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Mediation of peer education intervention effects on injection-related HIV risk behavior among male Tajik labor migrants

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Abstract

Introduction: The effects of network-based peer education interventions for HIV prevention presumably influence injection-related risk behavior through changes in peer norms and safer injection self-efficacy (SISE). In this paper, we test these mediating effects on receptive syringe sharing (RSS) and ancillary equipment sharing.

Methods: The "Migrants' Approached Self-Learning Intervention in HIV/AIDS for Tajiks" (MASLIHAT) intervention was tested in Moscow in a cluster-randomized controlled trial in comparison with a non-HIV health education training (TANSIHAT). Tajik migrants who inject drugs (N=140) were recruited as peer educators (PEs) to attend the 5-session MASLIHAT training or the TANSIHAT comparison condition. In both conditions, participants recruited two network members who inject drugs with the intent to share with them the information and positive strategies for change they had learned (n=280). PEs and network members in both conditions (n=420) participated in baseline and follow-up interviews at 3-month intervals for one year. We conducted causal mediation analyses to test the direct and indirect effects of intervention arm and psychosocial variables on injection practices.

Results: MASLIHAT participants reported greater HIV knowledge, greater SISE, and safer descriptive and injunctive peer norms at 3-month follow-up compared to TANSIHAT participants. In the MASLIHAT arm only, greater HIV knowledge was associated with lower odds of RSS, and greater SISE and safer descriptive peer norms were associated with lower odds of both RSS and equipment sharing at 6-month follow-up. Injunctive peer norms were not associated with either outcome. Causal mediation analysis indicated that treatment effects were mediated by SISE and descriptive peer norms; however the distributions of responses on peer norms were problematic.

Conclusions: The MASLIHAT intervention had a strong effect on SISE and descriptive peer norms for safer injection, and these variables were significantly associated with injection risk behaviors at 6-month follow-up. Analysis results are consistent with mediation, however estimates may be sensitive to model assumptions because of restricted overlap in mediator distributions between treatment conditions.

Introduction

Network-based peer education interventions for HIV prevention have proven to be effective in reducing injection-related HIV risk behaviors [1–6]. These interventions leverage the important role of injection drug use networks as a vector for HIV transmission and acquisition due to sharing of injection equipment [7, 8], and the power of peer relationships among people who inject drugs [9, 10]. Theoretically, network-based peer education interventions reduce HIV risk by promoting the diffusion of HIV transmission and prevention knowledge, modifying peer norms for safer injection practices, and increasing self-efficacy for safer injection [11–15].

Few studies have rigorously examined mediation of these intervention effects. While increasing knowledge of HIV transmission risk is a necessary component of any HIV prevention intervention, previous studies have found that knowledge is not the primary factor in explaining the effectiveness of these interventions [16, 17]. Self-efficacy has been shown to be predictive of reduced injection risk behavior over time in longitudinal cohorts [18, 19], however, support for self-efficacy as a mediator of intervention effects is mixed [17, 20, 21]. While social norms supporting safer injection practices have consistently been found to be associated with less risky injection behavior [22–25], evidence for changing peer norms as a mediator of intervention effects on injection risk behavior is lacking.

We developed the Migrants' Approached Self-Learning Intervention in HIV/AIDS for Tajiks (MASLIHAT) intervention to address the need for preventive interventions for Tajik labor migrants who inject drugs while living in Moscow [26]. MASLIHAT is a network-based, peer educator training intervention developed as a socio-cultural adaptation of the Self-Help in Eliminating Life-Threatening Diseases (SHIELD) model [27] to reduce risky drug, alcohol, and sexual behavior among male Tajik migrants in Moscow who inject drugs. The intervention was designed to have index participants discuss

HIV-related risk and prevention with their injection networks, and promote and model risk reduction behaviors. This type of intervention was considered to be culturally appropriate as Tajik migrants who inject drugs interact in small homogeneous networks, social norms are important in Tajik culture, and peer educators can normalize discussion of otherwise typically taboo topics.

