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ORIGINAL PAPER

Food Insecurity and Transmission Risks Among People with HIV Who Use Substances

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Abstract

Food insecurity (FI) impacts people with HIV (PWH) and those who use substances (i.e. drugs and alcohol). We evaluated the longitudinal association between FI and HIV transmission risks (unprotected sexual contacts and shared needles/syringes). Among 351 PWH who use substances in Russia, 51.6% reported FI and 37.0% past month injection drug use. The mean number of unprotected sexual contacts in the past 90 days was 13.4 (SD 30.1); 9.7% reported sharing needles/syringes in the past month. We did not find a significant association between mild/moderate FI (adjusted IRR = 0.87, 95% CI 0.47, 1.61) or severe FI (aIRR = 0.84, 95% CI 0.46, 1.54; global p = 0.85) and unprotected sexual contacts. We observed a significant association between severe FI and sharing needles/syringes in the past month (adjusted OR = 3.27, 95% CI 1.45, 7.39; p = 0.004), but not between mild/moderate FI and sharing needles/syringes in the past month (aOR = 1.40,95% CI 0.58, 3.38; p = 0.45). These findings suggest that severe FI could be a potential target for interventions to lower HIV transmission.

Keywords Food insecurity · HIV · Substance use · Eastern Europe

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Resumen
La inseguridad alimentaria (IF) afecta a las personas que viven con VIH (PVV y a personas con abuso desustancias (.ej. drogas y alcohol). Evaluamos la asociación longitudinal entre la IF y los riesgos de transmisión del VIH (relaciones sexuales sin protección y agujas/jeringas compartidas). Entre 351 PVVcon abuso de sustancias en Rusia, el 51,6% reportó FI y el 37,0% consumió drogas intravenosas en el último mes. El promedio de contactos sexuales sin protección en los últimos 90 días fue de 13,4 (DE 30,1); el 9,7% informó haber compartido agujas/jeringas en el último mes. No encontramos una asociación significativa entre IF leve/moderada (IRR ajustada = 0,87, IC 95% = 0,47, 1,61) o IF grave (IRRa = 0,84, IC 95% = 0,46, 1,54; p global = 0,85) y relaciones sexuales sin protección. Observamos una asociación significativa entre IF grave y compartir agujas/jeringas en el último mes (OR ajustado = 3,27, IC 95% = 1,45, 7,39; p = 0,004), pero no entre IF leve/moderada y compartir agujas/jeringas en el último mes (ORa = 1,40, IC 95% = 0,58, 3,38; p = 0,45). Estos hallazgos sugieren que la IF grave podría ser un enfoque para intervenciones que buscan reducir la transmisión del VIH.

Introduction

Access to nutrition is a basic biological human need and in order to achieve the United Nations Sustainable Development Goals, serious consideration to addressing the barriers for specific populations is needed [1, 2]. Unfortunately, food insecurity (FI) remains a prominent issue worldwide [3]. FI is characterized as having insufficient access to a nutritious diet, limited food availability, and the inability to acquire food in acceptable ways [4]. While FI affects various populations and facets of human experience, the association of FI with the global HIV epidemic is of particular interest. Addressing both HIV and food insecurity are important aspects to realizing the United Nations Sustainable Development Goals [5–7]. FI is common among people with HIV (PWH) and is associated with compromised physical and mental health status, lower adherence to antiretroviral therapy (ART), increased risk of HIV transmission via behavioral pathways and reduced access to medical care [5, 8].

The association between food insecurity and HIV transmission risk behaviors has not been well described among vulnerable populations, such as people with HIV who use drugs [8–10]. There is especially limited evidence from people with untreated HIV and substance use. Existing studies among people who use drugs (PWUD) demonstrate that there are various possible important mechanisms by which food insecurity exacerbates HIV acquisition risk: (1) FI contributes to less power in sexual relationships, increasing risky sexual practices (i.e., not feeling empowered to insist on condom use) [11, 12]; (2) FI leads to sex exchange for food [13–15]; (3) FI has been associated with intimate partner violence including sexual violence [16–19]; (4) FI has been associated with other sexually transmitted diseases [12, 20, 21]; (5) FI can reduce access to medical care including HIV prevention services for those uninfected, needle exchange to prevent needle sharing, and to HIV treatment and care for those infected, thereby potentiating secondary transmission risk [22, 23]; (6) FI contributes to poor mental health which can potentiate both unsafe sex/substance use practices and increased substance use [24, 25]; (7) FI leads to low ART adherence and higher HIV viral loads, which can potentiate secondary transmission to others [26–28]. There is also potential for HIV to cause food insecurity (2-way causation), e.g. HIV greatly reduces overall health and productivity by adversely impacting food utilization access which then could exacerbate FI [29, 30]. We have created a conceptual framework illustrating the potential interrelationship between FI and HIV transmission (Fig. 1). In our conceptual framework, we have three levels: structural, community/household, and individual. There are examples of mechanisms for each of these levels and describes potential interactions between these different mechanisms.

