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Synergistic Effects of Food Insecurity and Drug Use on Medication Adherence among People Living with HIV Infection

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Abstract

Food insecurity and drug use are closely connected in the context of poverty, and both have been suggested to interfere with HIV medication adherence among people living with HIV/AIDS (PLWH). Yet the potential interaction between the two factors on adherence has not been examined. For this study we collected longitudinal data on HIV medication adherence among PLWH in Atlanta, GA, to assess a possible synergistic effect between the two factors on HIV medication adherence. People informed about the study came to the research site and completed an audio computer-assisted self-interview and instructions for pill counting. Over the next five weeks participants received three unscheduled follow-up phone assessments conducted two weeks apart to collect pill counts of their HIV medication. The prevalence of food insecurity was 60% (488) and that of drug use was 33% (274) in the sample of 809 participants. Among 770 participants who completed follow-up phone assessments, both food insecurity and drug use were associated with HIV medication adherence after adjusting for socio-demographic characteristics. The negative association between drug use and adherence persisted after further adjusting for health-related characteristics. Moreover, drug use appeared to moderate the effect of food insufficiency on adherence, with drug users who were food insufficient being the least likely to achieve 85% adherence. Results from the current study demonstrate a synergism between food insecurity and drug use that may impede adherence among PLWH. The findings imply that the disruptive effects of food insecurity and drug use on adherence are likely to be intensified with the presence of each other, and encourage interventions to address the problem of HIV medication adherence from a multi-faceted perspective that takes into account detrimental combination of problem factors.

Keywords

Food insecurity; Drug use; HIV; ART; Adherence

INTRODUCTION

Food insecurity, defined as ‘limited or uncertain availability of nutritionally adequate and safe foods, or limited ability to acquire acceptable foods in socially acceptable ways’, is prevalent among people living with HIV/AIDS (PLWH), including those living in resource

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rich countries (USDA, 2006). The prevalence of food insecurity among PLWH in the United States and Canada is estimated to exceed 50% (Normen et al., 2005; Weiser, Bangsberg, et al., 2009; Weiser, Fernandes, et al., 2009). Growing evidence links food insecurity to incomplete and unsuccessful HIV treatment (Au et al., 2006; Weiser, Fernandes, et al., 2009; Weiser et al., 2011). Two prospective studies have shown that food insecurity predicts non-adherence (adherence rate lower than 90%) to HIV medication among PLWH in rural Uganda and among homeless PLWH in USA (Weiser, Fernandes, et al., 2009; Weiser, Frongillo, et al., 2009). Similar findings were also reported in a cross-sectional study in which food insecurity was associated with less than 95% of adherence among PLWH in Congo (Musumari et al., 2014). Although one cross-sectional study failed to show an association between food insecurity and non-adherence (Anema et al., 2013), most research supports a relationship between the two.

Food insecurity is one of several co-occurring adverse conditions of poverty that affects anti-retroviral therapy (ART) adherence (Leaver, Bargh, Dunn, & Hwang, 2007; Miller et al., 2011; Piot, Greener, & Russell, 2007). Among other poverty-related characteristics, illicit drug use is intimately related to food insecurity (Hendricks & Gorbach, 2009). Approximately 30%-70% of drug using-individuals experience some level of food insecurity (Anema et al., 2013; Anema et al., 2010; Strike, Rudzinski, Patterson, & Millson, 2012). Moreover, both drug use and food insecurity have been found to compromise pharmacokinetic efficacy of ART, reduce immunological response, and increase mortality of PLWH (Anema, Vogenthaler, Frongillo, Kadiyala, & Weiser, 2009; Antoniou & Tseng, 2002). A recent study of injection drug users living with HIV showed that those who were food insecure when first initiating ART were twice as likely to die compared to those who were food secure (Anema et al., 2013). Similar to food insecurity, drug use was also associated with poorer adherence. One study for example found drug use to be associated with over a fourfold greater risk of <90% of adherence among PLWH in Los Angeles (Hinkin et al., 2007).