The MASLIHAT intervention was successful in reducing HIV-related injection and sexual risk behavior among both index participants and network members [28]. In the present study, we test the mediating processes of changes in HIV knowledge, descriptive and injunctive peer norms for safer injection, and safer injection self-efficacy on changes in receptive syringe sharing and sharing of ancillary injection equipment using a potential outcomes framework [29, 30]. Under this framework, causal effects are defined as the difference between potential outcomes defined by counterfactual conditions.

Methods

Study procedures were conducted in accordance with the principles of the Belmont Report and were approved by the Institutional Review Boards of the University of Illinois Chicago, PRISMA Research Center in Tajikistan, and the Moscow Nongovernment Organization “Bridge to the future.” All participants provided written informed consent. Trial methods and primary outcomes have been previously reported [28].

Recruitment and Site Assignment

From October 2021 to April 2022, 140 male Tajik migrant workers were recruited and trained as peer educators (PEs) from 12 sites in Moscow: 2 Tajik diaspora organizations, 4 bazaars, and 6 construction work sites. To participate as a PE assigned to either the MASLIHAT intervention or the TANSIHAT comparison condition, prospective participants needed to be a male Tajik migrant aged 18 or older, a current or former person who injects drugs (PWID), give informed consent, intend to reside in Moscow for the next 12 months to participate in their assigned intervention and follow-up data collection, and be willing to recruit two male PWID to participate as network members for baseline and follow-up interviewing but who would not participate in either condition’s educational sessions or activities. Network members (n = 280) had to meet the same eligibility criteria as PEs but also: 1) have injected drugs at least once in the last 30 days; and 2) be someone whom the PE sees at least once a week to permit him to share intervention information and encourage possible normative and behavioral change within their social networks. Participants received the equivalent of $20.00 in Russian Rubles for their time and transportation costs in participating in intervention sessions (PEs only) and for being interviewed at baseline and follow-up (both PEs and network members).

To prevent MASLIHAT cross-contamination of the control condition through shared peer networks, 12 recruitment sites were pair-matched according to site characteristics and randomly assigned to the MASLIHAT versus TANSIHAT condition. Recruiters were blinded as to each site’s assignment condition. Site assignment was revealed to the local project coordinator only when it was needed for scheduling intervention sessions.

Intervention sessions

MASLIHAT is a small-group, interactive intervention that relies on peer networks to reduce drug, alcohol, and sexual risk behaviors among temporary migrant workers who inject drugs. Migrants in the host country who inject or previously injected drugs are trained as PEs to promote positive HIV risk-reduction norms and behavioral change through role modeling and by sharing what they learned during MASLIHAT training sessions with their at-risk network members. The intervention includes five HIV knowledge and skill-building sessions that involve goal setting, role playing, demonstrations, homework, and group discussions. These sessions teach participants techniques for personal HIV risk reduction and the communication and outreach skills needed to encourage others at risk for HIV to also adopt them. As migrants often

confront special challenges based on social marginalization and economic disadvantage as a population within the host country [31, 32], MASLIHAT sessions also address lifestyle, health, and safety issues.

The 5 sessions are: 1) Introduction to MASLIHAT; general risks and safety for Tajik migrant workers; living a healthy lifestyle, resources & organizations serving Tajik migrants; 2) HIV 101; peer communication skills; 3) HIV/STI risk/prevention through hazardous alcohol consumption/unsafe sex; 4) HIV risk/prevention related to drug use; 5) Maintaining a healthier lifestyle; graduation. Homework and case studies per session help to script peer educator messages.

The TANSIHAT program echoes MASLIHAT in style and time commitment over 5 sessions: 1) Introduction to TANSIHAT; general risks to health and safety for Tajik migrant workers; strategies for general risk-reduction and living a healthy lifestyle; available resources; 2) Healthy nutrition and personal hygiene; peer communication skills; 3) Fitness and stress management; promoting a healthy lifestyle through physical exercises and stress management; 4) TB risk and prevention; prevention of TB among migrants and preventing TB transmission to families back home; 5) Maintaining healthier living and risk reduction; graduation.