In this analysis we are focusing on current FI and HIV transmission, as FI might render vulnerable populations, such as PWH and PWUD, prone to risky sexual behavior and needle-sharing practices [8, 31, 32]. Previous studies have shown that food insecurity is related to sexual risk behaviors among both men and women [5, 31]. The association between current FI and HIV transmission is of particular interest, as little is known about FI's relation to HIV risks related to the use of shared injection equipment.

While most of the existing studies related to food insecurity and HIV transmission risks were conducted in North America, Africa, and Asia, this issue remains relatively understudied in the countries of Eastern Europe and specifically in the Russian Federation (Russia) [12, 13, 21, 33–39]. FI and malnutrition are common among vulnerable groups in Russia and are not routinely addressed by healthcare professionals. This gap in care may represent a missed opportunity for improving substance use-related HIV outcomes [40, 41]. Injection drug use has been one of the driving forces in the HIV epidemic in Russia, especially in the mid-1990s and early 2000s [42–47]. In 2018, nearly half of individuals with a substance use disorder (SUD) registered in addiction facilities were people who inject drugs (PWID), and 26% of those were people with HIV. This figure is twice as large as 2014, with higher values in some regions, including St. Petersburg [48]. Official Russian AIDS center data demonstrate that in 2019 nearly

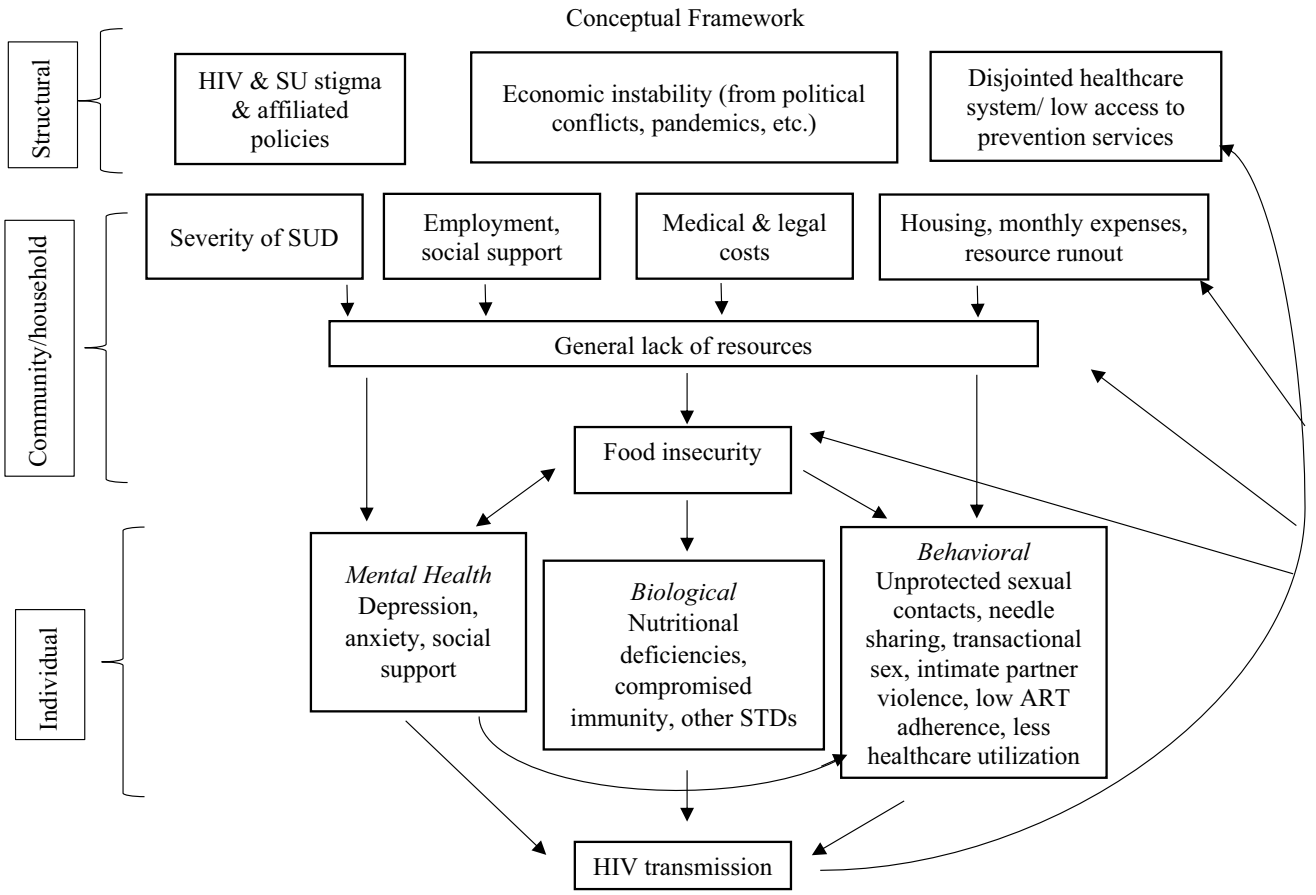

Fig. 1 Conceptual framework for food insecurity and HIV transmission in St. Petersburg, Russia cohort

35% of newly diagnosed HIV infections were acquired via parenteral injections [47]. According to the official HIV registry data, in 2019 there were nearly 1,106,513 people living with HIV and 662,208 among them were observed in HIV treatment facilities [49].