The interplay between food insecurity and illicit drug use can be discussed in the framework of “syndemics” – the co-occurrence of multiple interactive health-related problems that interact at biological and social level (Singer & Clair, 2003). The emergence of a syndemic is of particular concern in public health because it represents an aggregation of adverse conditions and the potential for multiple conditions to synergize and exacerbate burden of disease (Alcabes, Schoenbaum, & Klein, 1993; Ensoli & Sirianni, 2002; Rose, Sinka, Watson, Mortimer, & Charlett, 2002). While previous research has examined the co-occurrence of HIV infection, food insecurity and substance use, we are not aware of any study to examine the potential synergistic effect between substance use and food insecurity on HIV treatment adherence.

The current study seeks to fill an important gap in research by assessing the moderating effects of substance use on the association between food insecurity and anti-retroviral therapy adherence in PLWH. Adherence to ART is a critical predictor of treatment success and HIV-related survival. Sub-optimal adherence will lead to a series of clinical consequences including failure of viral suppression, emergence of drug resistance, increased progression of disease and greater mortality (Bartlett, 2002; Sethi, Celentano, Gange,

Moore, & Gallant, 2003; Wood et al., 2006). Consistently higher ART adherence is also essential to reducing the risk of sexual transmission of HIV (Cohen et al., 2011). Based on previous research findings and given the implications of a potential interactive relationship between co-existing health problems in the framework of syndemics, we hypothesize that the combination of food insecurity and active substance use may have more detrimental effects on health behaviors and health outcomes than either condition alone. Specifically, we hypothesized that food insecurity and drug use would both be associated with poorer ART adherence among PLWH. In addition, we predicted that the association between food insecurity and ART adherence would be moderated by drug use, such that drug-using individuals who experience food insecurity would demonstrate the poorest levels of ART adherence relative to others who are either food insecure or using drugs, or neither food insecure nor using drugs.

METHOD

Research setting

The site of the study was in Atlanta, Georgia, which had 23,138 reported cases of HIV infection, with an incidence rate of 30.3 per 100,000 population in 2010. This number exceeds the average rate of 19.6 per 100,000 population in major US cities. The poverty rate (24.4%) in Atlanta was also much higher than the average rate (13.7%) in the state of Georgia. The research base for the current study was located in a local community in Atlanta.

Participant Recruitment and Eligibility

Participants were informed about the study by word-of-mouth and through flyers at AIDS social service providers and infectious disease clinics. Each participant was given three study flyers to distribute to other PLWH they know. Eligible participants needed to be age 18 or older, being HIV positive and were currently taking HIV medication. All potential participants were asked to present proof of positive HIV status, and show a photo ID with matching ART prescription bottle. Eligible participants were provided with informed voluntary written consent to participate.

Procedures

The study was conducted in the pre-randomization period of an intervention trial for the purpose of collecting prospective baseline measures of ART adherence among potential participants. The entire study lasted approximately five weeks. Eligible participants first went through an informed consent process after which they were trained in the study procedures. Participants consented into the study then completed an audio computer-assisted self-interview (ACASCI). Each participant was then provided with a service-restricted cell phone for project contacts and emergency use (e.g. 911). Over the next month each participant was given three unscheduled phone assessments conducted two weeks apart. The phone assessments were conducted by trained phone assessors and primarily measured ART adherence using unannounced pill counts. Participants also provided their most recent HIV RNA (viral load) and CD4 cell counts from their medical records. The study procedures were approved by the University of Connecticut Institutional Review Board.

Measures

Demographic Characteristics—Participants provided basic demographic information regarding their age, sex, level of education (from 6th grade to completed college), annual income, ethnicity and etc.

Food Insecurity—We used eight items from the US Food Security Scale that have been validated in the past research and used by the US Census Bureau (Coates, Swindale, & Bilinsky, 2007). Food insecurity indicators were collected with respect to whether the participant had ever experienced a series of situations related to food insufficiency and food security. A detailed list of the indicators can be found in Table 1.

Current Drug Use—Drugs assessed in the study were marijuana, powder/ crack cocaine, poppers/nitrite inhalants, methamphetamine/crystal meth, and any injected drugs. Participants were asked the frequency by which they use each drug in the past month. Those who had used any one of the listed drugs at least once in the past month were categorized into the drug-using group, while those who reported zero use of all drugs were placed into non-drug-using group.

