

**Unhealthy Alcohol Use and HIV-1 Risk Behaviors and PrEP Adherence Among
Gay, Bisexual, and Other Men Who Have Sex with Men (GBMSM) in Kenya**

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Abstract

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Background: Gay, bisexual, and other men who have sex with men (GBMSM) in sub-Saharan Africa experience disproportionate rates of stigma and its social repercussions, including high rates of alcohol use. The burden of HIV in sub-Saharan Africa also disproportionately affects GBMSM populations. This work aimed to assess the variability of drinking patterns and determine associations between unhealthy alcohol use and HIV risk behaviors and adherence to HIV prevention medication among GBMSM in Kenya.

Methods: A secondary analysis of the Anza Mapema Mbili study, which followed HIV negative men for one year, was conducted to assess the prevalence of unhealthy drinking, as measured by phosphatidyl ethanol (PEth), and determine its association with (1) several HIV risk factors (condomless anal intercourse, multiple sex partners, and forced sexual violence) and (2) adherence to pre-exposure prophylaxis (PrEP). Descriptive statistics were used to identify differences between participants with and without unhealthy drinking at baseline. McNemar's test was used to assess whether the prevalence of unhealthy drinking changed over study visits. Generalized estimating equations with logit links and exchangeable correlation structures were used to determine associations between unhealthy drinking and study outcomes after adjustment for potential confounders.

Results: The prevalence of unhealthy drinking as determined by the first collected PEth measure was 56% (95% CI: 47% – 64%). The prevalence of unhealthy drinking did not change significantly over the next study visit where PEth was collected. Participants who had unhealthy drinking were, on average, 3.4 years older as compared to those without unhealthy drinking. Further, a larger proportion of those in the unhealthy drinking category were classified as having “Hazardous/Harmful Drinking” via the AUDIT test as compared to those without unhealthy drinking (62.0% vs. 27.4%, respectively). A borderline significant association was found between unhealthy alcohol use (≤ 200 ng/ml of PEth) and lower odds of having multiple sex partners, but there were no statistically significant associations with condomless anal intercourse, forced sex, or PrEP adherence.

Conclusion: Unhealthy alcohol use, as measured by PEth, was found in the majority of GBMSM study participants and did not change over follow-up. Unhealthy alcohol use was associated with older age and AUDIT score > 8 but was not strongly associated with HIV risk behaviors or PrEP adherence. Further work is needed to understand better the role of alcohol use, drinking patterns, and social harms in HIV risk perception and engagement in preventative measures among GBMSM.

Background:

Gay, bisexual, and other men who have sex with men (GBMSM) are at increased risk for HIV and other sexually transmitted infections (STIs) globally. Previous studies suggest the prevalence of HIV in GBMSM populations tends to be approximately 5 times higher than non-GBMSM men in the same populations.^{2,27} In Kenya and other rights-restricted countries where severe laws against same-sex relationships and sexual activity exist, GBMSM experience heightened discrimination, stigma, and high rates of substance use and mental health challenges.^{1,2,12,19,21} For instance, formative work with GBMSM populations has found alcohol consumption to be a common coping mechanism in response to perceived and enacted stigma and a predictor of poor engagement in HIV treatment and preventative services.³

Alcohol use is a major risk factor for HIV acquisition due to its association with increased sexual risk behaviors and decreased adherence to antiretroviral medications, including pre-exposure prophylaxis (PrEP).^{6,7,8,13,26} In a multi-site study of 1,476 self-identified GBMSM in Kenya, 44% of participants had hazardous or harmful alcohol use, as defined by a score of 8 or more on the Alcohol Use Disorder Identification Test (AUDIT).⁶ Although alcohol use was not directly associated with HIV status in this cross-sectional study, hazardous or harmful alcohol use was associated with engagement in transactional sex, another risk factor linked to HIV acquisition which is heightened in GBMSM due to condomless anal intercourse during these transactions.²² Other challenges commonly experienced among GBMSM in Kenya (e.g., unstable relationships, stigma and discrimination due to the criminalization of male-male sex, and other substance use) also increase the risk of acquiring HIV.

PrEP with oral emtricitabine and tenofovir disoproxil fumarate (Truvada[®]), introduced in Kenya in 2016, is highly effective in preventing HIV acquisition by uninfected individuals when taken as directed and with high levels of adherence.^{10,11,29} Increasing PrEP uptake and adherence among persons at risk—particularly GBMSM and persons with unhealthy alcohol use—is essential for ending the HIV epidemic, which continues to affect a disproportionate number of Kenyans. Although previous findings have found relatively high PrEP uptake among eligible participants in sub-Saharan Africa, adherence to the medication remains low. For instance, in a cohort study of 170 MSM in coastal Kenya who were eligible for PrEP, 82.4% initiated the medication, but only 57.7% reported PrEP use at the end of the study.²⁵