Understanding whether FI impacts Russian people with HIV who use drugs in a similar way to other populations, is an opportunity for renewed efforts to combat this epidemic.

In order to further understand the relationship between FI and HIV transmission via drug and sexual-risk pathways, we examined an existing observational longitudinal cohort of ART-naïve (at baseline) Russians with HIV, many of whom reported recent substance use and unhealthy alcohol use. Given that participants were untreated for their HIV at baseline, and many of this population engaged in unhealthy alcohol use given inclusion criteria, this study population was a particularly high risk cohort in which to answer the specific questions on HIV transmission via drug and sexual-risk pathways. While it was possible for participants to have initiated ART during the parent study, subsequent viral suppression is not assured. Thus, investigating the impacts of FI on modes of HIV transmission longitudinally in this population is relevant, especially given the fact that heavy drinking adversely impacts ART adherence [50]. The aims of the study were to explore the relationship between current FI and HIV sex transmission risks, and current FI and HIV drug transmission risks. We hypothesized that among PWH with recent heavy alcohol consumption, severity of current FI is associated with increased unprotected sexual contacts (primary outcome) and injection drug frequency (secondary outcome).

Methods

Design, Participants, and Settings

We conducted a secondary data analysis incorporating repeated, cross-sectional data from baseline and 12-month follow-up visits from the existing Russia Alcohol Research Collaboration on HIV/AIDS (ARCH) cohort of 351 PWH who were ART-naïve at enrollment. Within the Russia ARCH cohort is a nested double-blinded, randomized

placebo controlled trial of zinc supplementation (ZINC) (n = 254), clinicaltrials.gov number NCT01934803 [51, 52]. For the observational ARCH cohort study, the primary outcomes were IL-6, sCD14, and D-dimer (inflammatory biomarkers) [51]. For the ZINC study, the primary outcome was mortality risk measured as change between baseline and 18 months in the Veterans Aging Cohort Study (VACS) Index score [52]. Between November 2012 and June 2015, participants in St. Petersburg, Russia were recruited from clinical addiction and HIV sites, non-clinical sites, and via snowball recruitment. The Institutional Review Boards of Boston University Medical Campus and First St. Petersburg Pavlov State Medical University (Pavlov) approved these studies. Informed consent was conducted prior to enrollment at Pavlov. Inclusion criteria for the parent ARCH/ZINC studies were: (1) documented HIV-positive status; (2) documented ART-naïve status at baseline; (3) 18 to 70 years old; (4) stable address within 100 km of St. Petersburg; (5) access to a phone and two contacts to assist with follow-up; 6) past month risky drinking by NIAAA criteria (ZINC participants only). NIAAA defines risky drinking as greater than 4 standard drinks per day (or greater than 14 standard drinks/week) for men and greater than 3 standard drinks per day (or greater than 7 standard drinks/week) for women [53]. Participants were excluded from the parent ARCH/ZINC studies if they: (1) had cognitive impairment precluding informed consent; (2) were not fluent in Russian; (3) were pregnant or breastfeeding (ZINC participants only). After screening and informed consent, participants were administered an assessment and a blood draw. For the current sexual risk outcome analysis (primary), participants were only included if they had FI and sexual risk data at the baseline and/or 12-month study visit. For the drug risks outcome analysis (secondary), participants were only included if they had any data on FI and/or drug risks and they had past 30-day injection drug use. We did not anticipate any differences for participants from different arms of the zinc intervention, due to previous similar analyses that showed consistent results after adjusting for zinc intervention [41]. We also did not anticipate that zinc supplementation would affect behavioral outcomes, and thus did not control for randomization arm.

Variables

Outcomes

We assessed two outcomes in this study. The primary outcome, representing sexual risk, was self-reported "number of unprotected sexual contacts" (vaginal, anal) in the past 3 months [54]. The authors note that while this outcome does provide some insight into HIV transmission risk, it is limited by lack of information on the number of partners with whom participants had unprotected sexual contact and the HIV status of those partners, information that was not collected in this study. The secondary outcome, representing drug risk, was self-report of "any needle sharing, at least once in the past 30 days," a dichotomous variable [55]. Since not all study participants were actively using injection drugs, needle sharing analyses were conducted on participants with past 30-day injection drug use only (n = 146, for baseline and follow-up). Both outcomes were modeled as repeated measures using data from baseline and the 12 month follow-up.