Alcohol use—The 3-item Consumption Subscale of the Alcohol Use Disorder Identification Test (AUDIT-C) was used to assess frequency and quantity of alcohol use (Maisto, Conigliaro, McNeil, Kraemer, & Kelley, 2000). The final score is on a scale of 0-12 and men with a score of 4 or more or women with a score of 3 or more were considered as heavy drinkers.

ART Side Effects—We measured side effects of ART through 11 symptoms including nausea, diarrhea, stomach pain, and etc. Responses to each item ranged between 0=not experiencing to 3=severely experiencing and were summed into a final composite score with higher scores indicating stronger side effects (Carrieri, Villes, & 2007).

Depression—We used the 20-item Center for Epidemiologic Studies Depression Scale (CES-D) to assess symptoms of depression (Radloff, 1977). Based on the established scoring system, the final score (0-60) was categorized into no depression (<15), mild to moderate depression (15-21), and major depression (>21).

Adherence Self-efficacy—This 14-item measure (Cronbach's alpha = 0.95) was adapted from the HIV Adherence Self-Efficacy Scale (HIV-ASES) with two additional items (i.e. "How certain are you that you can follow your doctor's order?"; "How certain are you that you can keep your next doctor's appointment?").

ART Adherence—Telephone-based unannounced pill counts have been validated as a reliable and accurate measure of HIV treatment adherence (Kalichman et al., 2008). Each participant was given an office-based training session in the procedure of pill counting at baseline. Pill counts were conducted for each of the antiretroviral medications taken by the participants. Pharmacy information from pill bottles of each medication was also obtained to verify the number of pills dispensed between calls. Adherence was calculated as the ratio

(percentage) of pills counted relative to pills prescribed, taking into account the number of pills dispensed. Two consecutive pill counts were necessary for computing one adherence data point and the three assessments produced two adherence data points for each participant. Optimal adherence is defined as having an adherence ratio at 85% of ART medications taken over the 4 week period (Bangsberg, Kroetz, & Deeks, 2007).

CD4 Cell Count and Viral Load—We used medical record-abstracted values of most recent absolute CD4 cell counts and PCR determined viral load. Chart-abstracted values were used for continuous absolute measures of CD4 count and viral loads with <75 copies/ml being coded as undetectable viral load.

Analysis

Data were analyzed using Stata (version 12) (StataCorp., 2011). In the initial descriptive analyses, we compared people with and without food insecurity among drug users and non-drug users respectively. For the ease of description, we categorized education into below and above college level, CD4 cell count into above or below 200, and viral load into undetectable or detectable. Side effects and adherence self-efficacy were dichotomized at the median. We also report descriptive statistics by adherence status, using Wilcoxon rank-sum test for continuous variables, and χ^2 test for categorical variables. We then assessed bivariate associations of optimal adherence with relevant variables, using generalized estimating equation (GEE) modeling for logistic regression with robust variance estimator to adjust for within-participants correlation. All variables were kept in their observed forms during regression analysis, expect for viral load which was log transformed.

In the multivariate GEE analysis, we adopted a hierarchical multiple regression approach by dividing variables into three blocks. The first block “food and drug” was initially introduced in the model, followed by block 2 “social demographic characteristics”, and then block 3 “biomarkers and adherence-related characteristics”. Variables were selected into multiple regression models based on previous literature and bivariate associations, as well as examination of multi-collinearity, and QIC (quasilikelihood under the independence model criterion) score (Pan, 2001). Educational level, income and gender were therefore excluded from the models for being unassociated with adherence and costly to model parsimony. CD4 cell count was kept in the model given its conceptual relevancy despite of being insignificantly associated with adherence in the current sample. To test the existence of a potential interaction between food insecurity and substance use on ART adherence, we introduced an interaction term in the final model after controlling for relevant variables. All models were adjusted for the two time-points of data collection. A sensitivity analysis was also performed using 90% and 95% cut-off point for optimal adherence and the results were not materially different from analysis using 85% adherence.