Baseline and follow-up interviews

After giving informed consent, baseline interviews with PEs and network members were conducted at the PRISMA office in Moscow or a private location of the participant's choosing. Following the interview, participants were referred to the Moscow HIV Prevention Center to be tested for HIV and hepatitis C virus (HCV). Anonymized test results were reported to study staff with only a group number to identify the recruitment site. Follow-up interviews were conducted with PEs and network members at 3-month intervals. All participants were referred for repeat HCV testing following the 6 and 12-month interviews, and HIV testing following the 12-month interview.

Measures

The structured baseline questionnaire collected information on sociodemographic characteristics, migration characteristics, community involvement, injection drug use prior to migration and in the past six months in Moscow, sexual risk behavior, PWID network and injection risk behavior, HIV-related knowledge and attitudes, and psychosocial measures including depression, loneliness, and drug use and migrant stigma experience.

HIV knowledge was assessed with 13 items (Cronbach alpha = 0.91). Eight items assessed knowledge of HIV transmission routes with response options being "safe," "unsafe," or "not sure." Five additional true-false items measured HIV-related knowledge such as, "You can look at a person and tell if they are infected with HIV," and "There is a cure for HIV." Correct responses were summed for a possible total score of 13 with responses of "not sure" counted as incorrect.

HIV testing and serostatus was assessed by self-report at baseline, 3-month, 6-month, and 12-month follow-up by asking: a) "Have you ever been tested for HIV?" (Yes/No), and if yes, b) "What were the results of your most recent HIV test?" (1) HIV Positive (you have HIV), (2) HIV Negative (you don't have HIV), and (3) Decline to answer. Responses were collapsed across survey waves to create an indicator of reporting HIV positive.

Injection risk behavior: Recent receptive syringe sharing was assessed in response to the question, "When was the last time that you used a needle to shoot drugs after someone else used it first?" with 6 options: never, more than 4 weeks ago, in the last 4 weeks, within the last week, yesterday, or today. Responses were dichotomized into a binary measure of having or not having used a shared syringe within the past 3 months. Ancillary equipment sharing was assessed with the question, "In the past 3 months, how often have you used a cooker, cotton filter, or rinse water that someone else had

used?" with response options on a 7-point Likert scale from "Never" to "Always". Responses were dichotomized into a binary measure of having or not having used shared equipment.

Safer injection self-efficacy was assessed with six items developed for the CIDUS-III/DUIT study [33, 34] asking participants to rate their self-perceived ability to avoid sharing syringes and other injection equipment in different situations (e.g. "I can avoid using my injecting partner's needle, even if we have shared needles before.") Items were rated on a 4-point scale: (1) absolutely sure I cannot, (2) pretty sure I cannot, (3) pretty sure I can, (4) absolutely sure I can. Internal consistency was excellent for the six-item scale (alpha = 0.92) and principal factor analysis confirmed that the items loaded on a single factor. The scale score was computed as the average of item ratings.

Peer norms for safer injection. Descriptive and injunctive peer norms were assessed. All items were rated on a 6-point scale: 0="none", 1="a few (about 10%)", 2="some (about 25%)", 3="about half", 4="most (about 75%)", and 5="all". Descriptive norms were measured with five items asking how many of their friends in Moscow who inject drugs engage in various risk behaviors (e.g., "How many use a cooker that someone else has already used?"). Internal consistency was excellent for the 5-item scale (alpha = 0.91) and principal factors analysis confirmed that the items loaded on a single factor. Injunctive norms (self-perceptions of what others expect) were assessed with eight items asking how many of their friends who inject drugs care if the participant engages in unsafe behavior or would object to him taking HIV-related precautions, e.g. "How many would not say anything to you if they saw you use a dirty needle?" and "How many would get upset if you insisted on cleaning your needle before you lent it to them?" Internal consistency was good for the 8-item scale (alpha = 0.82). Principal factors analysis extracted two factors, with the first factor explaining 79% of the common variance. The scale scores were computed as the average of item ratings, ranging from 0 to 5. Scores were reversed so that higher scores indicated safer norms.