Main Independent Variable and Covariates

The Household Food Insecurity Access Scale (HFIAS) was used to assess the independent variable of food insecurity at baseline and 12-month follow-up visits [56]. This instrument measures FI in the past four weeks. We modified the scale to make it applicable to the context in Russia by assessing a participant's individual experience with FI, as opposed to the experience of all members in the household. Please see Appendix for the scale used in this study. The main independent variable (FI) was categorized into three levels: none; mild/moderate FI; and severe FI. We also conducted exploratory analyses where any FI was grouped together vs. no FI. FI was modeled as a time-varying exposure.

The HFIAS defines severe FI as cutting back on meal size or number of meals often and/or experiences one of the following: going to bed hungry, running out of food, or going the whole night/day without eating [56]. Moderate FI is defined as starting to cut back on meal size or number of meals and/or eating a monotonous diet or undesirable foods sometimes or often [56]. Mild FI is defined as being worried about having enough food sometimes or often and/or unable to eat preferred foods, and/or eats a monotonous diet or undesirable foods rarely [56].

Covariates included were age, underweight (BMI < 18.5), gender (man or woman), monthly income (high vs. low, with low consisting of monthly incomes lower than 20,000 rubles [which approximated between 300 and 600USD between 2012 and 2015, when this study was conducted]) [57], social support [58], depressive symptoms (Center for Epidemiologic Studies Depression Scale [CESD ≥ 16]) [59, 60], past month heavy alcohol use (NIAAA risky drinking criteria) [53], ART initiation at follow-up [61], and biomarkers of HIV infection (i.e., HIV viral load and CD4 cell count). ART initiation at follow-up and biomarkers of HIV infection were only used for descriptive analyses. With 52 events (n = 146) for the needle sharing outcome analysis, we limited the regression model to three covariates, however a sensitivity analysis including all covariates was also conducted.

Statistical Analyses

Descriptive statistics were conducted for baseline data for the overall cohort as well as for the FI severity groups as assessed at baseline. To further describe baseline differences between groups, we used ANOVA for continuous variables and chi-square for categorical variables. HIV viral load was $\log_{10}$-transformed. We used generalized estimating equations (GEE) repeated measures regression analyses to incorporate data from baseline and 12 months. FI and the outcomes were modeled as time-varying. We conducted preliminary unadjusted negative binomial regression analyses for the count outcome (sex risk outcome – number of unprotected sexual contacts) and logistic regression analyses for the binary outcome (drug risk outcome – any needle sharing) including only the main independent variable (food insecurity). An independence working correlation structure was used and empirical standard errors are reported for all results. For the outcome number of unprotected sexual contacts, the primary outcome analysis was based on an adjusted model with food insecurity and controlling for all covariates (income, age, gender, underweight, social support, heavy drinking, depressive symptoms). We report the adjusted incidence rate ratio (IRR) for the sex risk outcome and the adjusted odds ratio (OR) for the drug risk outcome, along with corresponding 95% confidence intervals. No pair of variables in the same regression models were highly correlated (Spearman correlation, $r < 0.4$, in all cases). The analyses were conducted with two-sided tests and an alpha level of 0.05. SAS version 9.3 was used for all statistical analyses (SAS Institute, Inc., NC, USA).

Results

Participant Characteristics

All 351 of the Russia ARCH participants were included in the analysis of the primary outcome, and 146 of the 351 participants were included in the secondary analysis based on eligibility criteria. All participants were living with HIV and reported not being on ART at baseline. A total of 102/351 (29.1%) participants at baseline experienced current mild/moderate FI and 79/351 (22.5%) experienced current severe FI (Table 1). Among the 251 participants with an available CD4 cell count, the mean CD4 cell count

Table 1 Baseline characteristics of 351 untreated HIV-positive Russians, overall and by food insecurity status

Characteristic	Total N = 351	Food secure N = 170	Mild/moderate food insecurity N = 102	Severe food insecurity N = 79	Test statistic	p value
Age: mean (SD)	33.7 (5.6)	33.9 (5.3)	33.3 (6.4)	33.7 (5.0)	F = 0.36	0.70
Male	248 (70.7%)	123 (72.4%)	73 (71.6%)	52 (65.8%)	$\chi = 1.17$	0.56
Underweight	19 (5.4%)	3 (1.8%)	6 (5.9%)	10 (12.7%)	$\chi = 12.56$	0.002
Unemployed	178 (50.7%)	65 (38.2%)	57 (55.9%)	56 (70.9%)	$\chi = 24.54$	< 0.0001
Low income	165 (47.4%)	62 (36.9%)	52 (51.5%)	51 (64.6%)	$\chi = 17.42$	0.0002
Depressive symptoms	161 (46.1%)	66 (39.1%)	44 (43.1%)	51 (65.4%)	$\chi = 15.41$	0.0005
Heavy drinking, past month	250 (71.2%)	123 (72.4%)	71 (69.6%)	56 (70.9%)	$\chi = 0.24$	0.89
Social support: mean (SD)	20.2 (5.3)	21.7 (4.8)	18.9 (5.2)	18.9 (5.6)	F = 12.85	< 0.0001
Shared needle/syringe, past month	34 (9.7%)	8 (4.7%)	8 (7.8%)	18 (22.8%)	$\chi = 20.71$	< 0.0001
Injected drug use, past month	130 (37.0%)	52 (30.6%)	36 (35.3%)	42 (53.2%)	$\chi = 11.98$	0.0025
Unprotected sex, past 3 months						0.70
mean (SD)[a]	13.4 (30.1)	14.8 (36.5)	11.8 (22.6)	12.5 (22.1)	F = 0.35	
HIV viral load, log						0.43
mean (SD)[b]	4.27 (1.09)	4.19 (1.10)	4.34 (1.08)	4.34 (1.09)	F = 0.85	
CD4 count					F = 0.27	0.77
mean, (SD)[c]	531 (295)	537 (286)	540 (294)	504 (325)		