RESULTS

Distribution of Food Insecurity Indicators by Drug-using Status

The percentages of participants experiencing each indicator of food insecurity are shown by drug-using status in Table 1. The indicators were listed in an increased order of severity, and

there was a declining trend in the prevalence of each condition as the severity increased. Drug-using participants were significantly more likely to experience each condition of food insecurity compared to non-drug users.

Food Insecurity and Relevant Characteristics by Drug-using Status

Among 809 study participants, 488 (60.32%) were food insecure and 274 (33.87%) were current drug users. The prevalence of food insecurity was 71.53% within drug users, and 54.58% within non-drug users. Food insecurity and drug use overlapped among 196 (24.23%) participants. Table 2 compares the demographic, health and psychosocial characteristics of participants who were food secure and insecure by drug-using status. We found that participants who were food insecure were younger, with less people above 50 years of age than those who had sufficient food. Food insecure participants were more likely to have severe depressive symptoms, experience side effects from ART and express lower adherence self-efficacy. Overall 75.38% of food insecure participants failed to achieve optimal adherence, and a comparable proportion (71.72%) of drug using participants also failed to do so. Patterns of moderation by drug using status also emerged in descriptive analysis. Nearly half (47.06%) of the food insecure drug users did not achieve optimal adherence, but this proportion dropped to 25.54% among people who were both food secure and not using drugs. Among drug users, participants who were food insecure were more likely to have detectable viral load as compared to those who were food secure. Among non-drug users, participants who were food insecure appeared to have earned less income, and have lower level of CD4 cell counts than those who were food secure.

Bivariate Associations between Optimal Adherence and Relevant Factors

Participant characteristics by optimal adherence are shown in Table 3. Follow-up adherence data were available among 770 participants. On average, a total of 244 (31.69%) participants failed to achieve optimal adherence. Both food insecurity and drug use were negatively associated with optimal adherence. Participants who achieved optimal adherence were older on average than those who did not. Participants who reported higher adherence self-efficacy were more likely to be adherent, while those who took more HIV medications per day, reported more side effects, had higher viral load and engaged in heavy drinking were less likely to achieve optimal adherence.

Multivariate Modeling of Food Insecurity, Drug use, and Optimal Adherence

Results of multivariate analyses are presented in Table 4. Food insecurity and drug use were both associated with lower odds of optimal adherence in Model 1(AOR: 0.68, 95%CI: 0.51-0.89 for food insecurity, AOR: 0.57, 95%CI: 0.43-0.74 for drug use). The inclusion of social demographic characteristics in Model 2 did not affect the magnitude and statistical significance of the two associations. Controlling for health characteristics and adherence-related factors in Model 3 diminished the effect of food insecurity on adherence to be non-significant, but the association between drug use and adherence still remained (AOR: 0.61, 95%CI: 0.46-0.81). We also observed a significant moderating effect of drug use on the relationship between food insecurity and treatment adherence (see Figure 1). As reflected in Model 4, food insecurity was not associated with adherence for non-drug users, but among people who were currently using drugs, food insecurity was associated with a 50% drop in

the odds of optimal adherence (AOR: 0.50, 95%CI: 0.29-0.87). In addition to food insecurity and drug use, factors also associated with suboptimal adherence were: age, ethnicity, number of HIV medications, and heavy drinking. Each year in age was associated with a 2% increase in the odds of optimal adherence (AOR: 1.02, 95%CI: 1.00-1.04); compared to non-African-American, African-American participants were half as likely to achieve optimal adherence (AOR: 0.53, 95%CI: 0.30-0.93); and heavy drinkers were 32% less likely to achieve optimal adherence as non- or light drinkers (AOR: 0.68, 95%CI: 0.49-0.95). These associations were stable across models 3 and model 4.

DISCUSSION

This study represents one of the first efforts to explore the interaction between food insecurity and drug use in relation to ART adherence. Findings from the current study demonstrated a synergism between food insecurity and drug use that may impede adherence among PLWH. Both food insecurity and drug use were prevalent within the sample, but it is noticeable that the prevalence of food insecurity is exceptionally high given that the study population is from a resource rich country. The proportion of people who were food insecure nearly doubled that of drug use. Food insecurity and drug use overlapped among a quarter of the participants, who were much less likely to achieve optimal adherence as compared to people with only one or none of the adherence risk factors.