Analysis

We conducted a series of analyses to examine (a) changes over time in proposed mediator variables by condition, (b) 3-month mediator effects on 6-month injection risk outcomes, and (c) causal mediation effects. Mixed effects regressions included random intercepts on network cluster, and robust standard errors. Recruitment site (6 matched pairs) was treated as a fixed effect. Since previous analyses found no significant differences in injection behavior outcomes between peer educators and network members, we did not undertake separate analyses by participant type but included participant type as a covariate. HIV status and income were identified as potential confounders and included as covariates. There was no loss to follow-up at 6 months, and covariate missingness was minimal. Regression analyses were conducted using Stata v. 18.5, and causal mediation analysis was conducted using R v. 4.5.2.

Mediator models. We conducted linear mixed effects regression analyses to test the effects of intervention arm on changes in HIV knowledge, safer injection self-efficacy, and peer norms for safer injection from baseline to 3-month follow-up (Eq. 1). The 3-month mediator variable was regressed on intervention arm, baseline mediator score, participant type (PE or network member), self-reported HIV status (ever reported positive vs. never reported positive during study), income, and matched recruitment site pair. HIV testing was conducted anonymously, and there were no incident cases of HIV detected at 12-month follow-up; thus, all HIV positive reports were treated as pre-existing. Baseline mediator score is included to control for individual differences unrelated to the intervention. Interactions with intervention arm were tested for baseline mediator, participant type, and HIV status. Interactions with p-values < 0.10 were retained in the model.

$$E(MedVar3) = Int + (MedVar0*Arm) + (PartType*Arm) + (HIVstatus*Arm) + Income + SitePair \quad [1]$$

Outcome models. We conducted mixed effects logistic regression analyses of 6-month receptive syringe sharing and equipment sharing on intervention arm, 3-month mediator, participant type, HIV status, income, and site pair (Eq. 2). Interactions with intervention arm were tested for 3-month mediator, participant type, and HIV status. The mediator by intervention interaction was retained for causal mediation analysis, as it is a part of the decomposition of the total effect

[35, 36]. Otherwise, interactions with p-values < 0.10 were retained in the model. We computed marginal predictions of syringe and other equipment sharing over mediator values by intervention arm.

E(OutVar6) = Int + (MedVar3*Arm) + (PartType*Arm) + (HIVstatus*Arm) + Income + SitePair [2]

Figure 1. Directed acyclic graph of mediation model with 3-month mediator and 6-month outcome and baseline mediator as a covariate

Causal mediation. Mediation analyses were conducted using the *mediation* package in R with 1000 simulations [37]. The mediator and outcome models were specified using *lmer* and *glmer* and included interactions identified in mixed effects regression analyses of mediator and outcome variables, and random intercepts for network cluster. The effects of interest are the average causal mediation effect (ACME), which can be broken down into the pure natural indirect effect, or ACME untreated (ACME[0]) and the total natural indirect effect, or ACME treated (ACME[1]). The basic mediation model is shown as a directed acyclic graph in Fig. 1.

Results

Participant Characteristics

Table 1 shows the baseline demographic characteristics of PEs (N = 140) and network members (N = 280) for the entire sample. More men in the control condition were married, and men in the MASLIHAT condition tended to have slightly higher income. Income was significantly associated with receptive syringe sharing (IRR = 0.987, 95% CI 0.98–0.99) and marginally associated with other equipment sharing (IRR = 0.99, 95% CI 0.98–1.00). Marital status was not associated with receptive syringe sharing or other equipment sharing.