[a]Sample sizes are different, due to missing data. Total n = 340, food secure n = 167, mild/moderate food insecurity n = 96, severe food insecurity n = 77

[b]Sample sizes are different, due to missing data. Total n = 348, food secure n = 170, mild/moderate food insecurity n = 100, severe food insecurity n = 78

[c]Sample sizes are different, due to missing data. Total n = 251, food secure n = 131, mild/moderate food insecurity n = 70, severe food insecurity n = 50

at baseline was 531 (SD 295). Among the 348 participants with an available HIV viral load at baseline, the mean log HIV viral load was 4.27 (SD 1.09); 307/351 (87.5%) participants had HIV viral load (HVL) of more than 500. Those with HVL less than 500 were coded as 250 prior to log-transforming.

Of the 351 participants in this cohort, 248 participants (70.7%) were male and the mean age was 33.7 years (SD 5.6). Substance use was common in this cohort, with 250/351 (71.2%) reporting heavy alcohol use at baseline in the past month. At baseline, 130/351 (37.0%) reported injection drug use in the past month. Overall, 146 unique participants had past month injection drug use (IDU) either at baseline or follow-up involving 196 total assessments (See Appendix). Of these 146 participants, 42 (23.3%) reported sharing needles and/or syringes in the past month. The mean number of unprotected sexual contacts in the past 90 days among the 340 participants who provided responses was 13.4 (SD 30.1) contacts (median 0, maximum 270). Specifically, 165/340 (49%) participants had unprotected sex in the past 90 days at baseline, 96/226 (42%) at 12 months. Overall, 192 unique participants had unprotected sex at baseline and/or 12 months. Of the 19 (5.4%) participants who were underweight (BMI < 18.5), 16 (84.2%) participants experienced some form of FI. Depressive symptoms (CESD ≥ 16) were common (161/351; 46.1%), with 95 (59.0%) of these individuals reporting some form of FI. In this cohort, 178 participants (50.7%)

Table 2 Longitudinal association between food insecurity and number of unprotected sexual contacts among untreated HIV-positive Russians with heavy alcohol use

Variable	Outcome								
	Number of unprotected sexual contacts (vaginal, anal) in past 3 months[a]			Number of unprotected sexual contacts (vaginal, anal) in past 3 months[a]			Number of unprotected sexual contacts (any vs. none) in past 3 months (exploratory)[b]		
	Unadjusted IRR (95% CI)	z-statistic	p-value	Adjusted IRR (95% CI)	z-statistic	p-value	Adjusted Odds Ratio (95% CI)	z-statistic	p-value
Mild or moderate food insecure (vs. food secure)	0.90 (0.54, 1.51)	0.17[c]	0.92[d]	0.87 (0.47, 1.61)	0.33[c]	0.85[d]	1.16 (0.75, 1.79)	4.31[c]	0.12[d]
Severe food insecure (vs. food secure)	0.94 (0.57, 1.57)			0.84 (0.46, 1.54)			1.72 (1.03, 2.85)		
12 month (vs. baseline)	1.00 (0.81, 1.23)	−0.01	0.99	1.09 (0.83, 1.44)	0.63	0.53	0.92 (0.78, 1.08)	−1.02	0.31
Income (above median vs below median)	–		–	0.91 (0.52, 1.58)	−0.34	0.75	1.25 (0.84, 1.87)	1.10	0.27
Age	–		–	0.95 (0.91, 0.99)	−2.26	0.02	0.98 (0.94, 1.01)	−1.33	0.18
Gender (female vs. male)	–		–	1.34 (0.85, 2.10)	1.26	0.21	2.93 (1.89, 4.55)	4.78	< 0.001
Underweight	–		–	0.52 (0.20, 1.34)	−1.35	0.18	0.40 (0.17, 0.92)	−2.16	0.03
Social support	–		–	1.03 (0.97, 1.09)	0.97	0.33	1.02 (0.99, 1.06)	1.40	0.16
Heavy drinking past month (yes vs. no)	–		–	1.42 (0.82, 2.46)	1.25	0.21	1.25 (0.84, 1.84)	1.10	0.27
Depressive symptoms (past month symptoms)	–		–	1.11 (0.70, 1.77)	0.44	0.66	0.97 (0.66, 1.42)	−0.15	0.88