Younger age was associated with poor ART adherence in the current study. This finding was consistent with those from other studies. Being younger has been found to be associated with lower compliance to HIV treatment among HIV/AIDS outpatients in French and among HIV seropositive injection drug users in Canada (Peretti-Watel et al., 2006; Shannon et al., 2011). Also age as a reflection of longevity may be positively associated with adherence because PLWH who were more adherent were more likely to live longer. Some researchers suggest that younger PLWH were less adherent because they perceived low treatment utility (Barclay et al., 2007), or they could not afford their medical visits and medication copayments (Hadland et al., 2012). We therefore encourage future studies to further explore these possibilities.

The interaction between substance use and food insecurity found in the current study may imply that the association between food insecurity and adherence is not a simple and isolated relationship, and rather it needs to be understood in the context of potential moderators. In fact, a close examination of previous studies suggests a pattern of food insecurity as being a barrier among PLWH with certain characteristics. A cross-sectional study from France, for example, reported that food insecurity was associated with non-adherence among heterosexual men but not women (Peretti-Watel et al., 2006). A prospective study from the US documented an adverse effect of food insecurity on adherence among people who live outside the city but not inside (Kalichman et al., 2011). Similarly, the current study showed that food insecurity predicted suboptimal adherence among drug users but not non-drug users. These findings suggest that the disruptive effect of food insecurity on adherence is likely to be intensified with the presence of another intersecting factor. Studies are needed to identify the interplay among factors that may lower ART adherence synergistically in combination with food insecurity.

Our finding that food insecurity was particularly detrimental to ART adherence among individuals using illicit drugs suggests a mutual enhancement between food insecurity and substance use. This finding coincides with the concern of an intertwining relationship between food insecurity and illicit drug use in the HIV epidemic. Researchers have proposed several mechanisms that may underlie the mutually enhancing relationship between food insecurity and drug use. Drug addiction for example may alter dietary consumption patterns and lead to fewer meals (Himmelgreen et al., 1998) and significantly less energy consumption (Campa et al., 2005). Apart from being calorically insufficient, diets of illicit drug users also tend to be poor in quality (Campa et al., 2005), and many of the drug users actually rely on food distribution services for subsistence (Romero-Daza N., Himmelgreen D.A., Pérez-Escamilla R., Segura-Millán S., & M., 1999). These situations are further aggravated by an increasingly chaotic lifestyle among drug users (Campa et al., 2005; Weiser, Bangsberg, et al., 2009). Additionally, we also speculate that the synergistic effect between food insecurity and drug use may be due to their competitive relationship over resources. Drug addiction creates a basic physiological need, in parallel to hunger and the need for food. Resolving these two physiologic needs with limited resources will be more taxing than satisfying either of the two needs alone, especially for people struggling with HIV infection. Therefore a combination of the two factors may pose greater threat for PLWH regarding their medication adherence. This potential mechanism is in need of future research as it indicates avenues for simultaneous interventions to address food insecurity and drug use.

The findings from the current study should be interpreted in light of the following limitations. Except for ART adherence, viral load, and CD4 cell count, all other measures were collected through self-report and may be subject to social desirability and recall bias. Of particular importance is the use of self-report for assessing illegal drug use. Thus, the rates of substance use, where were high in this sample, may be suppressed and should be considered a lower-bound estimate. In addition, our study is based on a convenience sample of PLWH in one southern US city and caution is warranted before generalizing the findings from this study to other PLWH. Additionally, food insecurity and drug use were only measured at baseline, we were unable to assess the effect of changes in the status of food sufficiency or drug use on ART adherence. We also do not know the nutritional quality of participants' food or the accurate frequency and dosing of drug use. With these limitations in mind, the current research provides implications for understanding the interrelationship between food insecurity and drug use from the perspective of HIV treatment management.