To improve HIV prevention efforts, studies are needed to understand unhealthy alcohol use and its relationship to HIV risk behaviors and PrEP use among GBMSM in Kenya. Though prior studies have identified high levels of unhealthy alcohol use among Kenyan GBMSM, alcohol use can be hard to measure in African settings and may not be captured well by the AUDIT, which assesses the quantity and frequency of standard drinks (e.g., a 12-ounce beer at around 5% alcohol content) consumed. Chang'aa, otherwise known as “homebrew,” is a traditional homemade alcoholic beverage and is among the most consumed alcoholic beverages in Kenya and other parts of Sub-Saharan Africa.⁴ The alcohol content in homebrew is difficult to quantify given the variability in production processes between brewers and the lack of agreed-upon standards for production.⁵ However, homebrew’s alcohol content is typically higher than that of spirits, and consumption of homebrew in large amounts has been linked to deaths from methanol poisoning in Kenya and other countries where the beverage is produced and consumed.⁴⁻⁵

Measurement of PrEP adherence is also challenging. Previous studies among GBMSM have found differences between self-reported PrEP adherence measures and tenofovir-diphosphate (TFV-DP) in stored dried blood samples (DBS). An analysis of dried blood samples from previous work with participants of this sample found that only 14.6% of participants had protective levels of TFV-DP at any visit. However, self-reported adherence rates remained high throughout the study period.²⁵ These results indicate that self-reported adherence measures may not accurately represent actual adherence rates, potentially leading to an overestimate of PrEP adherence and a distorted association between alcohol use and medication adherence among GBMSM populations.

To better understand the role that unhealthy alcohol use plays in moderating behaviors that increase the risk for HIV, it is important to take advantage of biomarker measures that may provide more reliable estimates of alcohol intake and PrEP adherence. In this work, we build on previous work, using PEth measured in stored DBS as a biomarker of unhealthy alcohol use to delineate better the association between the unhealthy use of alcohol and both HIV risk behaviors and adherence to PrEP.

Study Cohort and Motivation

The Anza Mapema Mbili study was a prospective cohort study established in October 2017, which followed 160 HIV-negative men in Kenya for 12 months after they were offered HIV PrEP. The outcomes of interest in this study were self-reported sexual risk behaviors and adherence to PrEP. Participants attended clinic visits at baseline and months 3, 6, 9, and 12. At each study visit, participants completed an audio computer-assisted self-interview (ACASI) that collected several measures, including self-reported alcohol use, sexual risk behaviors, and PrEP adherence. In addition, dried blood spot samples were collected at months 3 and 9 to measure TFV-DP, a biomarker capable of serving as a proxy for measuring PrEP adherence. Alcohol use was subsequently assessed in the same dried blood spot samples by measuring phosphatidyl ethanol (PEth) levels, a biomarker of alcohol use that can detect alcohol consumption levels from the past 4 weeks.²⁴

The goal of this work will be to conduct a secondary data analysis from the Anza Mapema Mbili cohort using unhealthy alcohol use as defined by a PEth level of 200 ng/ml or greater and to determine if there is an association with (1) self-reported HIV risk behaviors (i.e., condomless anal sex, multiple male sex partners, and forced sexual violence) and (2) adherence to PrEP as measured by TFV-DP levels. The results gathered from this study will contribute to the development of integrated harm-reduction and HIV prevention interventions for GBMSM in Kenya.

Study Aims

Aim 1: To determine (A) the prevalence of unhealthy alcohol use (i.e., PEth level \geq 200 ng/ml) in 141 month-3 samples and (B) its persistence at a subsequent visit as measured in 90 samples from month 9 visits among Anza Mapema Mbili participants.

Aim 2: To determine if there is an association between unhealthy alcohol use measured at month 3 and potential exposure to HIV risk behaviors (i.e., condomless anal sex, multiple male sex partners, and sexual violence) across all visits on which sexual outcomes were measured.

Aim 3: To determine if there is an association between unhealthy alcohol use measured at month 3 and adherence to PrEP (as measured by the biomarker TFV-DP) at Anza Mapema Mbili study visits in which both biomarkers were measured (i.e., month 3 and month 9).

Methods

Study Design

This study will be a sub-analysis of the longitudinal cohort study *Anza Mapema Mbili*, which followed HIV-negative men in Kenya over 12 months after PrEP initiation.

Study Population

The study population will comprise 141 HIV-negative men who participated in the *Anza Mapema Mbili* study and have at least one PEth measure available. Participants in this study had to be biologically assigned male sex at birth, be at least 18 years of age, be residents of Kisumu, Kenya, have participated in anal or oral intercourse with another man in the past 6 months, and be willing to participate in all scheduled visits. Participants could also not concurrently participate in any other HIV studies or vaccine trials upon enrollment and had to plan to remain in the study area for the 12-month study period.

Procedures and Data Collection

ACASI surveys were used to collect self-reported data on participant demographics, self-reported alcohol use, AUDIT responses (classified as harmful or hazardous if the AUDIT score was >8), sexual risk behaviors, and PrEP adherence at select study visits. To determine PrEP adherence by biomarker, dried-blood spot samples (DBS) collected at study visits (months 3 and 9 per protocol) were tested for TFV-DP levels at the University of Colorado. PEth levels were also tested at the University of Colorado on the first DBS from each participant (141 total) and on a random selection (90 total) of second DBS samples (due to budgetary constraints).

Outcome Measures

Aim 1A Outcome: This study's first outcome of interest will be the prevalence of unhealthy alcohol use at baseline defined by PEth levels of 200 ng/ml or higher.