[a]n = 351 unique individuals contributing 566 observations. The outcome is a count variable analyzed using negative binomial regression. The independent variable in the model is a 3-level variable: severe; mild/moderate; food secure

[b]n = 351; observations 562. This outcome is continuous, but the independent variable in the model is dichotomized as any food insecurity, vs food secure

[c]Chi-square statistic corresponding to global p-value for 3-category food insecurity variable

[d]Global p-values

reported unemployment, with the majority of these individuals reporting FI (113/178; 63.4%). Likewise, the majority of participants who reported low income also reported some form of FI (103/165; 62.4%). Participants with mild/moderate and severe FI reported lower social support than food secure participants.

Food Insecurity and Sex Risks

We did not detect an association between current FI and the primary sex risk outcome, number of unprotected sexual contacts (vaginal, anal) in the past 3 months (mild/moderate FI vs. food secure: adjusted IRR = 0.87 [95% CI 0.47, 1.61]; severe FI vs. food secure: adjusted IRR = 0.84 [95% CI 0.46, 1.54]; global p = 0.849), in adjusted analyses controlling for demographics, BMI, social support, alcohol use, and depressive symptoms (Table 2). Exploratory analyses categorizing FI as any vs. none (not shown), and categorizing sex risk variable as any sex risks vs. none (Table 2 last column), did not show the hypothesized associations.

Food Insecurity and Drug Risks

For the secondary outcome of the association of FI and needle sharing, we restricted the analysis to those who reported current injection drug use (past 30 days) at either baseline or 12 months (n = 146). There was a significant association between current severe FI and needle sharing, as assessed at the baseline and 12-month study visits (adjusted OR 3.27 [95% CI 1.45, 7.39]; p = 0.004) in analyses only controlling for income, age and gender. There was not a significant association between mild/moderate FI and needle sharing (adjusted OR 1.40 [95% CI 0.58, 3.38]; p = 0.453). Given the smaller sample size in this analysis (n = 52 events), we initially restricted the adjusted model to only controlling for income, age and gender (Table 3). Further analyses with all preselected confounders showed an attenuated association that was no longer statistically significant between food insecurity and needle sharing. The full model suggests additional confounding not captured by the smaller model.

Table 3 Secondary analyses of the association between food insecurity and needle sharing among HIV-positive Russians with heavy alcohol use

Variable	Outcome								
	Needle sharing (yes vs. no), past 30 days, dichotomous[a]			Needle sharing (yes vs. no), past 30 days, dichotomous			Needle sharing (yes vs. no), past 30 days, dichotomous		
	Unadjusted odds ratio (95% CI)	z-statistic	p-value	Adjusted odds ratio (95% CI)	z-statistic	p-value	Adjusted odds ratio (95% CI)	z-statistic	p-value
Mild or moderate food insecure (vs. secure)	1.41 (0.59, 3.33)	8.55[e]	0.01[b]	1.40 (0.58, 3.38)	7.74[e]	0.02 [c]	1.03 (0.40, 2.62)	4.36[e]	0.11[d]
Severe food insecure (vs. secure)	3.26 (1.50, 7.06)			3.27 (1.45, 7.39)			2.21 (0.92, 5.29)		
12 month (vs. baseline)	1.02 (0.76, 1.37)	0.12	0.91	1.05 (0.76, 1.46)	0.29	0.77	1.00 (0.71, 1.41)	0.00	1.00
Income (above median vs below median)	–		–	1.13 (0.53, 2.38)	0.32	0.75	1.13 (0.51, 2.52)	0.30	0.76
Age	–		–	0.95 (0.87, 1.03)	−1.33	0.18	0.94 (0.86, 1.03)	−1.31	0.19
Gender (female vs. male)	–		–	1.70 (0.78, 3.69)	1.34	0.18	1.72 (0.78, 3.78)	1.35	0.18
Underweight	–		–	–		–	1.31 (0.37, 4.67)	0.42	0.67
Social support	–		–	–		–	0.95 (0.88, 1.03)	−1.15	0.25
Heavy drinking past month (yes vs. no)	–		–	–		–	1.27 (0.63, 2.54)	0.67	0.50
Depressive symptoms (past month symptoms)	–		–	–		–	3.71 (1.65, 8.36)	3.17	0.002

[a]n = 146; 52 events. Only participants with past 30 day injected drug use were included in the model. The outcome needle sharing is binary (yes vs. no), but the independent variable FI in the model is a 3-level variable: severe; mild/moderate; food secure

[b]Pairwise p-values: Mild or moderate food insecure vs. secure: z = 0.78, p = 0.44; Severe food insecure (vs. secure): z = 2.99, p < 0.01

