating emotions, and reducing

stimulant use also need to be tailored for, and targeted to BPLWH.

Compliance with Ethical Standards

Conflict of interest All authors declare that no conflicts of interest exist.

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.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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