The value of HIV treatment adherence lies not only in the restoration and maintenance of health among PLWH, but also in the reduction of HIV transmission. The criticality of treatment adherence has posed an urgency to identify modifiable factors associated with ART non-adherence. Food insecurity and illicit drug use are both associated with ART non-adherence. Yet the negative impact of both factors on ART adherence may be further amplified by their co-occurrence. Multiple adverse conditions may therefore pose significant threats to improving HIV treatment engagement, adherence, and prevention. Interventions should be the focus of efforts to improve ART adherence and HIV-related health outcomes. Of particularly urgency are interventions that address co-occurring conditions of poverty as these approaches will offer considerable opportunities to improve ART adherence. Food

insecurity interventions such as free food assistance and micronutrient supplementations may be viewed as gateway to adherence interventions, especially among HIV infected drug users. Adherence intervention may seek collaboration with food distribution programs to provide food and nutrition support to food insecure PLWH, along with its effort to alleviate the negative impact of drug use on HIV medication adherence. Establishing food security and reducing drug use simultaneously should be expected to resolve the synergistic effects of multiple impediments and improve mediation adherence. Coordination between multiple social programs to address co-occurring issues among PLWH may help to generate a stronger overall effect on improving HIV medication adherence and treatment outcomes.

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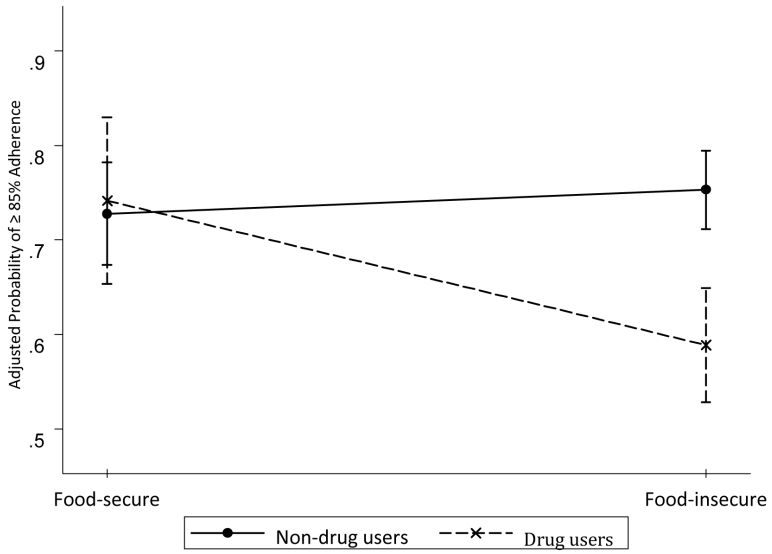

Figure 1.

Food insecurity–drug use interaction on probability of optimal adherence (with 95% CI), adjusting for all covariates.

Table 1

Distribution of food insecurity indicators by drug-using status*

	Drug users (N=274)	Non-drug users (N=535)
Items of food insecurity*	**%(n)**	**%(n)**
1. Worried if food would run out before having money to buy more.	64.23(176)	48.22(258)
2. Food didn't last and didn't have money to get more.	66.42(182)	48.22(258)
3. Couldn't afford to eat balanced meals.	61.31(168)	44.67(239)
4. Adults in household cut meal size for not having money for food.	46.72(128)	30.84(165)
5. Eat less than one felt like eating for not having money for food.	53.28(146)	32.90(176)
6. Being hungry without eating for not being able to afford food.	40.88(112)	21.50(115)
7. Lose weight for not having enough money for food.	34.67(95)	15.70(84)
8. Adults in household not eat for a whole day for no money for food.	20.44(56)	10.09(54)

* Distribution of each indicator differs by drug-using status at significance level of p=0.001

Table 2

Baseline characteristics of participants by status of food security and substance use (N=813)