Aim 1B Outcome: We will also evaluate the persistence of unhealthy alcohol use among participants with both a baseline and follow-up measure available. We will utilize descriptive statistics to classify participants into two categories: those with abstinent to moderate levels of alcohol consumption (< 200 ng/ml) and those with unhealthy levels of PEth (\geq 200 ng/ml).

Aim 2 Outcome: Potential sexual exposure to HIV, as indicated by ACASI surveys, will be the Aim 2 outcome of this study. The following self-reported behaviors and events will be considered: condomless anal sex in the last 3 months (yes/no), multiple sex partners in the last three months (0 or 1 vs. 2+) and forced ssexualviolence in the last 3 months (yes/no).

Aim 3 Outcome: The third outcome is adherence to PrEP as measured by the biomarker TFV-DP. We will binary TFV-DP levels to determine protective PrEP levels. The following cut-points will be used for the

classification of TFV-DP levels: protective or ≥ 4 doses of PrEP per week (≥ 700 ng/ml) or not protective or < 4 doses of PrEP per week (< 700 ng/ml)

Predictor Measures

Aim 2 and 3 Predictor:

The primary predictor for the Aim 2 and 3 analyses is unhealthy alcohol use as defined by a PEth level equal to or above 200 ng/ml in a dried blood spot sample at month 3.

Potential Confounders

We identified age and transactional sex as a priori confounders based on previous work on alcohol and risk HIV behaviors. Occupation, education, and marital status were included as potential confounders to be tested for bivariable associations with the outcome and included in multivariable modeling if $p < 0.10$. All data on potential confounders was assessed via the ACASI self-reported surveys.

Statistical Analysis

Aim 1A Analysis: 141 baseline samples from the month 3 study visit (or first study visit with PEth measurement if collected off schedule) were used to determine the prevalence of unhealthy alcohol use at baseline. Descriptive statistics (Chi-Square or Fisher's exact for categorical variables; Wilcoxon Signed Ranked Test for continuous variables) were used to identify differences between those with and without unhealthy alcohol use at baseline.

Aim 1B Analysis: 90 paired samples from two different study visits were used to determine the persistence of unhealthy alcohol use over time. The mean, standard deviation, and variability of PEth levels and their distribution were first assessed. The prevalence of unhealthy alcohol consumption (PEth level ≥ 200 ng/ml) with exact binomial confidence intervals was calculated for all samples available at each time point assessed. McNemar's test was then used to determine whether the prevalence of unhealthy alcohol use changed over follow-up, using paired data from all participants who have two PEth levels.

Aim 2 Analysis: Generalized Estimated Equations (GEE) with a logit link was used to determine associations between unhealthy alcohol use and each outcome indicating potential sexual exposure to HIV (condomless anal intercourse and multiple sex partners). Age and transactional sex were added as a priori confounders, and occupation, education, and marital status will be added as potential confounders to be added if they are associated with the outcome at $p < 0.10$.

Aim 3 Analysis: Generalized Estimated Equations (GEE) with a logit link were used to determine associations between unhealthy alcohol use and PrEP adherence as determined by the presence of protective levels of TFV-DP. Age and transactional sex were added as a priori confounders and occupation, education, multiple sex partners, and marital status were added as potential confounders if they were associated with the outcome at $p < 0.10$.

Results

Prevalence of Unhealthy Alcohol Use

The study population consisted of 141 participants with PEth measured in at least one sample. The prevalence of unhealthy alcohol use for the first PEth measure was 56% (95% CI: 47% – 64%). Table 1 presents characteristics of this population, both overall and by whether the measured PEth level was consistent with unhealthy alcohol use or not. The mean age of participants was 28.1, ranging from 20 to 51. Most participants (91.5%) identified as male, and the majority (51.1%) had an education level between 9 and 12 years. Most participants were also employed, with 58.9% indicating traditional employment, 18.4% reporting participating in casual sex work, and 9.9% reporting sex work as their primary employment. The majority (66.7%) of participants were single, and most (68.1%) had reported transactional sex in the last three months.

When looking at differences between participants in the two different drinking categories, age and AUDIT classification were significantly different between the two groups at $p = 0.001$. Participants with unhealthy levels of drinking based on PEth classification were, on average, 3.4 years older, with a mean age of 29.6. More (62%) participants in the unhealthy drinking group were classified as having hazardous drinking via AUDIT as compared to 27.4% in the group without unhealthy drinking. No significant differences were found between the two groups with respect to all other variables.

Table 1. Participant characteristics at baseline or first biomarker collection

Variable	Overall Population (n=141)	PEth < 200 (n = 62)	PEth >= 200 (n= 79)	p-value
Age				
Median [Min, Max]	26.0 [20.0, 51.0]	25.0 [20.0, 43.0]	27.5 [20.0, 51.0]	0.001
Gender Identification				
Male	129 (91.5%)	57 (91.9%)	72 (91.1%)	0.73
Female	6 (4.2%)	2 (3.2%)	4 (5.1%)	
Other	6 (4.2%)	3 (4.9%)	3 (3.8%)	
Education Level				
0-8 years	34 (24.1%)	16 (25.8%)	18 (22.8%)	0.41
9-12 years	72 (51.1%)	34 (54.8%)	38 (48.1%)	
13+ years	35 (24.8%)	12 (19.4%)	23 (29.1%)	
Occupation				
Employed	83 (58.9%)	38 (61.3%)	45 (56.9%)	0.15
Employed & Casual Sex Worker	26 (18.4%)	7 (11.3%)	19 (24.05%)	
Sex Worker	14 (9.9%)	6 (9.7%)	8 (10.1%)	
Unemployed	18 (12.8%)	11 (17.7%)	7 (8.8%)	
Marital Status				
Married or Living with Female Partner	25 (17.7%)	10 (16.1%)	15 (18.9%)	0.61
Separated or Divorced from Female Partner	22 (15.6%)	8 (12.9%)	14 (17.7%)	
Single	94 (66.7%)	44 (70.9%)	50 (63.3%)	
Any Sex for Money (Last 3 months)				0.66