[c]Pairwise p-values: Mild or moderate food insecure vs. secure: z = 0.75, p = 0.45; Severe food insecure (vs. secure): z = 2.85, p < 0.01

[d]Pairwise p-values: Mild or moderate food insecure vs. secure: z = 0.05, p = 0.96; Severe food insecure (vs. secure): z = 1.78, p = 0.08

[e]Chi-square statistic corresponding to global p-value for 3-category food insecurity variable

Discussion

This study was able to examine longitudinally a particularly important population that is at risk for HIV transmission: self-reported ART naïve at baseline PWH who use substances. Over half of the participants (51.2%) in this cohort of 351 PWH in St. Petersburg, Russia, experienced some form of current food insecurity. This level of FI is similar to comparable populations of HIV positive people with substance use in studies conducted in North America [21, 62–65]. However, there are differences in levels of FI among the general population and PWH who use substances. In 2012–2015 reports in the U.S. (the time period of data collection for this analysis) demonstrated that 12.7% to 14.5% of U.S. households experienced FI at some point in the last year, emphasizing the stark differences in FI between the general population in the U.S. and this study's population of people with HIV who use substances in Russia [66, 67]. Since there are limited studies on FI in Russia among people with substance use, we cannot comment on whether FI in this cohort (51.2%) is typical for the general Russian population. Our assumption is that in general about half of PWH and substance use experience FI. In Russia, there are few studies on FI and this condition among those with HIV has received very limited attention. Individuals with FI in this cohort demonstrated depressive symptoms, unemployment, lower social support, lower weight, or lower income. Of note, reported FI was for the past four weeks; it is unknown whether participants were experiencing FI when they acquired HIV.

In this study we sought to evaluate if FI was associated with behaviors that exposed others to a higher risk of HIV transmission. To understand the potential interrelationship between FI and HIV transmission among this population of PWH and substance use, we depicted a potential conceptual framework (Fig. 1). This framework builds on an extensive prior research conducted by one the co-authors (SW) of this study [29], and was modified by us, specifically for this analysis. In this study, we did not find a significant association between any form of FI and sex risks as measured by unprotected sexual contacts, in longitudinal regression analyses adjusted for confounders. However, among those who injected drugs in the past month, we did observe a significant association between severe FI and drug risks as measured by shared needles/syringes, in adjusted analyses limited to three variables (income, age, and gender). Notably, the results were attenuated and no longer significant after adjustment for additional covariates including depressive symptoms. The associations between depression and needle sharing among PWH has been explored and shown in the past to contribute to HIV transmission [68]. Potentially there is an association between FI and depression, as depicted in the conceptual framework (Fig. 1). Studies have demonstrated associations between FI and increased risk of depression [25, 69, 70], as well as the potential to reduce depression by intervening on FI [71]. FI has also been shown to partially mediate the relationship between drug use and depressive symptoms. In the present study, it is possible that FI is affecting HIV transmission risk outcomes through depression, given the high prevalence of depressive symptoms in this cohort.

Our findings did not show any significant associations between FI and unprotected sexual contacts among PWH, which is inconsistent with existing literature. Most other studies showed a positive association between FI and unprotected sexual contacts [12, 31, 36, 72–74]. In contrast, one study showed that FI was associated with fewer unprotected sexual contacts; this association was only among the men in this South Africa cohort [75]. The authors explained this finding as follows: men who have more resources are more likely to partake in risky sexual behaviors.

The current study's findings with regard to no apparent association between FI and HIV sex risk might be due to the high prevalence of substance use and high prevalence of risky sex. Most participants disclosed heavy alcohol use and many also used other substances. Previous studies reporting an association between FI and unprotected sexual contacts had recruited populations with unreported, low or mono-substance use. In this analysis, almost 70% of participants reported heavy drinking in the past month, as well as many reporting using more than one substance. These factors are strong drivers of risky sex, making it harder to separate out the role of FI versus substance use on risky sexual behavior, which may explain potential inconsistencies with the literature.

HIV, substance use, and food insecurity stigmas could have also contributed to a lack of association between FI and HIV transmission risks in the current study [76–84]. We have documented elsewhere the high prevalence of HIV stigma in this cohort, and possible that substance use stigma was involved, given that all participants engaged in heavy drinking [85]. In addition, the Russian context, including the economic situation, federal and local policies, and the healthcare system could have influenced HIV transmission risk behaviors and/or FI [40, 86–89].

While our findings did not seem to demonstrate associations between FI and unprotected sexual contacts, the data did suggest a potential association between severe FI and needles/syringe sharing. There have been mixed findings in the literature regarding this topic, but the majority of studies have found a positive association between FI and needle sharing [8, 90]. In Strike et al., the authors found that PWID in Canada had an increased odds of sharing injection equipment if they were experiencing FI [8]. When FI interferes

with PWID's access to harm reduction and other health or social programs, PWID are more likely to engage in unsafe injection practices [8, 91]. In Russia, harm reduction programs are less accessible than the setting of the previous noted research (i.e., Canada) [92].