	HIV+ Drug Users			HIV+ Non-drug Users		
	Food secure (n=78)	**Food insecure (n=196)**	**p-value**	**Food secure (n=243)**	**Food insecure (n=291)**	**p-value**
Age			0.003			<0.001
≤30	10.26(8)	8.67(17)		2.88(7)	7.90(23)	
30-50	37.18(29)	59.18(116)		41.98(102)	55.67(162)	
≥50	52.56(41)	32.14(63)		55.14(134)	36.43(106)	
Gender			0.066			0.897
Female	10.26(8)	19.49(38)		35.12(85)	34.59(101)	
Male	89.74(70)	80.51(158)		64.99(157)	65.41(191)	
Education			0.567			0.602
Below college	48.72(38)	44.90(89)		52.26(127)	50.00(146)	
College and above	51.28(40)	55.10(108)		47.74(116)	50.00(146)	
Annual income			0.543			0.003
$0-$10,000	64.10(50)	66.84(131)		58.85(143)	72.16(210)	
$11,000-$20,000	25.64(20)	27.55(54)		30.45(74)	21.65(63)	
$21,000-$30,000	6.41(5)	4.08(8)		4.94(12)	4.47(13)	
Over $30,000	3.85(3)	1.53(3)		5.76(14)	1.72(5)	
Ethnicity			0.941			0.558
Non-African-American	11.54(9)	11.22(22)		7.82(19)	9.25(27)	
African-American	88.46(69)	88.78(174)		92.18(224)	90.75(265)	
Side effect (range: 0-36)			<0.001			<0.001
≤5	74.36(58)	38.27(75)		74.07(180)	45.55(133)	
>5	25.64(20)	61.73(121)		25.93(63)	54.45(159)	
CD4 cell count			0.588			0.053
≤200	14.85(11)	17.65(33)		12.89(29)	19.54(53)	
>200	85.14(63)	82.35(154)		87.11(196)	80.66(221)	
Viral load			0.001			0.333
Undetectable (<75)	66.22(49)	43.09(81)		56.89(128)	52.55(144)	
Detectable (≥75)	33.78(25)	56.91(107)		43.11(97)	47.45(130)	
Heavy drinker			0.147			0.474
No	75.64(59)	66.67(130)		88.38(213)	86.30(252)	
Yes	24.36(19)	33.33(65)		11.62(28)	13.70(40)	
Adherence self-efficacy			<0.001			<0.001
<8	33.33(26)	66.67(130)		34.98(85)	55.48(162)	
≥8	66.67(52)	33.33(65)		65.02(158)	44.52(130)	
Depression			<0.001			<0.001
None	57.69(45)	20.92(41)		60.08(146)	28.77(84)	
Mild/moderate	25.64(20)	24.49(48)		20.99(51)	25.34(74)	
Major	16.67(13)	54.59(108)		18.93(46)	45.89(134)	

	HIV+ Drug Users			HIV+ Non-drug Users		
	Food secure (n=78)	**Food insecure (n=196)**	**p-value**	**Food secure (n=243)**	**Food insecure (n=291)**	**p-value**
Average adherence ≥ 85%			0.001			0.483
No	24.66(18)	47.06(88)		25.54(59)	28.32(79)	
Yes	75.34(55)	52.94(99)		74.46(172)	71.68(200)	

Table 3

Bi-variate analysis of optimal adherence using GEE with robust variance estimator