No	45 (31.9%)	21 (33.9%)	24 (30.4%)	
Yes	96 (68.1%)	41 (66.1%)	55 (69.6%)	
AUDIT Category				0.001
Hazardous/Harmful Alcohol Use	66 (46.8%)	17 (27.4%)	49 (62.0%)	
No Harmful Use	74 (52.5)	44 (70.9%)	30 (37.9%)	
Missing	1 (0.07%)	1 (1.6%)	0 (0.0%)	
Condomless Anal Intercourse				0.17
No	48 (34.1%)	25 (40.3%)	23 (29.1%)	
Yes	93 (65.9%)	37 (59.7%)	56 (70.9%)	
Multiple Sex Partners (Last 3 months)				0.50
No	19 (13.5%)	7 (11.3%)	12 (15.2%)	
Yes	122 (86.5%)	55 (88.7%)	67 (84.8%)	
Forced Sexual Violence				0.86
No	121 (85.8%)	55 (88.7%)	66 (83.5%)	
Yes	12 (8.5%)	4 (6.5%)	8 (10.1%)	
Missing	8 (5.7%)	3 (4.8%)	5 (6.3%)	
PrEP Levels				0.51
Mean (SD)	199.2 (441.9)	196.1 (363.7)	201.7 (499.8)	
PrEP Detection				0.24
PrEP Detected	55 (39.0%)	19 (30.6%)	32 (40.5%)	
PrEP not Detected	86 (61.0%)	43 (69.4%)	47 (59.5%)	
PrEP Dose Level				0.34
< 4 doses per week	123 (73.8%)	55 (71.4%)	67 (84.8%)	
4 or more doses per week	18 (9.7%)	7 (7.3%)	12 (15.2%)	

Persistence of Unhealthy Alcohol Use

PEth levels at the first visit for the entire sample had a mean of 1195.6 ng/ml and a standard deviation of 1698.5 ng/ml. The distribution was right skewed, with 23.4% of samples having undetectable PEth levels. Among the 90 samples tested later in follow-up, the mean PEth level was 998.5 ng/ml, with a standard deviation of 1622.9 ng/ml, and 27.7% were undetectable. The prevalence of unhealthy alcohol use was 56% (95% CI: 0.47 – 0.64) at the first visit and 51.1% (95% CI: 0.40 – 0.62) at the second visit. McNemar’s test on the 90 paired PEth measures had a Chi-squared statistic of 0.004 with one degree of freedom and a p-value of 0.83, indicating no significant differences in the prevalence of unhealthy alcohol use across study visits. Supplemental Figure 1 (appendix) presents the actual PEth values for these paired measures in a scatter plot with lines connecting each participant’s measures, with the blue line indicating the threshold for unhealthy alcohol use (200+ ng/ml).

Condomless Anal Intercourse

The prevalence of condomless anal intercourse in the last three months was 65.9% at the baseline visit, with 93 participants indicating condomless anal intercourse in the last three months and 48 (34.1%) indicating using condoms during anal intercourse.

Table 2 presents the results of the unadjusted and adjusted associations between unhealthy alcohol use and condomless anal intercourse in the last three months. Although the risk estimate for condomless anal intercourse was greater than 1, unhealthy alcohol use was not associated with the odds of condomless anal intercourse in the last three months in unadjusted (1.15 [95% CI 0.69 – 1.90]) or

adjusted (OR = 1.02 [95% CI: 0.60 – 1.75]) analysis. In adjusted analysis, having completed 13+ years of education was associated with approximately 74% lower odds of condomless anal intercourse (OR = 0.26 [95% CI: 0.12 – 0.57]), while older age was associated with higher odds of condomless anal intercourse in the last three months (OR = 1.07 [95% CI: 1.01 – 1.12]).

Table 2. Results for Condomless Anal Intercourse.