The findings from our study can inform non-governmental organizations' (NGOs) programming and may have policy implications in Eastern Europe and other regions of the world for decreasing HIV transmission. Harm reduction programs might benefit from partnering with food support programs, where there could be bidirectional intervention: sterile injection equipment and information about safe injection practices could be offered at local food banks, while food items that are normally provided by food banks could be offered at harm reduction programs. Policymakers who are concerned about HIV transmission should note the overlap between severe FI and the use of unsterile equipment, and consider prioritizing policies that will alleviate FI for the most vulnerable persons.

This study was conducted before the global COVID-19 pandemic caused by the SARS-CoV2 virus [93]. However, the COVID-19 pandemic has likely exacerbated FI, making the findings in this study more concerning. Research has highlighted the interactions between FI, HIV, and COVID-19 on multiple levels impacting HIV care outcomes, mental health, and other important public health priorities [16, 94–105]. In addition, there have been reports of increases in substance use during the pandemic [106–108]. In the context of this study, it is possible that the additional prevalence of FI and substance use will exacerbate the use of unsterile equipment, leading to increased HIV transmission.

This study has a few limitations: (1) The data collected for the main analyses, unprotected sexual contacts, shared needles/syringes, and FI, were all self-reported, which could be affected by recall bias and/or social desirability bias although this is the standard means of collecting such information. (2) Power may have been an issue, particularly for the needles/syringe sharing risk analyses. However, the results generated from these analyses provide useful estimates for the design of future larger studies on food insecurity and HIV risk behaviors. (3) In this analysis we had a limited number of events for the shared needle variable. (4) This study collected information on count of sexual contact events, however it would have been valuable to have information about participants' number of different partners. (5) This study collected information on the type of drugs participants used, but not the type of drugs used for injections specifically. This is a limitation, given that the risk of HIV acquisition may be different for distinct drugs [109, 110]. Of note, other analyses of this cohort found that 121 (34%) participants used opioids and 22 (6%) used stimulants in the past 30 days at baseline [111]. Future studies would benefit from inquiring on mode of use for each drug. (6) A large proportion of the participants (all ZINC participants) had risky drinking as an inclusion criteria to the parent study. Risky drinking may be a confounder for FI in combination with social and behavioral factors and hence we attempted to control for this factor in the analysis but nonetheless this characteristic may have skewed the results of the present analysis. (7) ART use may have changed for participants throughout the study, a factor for which we were unable to account, given that we did not have viral load suppression data which would have impacted the HIV transmission risks. (8) Given that housing insecurity and food insecurity overlap, we may have excluded a number of FI individuals, as one of the inclusion criteria for the study was a "stable address within 100 km of St. Petersburg." Screening data shows that only six of 556 potential participants were excluded solely due to this exclusion criterion, and thus this is not a serious limitation. Given that housing insecurity and food insecurity overlap we may have excluded a number of food-insecure individuals, as the inclusion criteria for the study were those who had a "stable address". Screening data shows that only six of 556 potential participants were excluded solely due to this exclusion criterion, and thus this is not a serious limitation. These participants may have had a stable address, but not within the study catchment area or they may have been experiencing housing insecurity and interpreted this question as needing stable housing. Even with this screening question, 1.4% of the study population reported current homelessness and 4% reported unstable living situation in the past 30 days at baseline, and thus this question did not exclude all housing insecure people.

Conclusion

This study explored associations between current FI and HIV transmission via sexual and needle sharing pathways among a very high-risk population, PWH not on ART at baseline with substance use. Although no significant association between FI and sex risks was observed, we detected a potential association between severe FI and unsafe injection practices that requires further research to confirm. The latter could have important implications for how the public health community considers harm reduction programming and suggests benefit may be possible by going beyond targeting only needle sharing practices. Further studies on PWH with substance use are warranted to further investigate the impact of FI on HIV transmission. Potentially, NGOs and government programs can explore curbing HIV transmission via programs that aim to alleviate FI in this population.

Appendix: Modified Household Food Insecurity Access Scale, Used in Our Study

In the past four weeks…	1. No	2.Rarely (1-2 times)	3.Sometimes (3-10 times)	4.Often (>10 times)	Refused
1. Did you worry that the household would not have enough food?	0	2	3	4	8
2. Were you not able to eat the kinds of food preferred?	0	2	3	4	8
3. Did you eat a limited variety of foods?	0	2	3	4	8
4. Did you eat some foods that you really did not want to eat?	0	2	3	4	8
5. Did you eat a smaller meal than you felt you needed?	0	2	3	4	8
6. Did you eat fewer meals in a day?	0	2	3	4	8
7. Was there no food to eat of any kind in your household?	0	2	3	4	8
8. Did you go to sleep at night hungry?	0	2	3	4	8
9. Did you go a whole day and night without eating?	0	2	3	4	8

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Declarations

Conflict of interest The authors declare no conflicts of interest.

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Informed Consent This research involved human subjects and all participants provided written informed consent.

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