	Average adherence<85%	Average adherence≥85%		Optimal adherence (≥85%)	
	(n=244)	(n=526)	P-value	OR	95%CI
Food and Drug					
Food insecurity (n, %)			0.002		
No	25.33(77)	74.67(227)		REF	REF
Yes	35.84(167)	64.16(299)		0.62**	(0.47-0.81)
Drug use (n, %)			<0.001		
No	27.06(138)	72.94(372)		REF	REF
Yes	40.77(106)	59.23(154)		0.53***	(0.41-0.70)
Social Demographic Characteristics					
Age (mean, sd)	45.57(9.54)	47.64(8.34)	0.013	1.03***	(1.01-1.04)
Gender			0.682		
Female (n, %)	32.783(72)	67.27(148)		REF	REF
Male (n, %)	31.20(171)	68.80(377)		0.96	(0.72-1.28)
Education (mean, sd)	12.52(1.85)	12.67(1.77)	0.310	1.04	(0.97-1.12)
Ethnicity (n, %)			0.627		
Non-African-American	27.03(20)	72.97(54)		REF	REF
African-American	32.18(224)	67.82(472)		0.65	(0.30-2.74)
Annual income (n, %)			0.854		
$0-$10,000	31.30(159)	68.70(349)		REF	REF
$11,000-$20,000	31.22(64)	68.78(141)		0.95	(0.71-1.27)
$21,000-$30,000	36.11(13)	63.89(23)		0.76	(0.42-1.40)
Over $30,000	38.10(8)	61.90(13)		0.60	(0.34-1.62)
Health and adherence-related characteristics					
Side effect (mean, sd)	7.13(5.87)	5.76(5.54)	0.001	0.97**	(0.95-0.99)
CD4 cell count			0.681		
≤200	33.06(40)	66.94(81)		REF	REF
>200	31.16(191)	68.84(422)		1.05	(0.97-1.13)
Viral load (logmean, sd)	4.80(2.15)	4.45(1.87)	0.025	0.91**	(0.85-0.97)
Heavy drinker (n, %)			0.001		
No	28.96(181)	71.04(444)		REF	REF
Yes	42.96(61)	57.04(81)		0.56***	(0.41-0.76)
Adherence self-efficacy	7.41(1.98)	7.91(1.94)	<0.001	1.11***	(1.04-1.19)
Depression (n, %)			0.001		
None	26.07(79)	73.93(224)		REF	REF
Mild/moderate	28.65(53)	71.35(132)		0.82	(0.58-1.16)

	Average adherence<85%	Average adherence≥85%		Optimal adherence (≥85%)	
	(n=244)	(n=526)	P-value	OR	95%CI
Major	39.72(112)	60.28(170)		0.59**	(0.44-0.80)

*p<0.05,

** p<0.01,

*** p<0.001.

Table 4

Multivariate analysis of optimal adherence using random-effects models with robust variance estimator

	Model 1		Model 2		Model 3		Model 4	
	Optimal adherence		Optimal adherence		Optimal adherence		Optimal adherence	
Variable name	**AOR[1]**	**95%CI**	**AOR[1]**	**95%CI**	**AOR[1]**	**95%CI**	**AOR[1]**	**95%CI**
Food and drug								
Food insecurity	0.68**	(0.51-0.89)	0.73*	(0.55-0.96)	0.92	(0.67-1.26)	1.20	(0.83-1.74)
Drug use	0.57***	(0.43-0.74)	0.57***	(0.44-0.75)	0.61**	(0.46-0.81)	1.12	(0.65-1.92)
Food insecurity × drug use	--	--	--	--	--	--	0.42**	(0.22-0.79)
Social demographic characteristics								
Age	--	--	1.02**	(1.01-1.04)	1.02*	(1.00-1.04)	1.02*	(1.00-1.04)
Ethnicity				(0.37-1.04)		(0.30-0.94)		(0.30-0.93)
(African-American)			0.63Δ		0.53*		0.53*	
Health and adherence-related characteristics								
Side effect	--	--	--	--	1.00	(0.97-1.02)	0.99	(0.97-1.02)
CD4 cell count >200	--	--	--	--	1.01	(0.69-1.47)	1.02	(0.70-1.49)
Log viral load	--	--	--	--	0.96	(0.89-1.03)	0.96	(0.90-1.03)
Heavy drinker	--	--	--	--	0.67*	(0.48-0.93)	0.68*	(0.49-0.95)
Adherence self-efficacy					1.06	(0.98-1.14)	1.05	(0.97-1.13)
Depression	--	--	--	--				
No depression	--	--	--	--	REF	REF	REF	REF
Mild/moderate	--	--	--	--	0.96	(0.66-1.40)	0.97	(0.67-1.42)
Major	--	--	--	--	0.83	(0.57-1.18)	0.85	(0.59-1.23)
Visit	0.93	(0.78-1.11)	0.93	(0.78-1.11)	0.95	(0.79-1.15)	0.95	(0.79-1.15)

Δ p<0.1,

* p<0.05,

** p<0.01,

*** p<0.001;

1 Adjusted odds ratio.