	Unadjusted Analysis		Adjusted Analysis	
	Unadjusted OR (95% CI)	P-Value	Adjusted Odds Ratio 95% CI	P-Value
Unhealthy alcohol use	1.15 (0.69 - 1.90)	0.58	1.03 (0.60 – 1.77)	0.90
Age	1.03 (0.97 – 1.08)	0.26	1.07 (1.01 - 1.12)	0.02 *
Any Sex for Money (last 3 months)	1.28 (0.74 – 2.22)	0.37	1.11 (0.63 – 1.96)	0.70
Marital Status		0.44		
Married/Living with Female Partner	Reference			
Separated or Divorced from Female Partner	0.83 (0.34 – 2.01)			
Partner	0.66 (0.33 – 1.33)			
Single				
Education Level		0.001 *		0.001 ***
0-8 years	Reference		Reference	
9-12 years	0.30 (0.15 – 0.59)		0.32 (0.12 – 0.61)	
13+ years	0.27 (0.13 – 0.59)		0.27 (0.12 – 0.57)	
Occupation		0.62		
Employed	Reference			
Employed/Casual Sex Worker	1.26 (0.84 – 1.90)			
Sex Worker	1.27 (0.76 – 2.13)			
Unemployed	1.04 (0.64 – 1.69)			

Multiple Sex Partners

At baseline, the prevalence of having multiple sex partners was 86.5% (95% CI: 80% - 92%). In adjusted analysis, there was a borderline significant association between unhealthy alcohol use and lower odds of having multiple sex partners in the last three months (OR = 0.60 [95% CI: 0.34 – 1.05]). Being single was associated with approximately 77% lower odds of having multiple sex partners in the last three months (OR = 0.23 [95% CI: 0.09 – 0.62]), and those who reported transactional sex in the last three months had almost twice the odds of having multiple sex partners as compared to those without transactional sex in the last three months (OR = 2.31 [95% CI: 1.33 – 4.02]). Further, being unemployed was associated with lower odds of having multiple sex partners (OR = 0.43 [95% CI: 0.24 – 0.76]).

Table 3. Results for Multiple Sex Partners

	Unadjusted Analysis		Adjusted Analysis	
	Unadjusted OR (95% CI)	P-Value	Adjusted Odds Ratio 95% CI	P-Value

Unhealthy Alcohol Use	0.75 (0.43 – 1.27)	0.32	0.63 (0.36 -1.09)	0.10
Age	1.03 (0.98 – 1.09)	0.209	1.02 (0.92 – 1.08)	0.37
Sex for Money in the Last 3 Months	2.64 (1.51 – 4.60)	0.001 **	2.21 (1.27 – 3.85)	0.01 **
Marital Status Married/Living with Female Partner Separated or Divorced from Female Partner Single	Reference 0.40 (0.12 – 1.30) 0.20 (0.07 – 0.54)	0.001*	Reference 0.37 (0.11 – 1.25) 0.23 (0.09 – 0.61)	0.01 **
Education Level 0-8 years 9-12 years 13+ years	Reference 1.76 (0.89 – 3.48) 0.55 (0.26 – 1.12)	0.002 *	Reference 2.20 (1.09 – 4.4) 0.79 (0.38 – 1.68)	0.01 **
Occupation Employed Employed/Casual Sex Worker Sex Worker Unemployed	Reference 1.25 (0.77 – 2.05) 1.14 (0.62 – 2.10) 0.43 (0.26 – 0.72)	0.002 *	Reference 1.26 (0.72 – 2.18) 0.98 (0.47 – 2.06) 0.43 (0.24 – 0.76)	0.01 *

Forced Sexual Violence

At baseline, the prevalence of individuals who had experienced forced sexual violence was 8.5% (4.5% - 14.4%). There was no association between unhealthy alcohol levels and being a victim of forced sexual violence (OR = 1.08, [95% CI: 0.32 – 2.68]). Being separated or divorced from a female partner was significantly associated with higher odds of being a victim of forced sexual violence (OR = 5.66 [95% CI: 0.86 – 37.42]), although confidence intervals were very wide given small numbers of participants with this outcome. No other significant associations were found between covariates and forced sexual violence.

Table 3. Results for Forced Sexual Violence

	Unadjusted Analysis		Adjusted Analysis	
	Unadjusted OR (95% CI)		Adjusted Odds Ratio 95% CI	P-Value
Unhealthy Alcohol Use	1.21 (0.41 – 3.54)	0.73	1.08 (0.32 – 3.68)	0.91

Age	1.01 (0.93 – 1.11)	0.73	0.99 (0.90 – 1.09)	0.88
Any Sex for Money in the Last 3 Months	5.59 (0.80 – 38.77)	0.08 *	4.58 (0.65 – 32.27)	0.12
Marital Status		0.01 *		0.04 *
Married/Living with Female Partner	Reference		Reference	
Separated or Divorced from Female Partner	5.85 (0.95 – 35.98)		5.66 (0.86 – 37.42)	
Single	1.14 (0.20 – 6.60)		1.34 (0.21 – 8.49)	
Education Level		0.22		
0-8 years	Reference			
9-12 years	0.78 (0.25 – 2.41)			
13+ years	0.13 (0.01 – 1.33)			
Occupation		0.50		
Employed	Reference			
Employed/Casual Sex Worker	1.03 (0.48 – 2.26)			
Sex Worker	1.52 (0.65 -3.59)			
Unemployed	0.53 (0.15 – 1.90)			

PrEP Adherence

The average level of TFV-DP was 199.2 /ml, with a standard deviation of 441.2. The majority (61.0%) of participants had undetectable PrEP levels, and 73.8% had levels that were consistent with less than 4 doses of PrEP per week.

In adjusted analysis, unhealthy alcohol use was not associated with protective levels of TFV-DP (OR = 0.44 [95% CI: 0.15 – 1.32]), but increasing age was associated with increased odds of adherence to PrEP (OR = 1.11 [95% CI: 1.04 – 1.32]). All other covariates were not associated with the outcome.

Table 4. Results for PrEP Adherence

	Unadjusted Analysis (PrEP Adherence)		Adjusted Analysis (PrEP Adherence)	
	Unadjusted OR (95% CI)	P-Value	Adjusted Odds Ratio 95% CI	P-Value
Unhealthy Alcohol Use	0.69 (0.26 – 1.81)	0.45	0.41 (0.14 – 1.20)	0.15
Age	1.09 (1.01 - 1.18)	0.02 *	1.12 (1.03 – 1.21)	0.006*
Any Sex for Money in the Last 3 Months	1.62 (0.50 – 5.19)	0.42	1.76 (0.54 – 5.76)	0.35
Marital Status		0.72		-
Married/Living with Female Partner	Referent			
Separated or Divorced from Female Partner	1.20 (0.26 – 5.51)			

Single	0.75 (0.21 – 2.64)			
Education Level		0.20		
0-8 years	-Referent			
9-12 years	0.39 (0.13 – 1.16)			
13+ years	0.42 (0.12 – 1.56)			
Occupation		0.31		
Employed	Referent			
Employed/Casual Sex Worker	2.51 (0.95 – 6.65)			
Sex Worker	1.08 (0.22 – 5.25)			
Unemployed	1.60 (0.43 – 5.90)			

Discussion

In this study, we first tested the variability of unhealthy drinking among participants who had two biomarker measures available. We also tested associations between unhealthy levels of drinking and (1) exposure to HIV risk behaviors and (2) adherence to PrEP. We found there to be a high prevalence (56%) of unhealthy alcohol use as measured by PEth and low variability in drinking behaviors between the 90 samples that had two biomarker measures collected. We found a borderline significant association between unhealthy levels of PEth and decreased odds of having multiple sex partners but not with condomless anal intercourse or forced sexual violence. Adherence to PrEP was also not found to be associated with unhealthy drinking.

The present study was motivated by the ongoing HIV pandemic that continues to burden GBMSM individuals in sub-Saharan Africa. While previous studies have assessed associations between self-reported drinking and adherence to medications, few studies have looked at biomarkers such as PEth, which provide a more accurate measure of alcohol consumption than self-reported. To our knowledge, this was the first study to look at PEth levels as an indicator of alcohol consumption among GBMSM in sub-Saharan Africa. We found that unhealthy alcohol use, as defined by a PEth level ≥ 200 ng/ml, was associated with an AUDIT score >8 , which is considered to indicate potentially harmful or hazardous alcohol use. Of interest, 37.9% of participants whose PEth levels were compatible with unhealthy drinking had an AUDIT score of 8 or below, and 27.4% of those with an AUDIT score >8 did not have unhealthy alcohol use by PEth levels. It is important to keep in mind that AUDIT utilizes a comprehensive list of questions to assess both alcohol consumption (in standard drinks) and the impact of drinking on one's life (e.g., failing to do what was normally expected). In contrast, PEth levels provide an estimate of alcohol consumption in the previous 4 weeks. As seen in supplemental figure 4 (appendix), there is a weak positive correlation between these two measures. It remains to be seen which measure correlates best with sexual behavior and PrEP adherence; further analysis is planned to investigate this question.

While we did not find a strong association between unhealthy drinking and condomless anal intercourse, increasing education level was significantly associated with lower odds of having condomless anal intercourse. Conversely, increasing age was associated with higher odds of the outcome. Studies on the role of education and HIV risk behaviors have been inconsistent, but some evidence has found associations between higher educational attainment and decreased odds of HIV acquisition. Similar work has also pointed to possible associations between higher education and better

comprehensive knowledge about HIV risks, pointing to the role that educational attainment may have in preventing HIV acquisition.^{30, 31.}

In the present study, we found a borderline significant association between unhealthy drinking and lower odds of having multiple sex partners. In some instances, excessive alcohol consumption may lead to physical impairment or inability to perform sex work transactions, possibly explaining the weak observation we found. Transactional sex was significantly associated with increased odds of having multiple sex partners, meaning that transactional sex in this population typically involves sexual encounters with different individuals. This finding is consistent with previous literature that has found evidence suggesting that those who participate in transactional sex also have higher odds of having multiple sex partners.³² Both transactional sex and having multiple sex partners have been found to increase the risk for HIV acquisition, pointing to the need to develop targeted interventions for those who are sex workers.^{32, 33.}

The finding that being single or separated/divorced from a female sex partner was associated with lower odds of having multiple sex partners may be explained by the fact that most men in this study tended to prefer sex with men and being in a relationship with a female partner may be correlated with higher levels of internalized homophobia. Previous literature has pointed to the role of internal and external homophobia and the role of that non-gay identification (NGI) among GBMSM in moderating sexual risk behaviors. For instance, in a study looking at risk behaviors among gay and NGI males who have sex with men, gay-identifying men had higher odds of engaging in HIV prevention behaviors as compared to NGI MSM.³⁴ These findings support the notion that GBMSM who are in heterosexual relationships may benefit from targeted interventions that address the psychosocial processes that may prevent engagement in preventative measures and contribute to unhealthy drinking.

In our analysis of adherence to PrEP, unhealthy drinking was not associated with the outcome. However, a statistically significant association was found between increasing age and increasing odds of adherence to PrEP. In our sample, participants who had unhealthy levels of drinking also tended to be older compared to those without unhealthy drinking. Previous literature has found increased adherence to PrEP with increasing age and increasing perceived risk of HIV.^{35, 36} In these studies, older individuals were found to have higher levels of perceived risk as compared to their younger counterparts. Further, in a prior analysis of Anza Mapema Mbili participants, protective levels of TFV-DP were found to be associated with moderate levels of perceived susceptibility to HIV.²⁵ It may be that the older participants in our study who had unhealthy levels of drinking may have a higher perceived risk of HIV acquisition and have better adherence to PrEP. Future interventions should consider the role that risk perception plays in adhering to HIV prevention efforts.

Limitations

The findings from this study come with several limitations. For one, although the ACASI surveys were intended to maximize participant privacy when answering sensitive questions, it is still important to remember that same-sex and HIV risk behaviors carry much stigma among this population. It is possible that participants experienced social desirability bias while reporting potentially stigmatizing behaviors like transactional sex, condomless anal sex, or multiple sex partners, leading to outcome

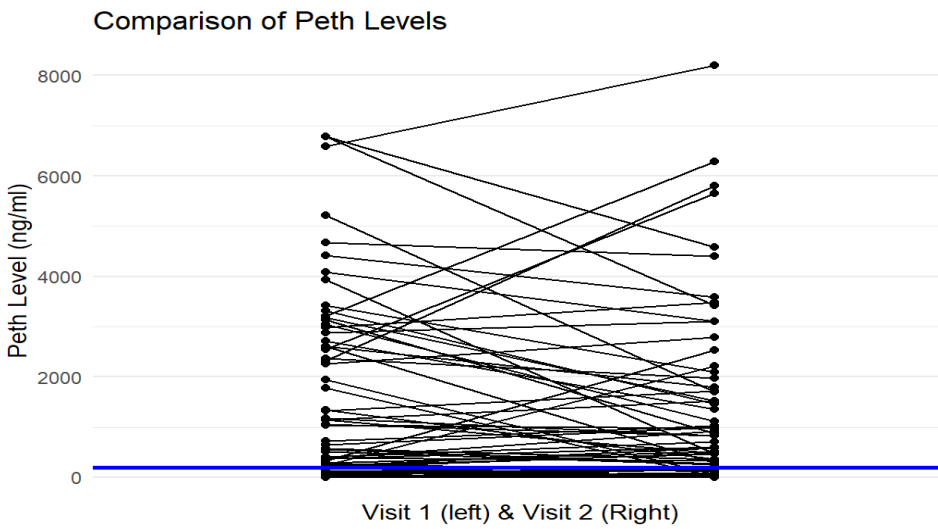
misclassification and biased estimates. Further, findings from this study have limited generalizability as participants were selected from Kisumu, Kenya, only. The sample of participants may not be representative of all GBMSM in the Kisumu area or those in the overall GBMSM Kenyan population.

Conclusion

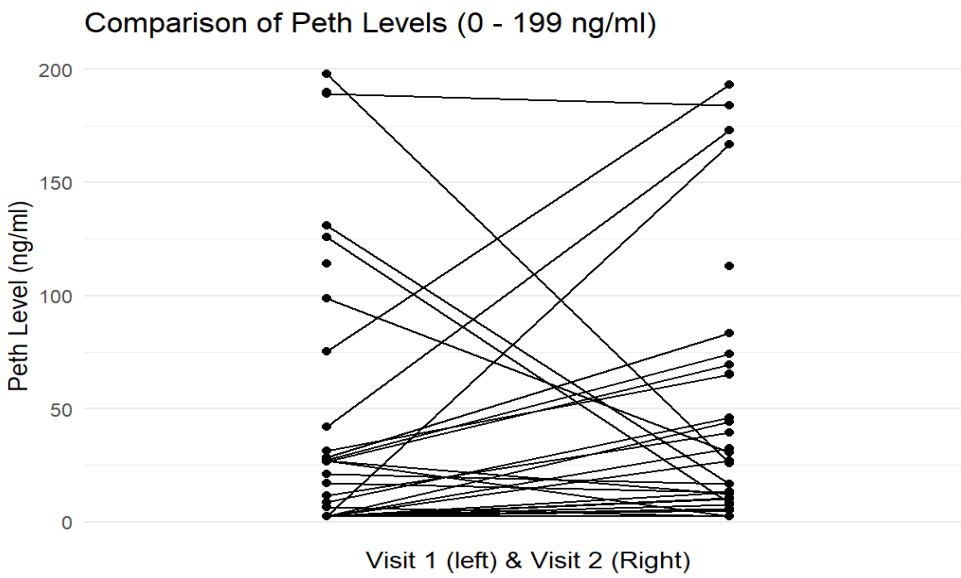
Though previous work has shown that unhealthy alcohol use may be associated with increased odds of HIV risk behaviors and adherence to PrEP, this present study did not find significant evidence to suggest that association. However, we must keep in mind that this is the first study to assess unhealthy drinking via PEth biomarkers in this population. Additionally, the recommendations for PEth cut points were taken from limited literature on the use of PEth as a biomarker, and despite a significant association with AUDIT score >8, there were discrepancies between these two measures of alcohol consumption.³⁷ Thus, future work may consider varying levels of PEth cut points for determining unhealthy drinking categorization and investigate further the ability of PEth versus the AUDIT score to predict HIV risk behaviors and PrEP adherence among GBMSM and other populations vulnerable to HIV.

Appendix

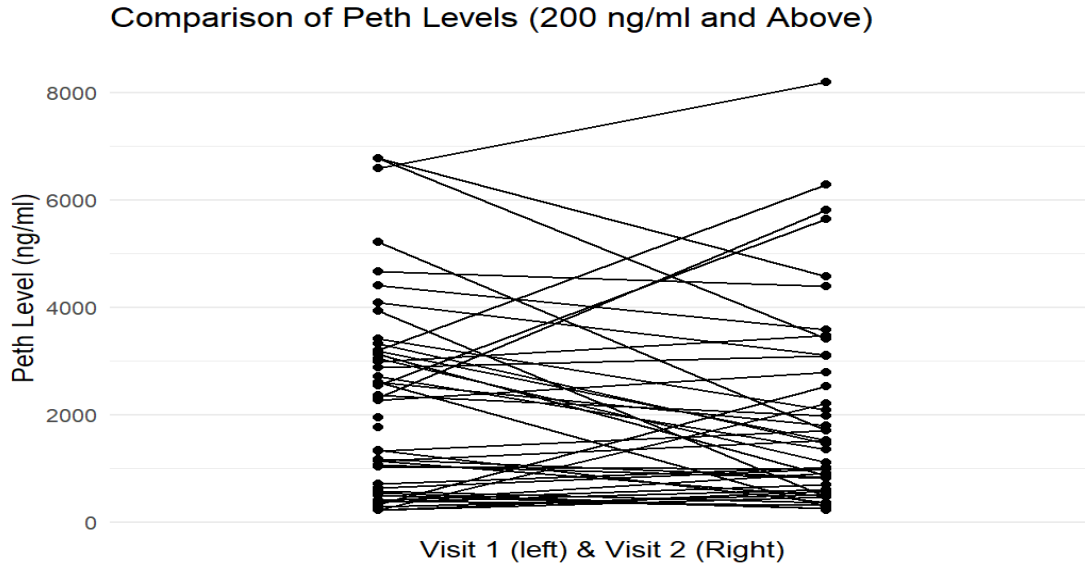
Supplemental Figure 1. Variability of PEth levels for those with repeated measures (all PEth levels)



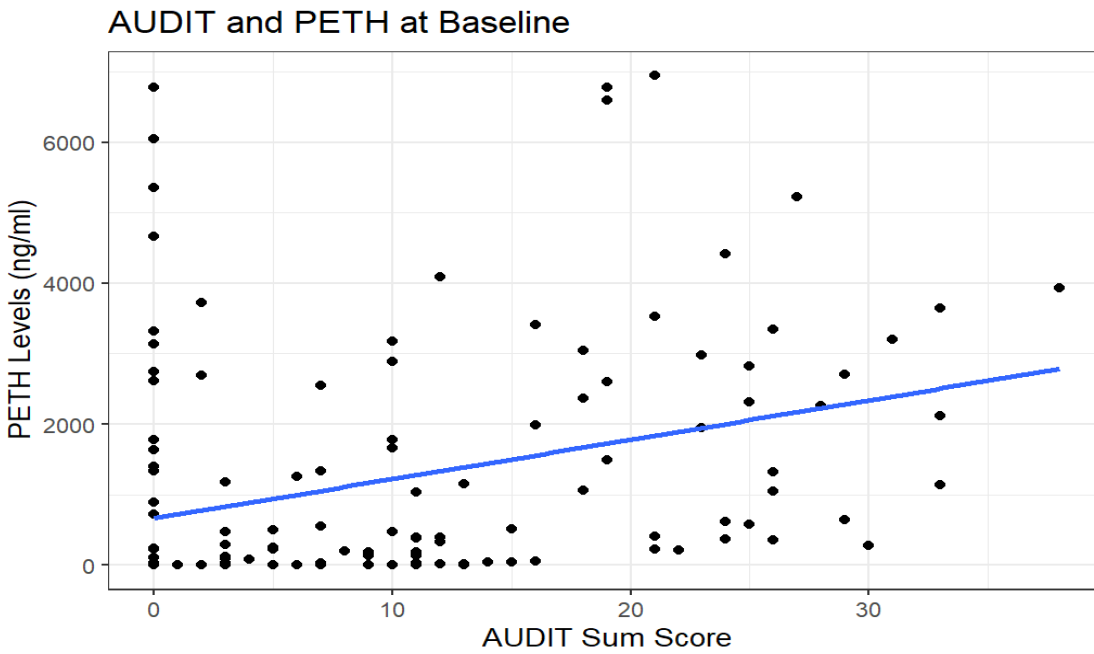
Supplemental Figure 2. Variability of PEth levels for those with repeated measures (0-199 ng/ml)



Supplemental Figure 3. Variability of PETH levels for those with repeated measures (200+ ng/ml)



Supplemental Figure 4. Variability of PETH levels for those with repeated measures



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