Table 1
Baseline demographic characteristics of MASLIHAT trial participants by intervention arm (N = 420)

Variable	**MASLIHAT** **n = 210**	**TANSIHAT** **n = 210**	
	N (%)	***N (%)***	***Chi2 (p)***
Peer Educator (PE)	70 (33.3)	70 (33.3)	
Network Member	140 (66.7)	140(66.7)	
Education [a]			0.59 (0.441)
Primary or Secondary	124 (59.1)	132 (62.9)	
Any higher education	86 (41.0)	78 (37.1)	
Employment [b]			1.54 (0.673)
Construction	114 (54.5)	116 (55.5)	
Loading in bazaar	41 (19.6)	46 (22.0)	
Selling or food service in bazaar	42 (20.1)	33 (15.8)	
Other	12 (5.7)	14 (6.7)	
Marital status [c]			6.18 (0.046)
Not married	100 (47.8)	76 (36.4)	
Married	18 (8.6)	34 (16.3)	
Divorced	91 (43.5)	99 (47.4)	
	Mean (SD)	*Mean (SD)*	*Chi2 (p)*
Age [d]	29.7 (6.1)	30.3 (6.3)	0.41 (0.523)
Monthly income [d]	44.9 (9.5)	42.7 (9.2)	3.30 (0.069)
Note. Monthly income is reported in thousands of rubles; SD: standard deviation			
[a] Wald chi2, cluster-adjusted GEE logistic regression; [b] Pearson chi2 (essentially no within cluster variation); [c] Wald chi2, random intercepts multinomial regression; [d] Wald chi2, cluster-adjusted GEE linear regression			

Of 413 participants who participated in anonymous HIV testing at baseline, 28 (6.8%) tested positive. Across all follow-up, 6.4% of participants self-reported a positive HIV test result (12 in MASLIHAT, 15 in TANSIHAT). There were no new HIV infections found in testing at 12-month follow-up.

Intervention effects on mediators

Descriptive statistics of the mediator and outcome variables across conditions and over time are shown in Table 2. Mediator values in the MASLIHAT group showed ceiling effects and restricted range, with limited or little overlap in values between conditions (see Appendix A, Supplementary File S1).

Table 2
Descriptive statistics of mediator and outcome variables (N = 420)

Variable	MASLIHAT (N = 210)		TANSIHAT (N = 210)	
	Baseline	**3-month Follow-up**	**Baseline**	**3-month Follow-up**
Mediators	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
HIV knowledge	7.84 (3.40)	12.66 (0.61)	7.03 (3.57)	7.20 (3.17)
SISE	2.08 (0.48)	3.11 (0.27)	2.01 (0.55)	2.00 (0.52)
Descriptive peer norms	0.79 (0.93)	4.89 (0.31)	0.83 (0.79)	0.95 (0.89)
Injunctive peer norms	0.89 (0.67)	4.64 (0.24)	0.93 (0.66)	0.91 (0.62)
	Baseline	**6-month Follow-up**	**Baseline**	**6-month Follow-up**
Outcomes	*n (%)*	*n (%)*	*n (%)*	*n (%)*
RSS	158 (75%)	15 (7%)	161 (77%)	175 (83%)
Equipment sharing	119 (68%)	16 (8%)	124 (61%)	170 (81%)

SISE: safer injection self-efficacy; RSS: receptive syringe sharing

Results of the mediator mixed effects regression models are presented in Table 3. At 3-month follow-up, compared to TANSIHAT participants and adjusted for baseline values, MASLIHAT participants reported greater HIV knowledge, greater self-efficacy for safer injection, and safer descriptive and injunctive peer norms. Significant interactions between intervention arm and baseline values reflect ceiling effects for HIV knowledge, safer injection-self-efficacy, and peer norms. In the TANSIHAT control group, baseline scores predicted follow-up scores. We also noted slightly higher HIV knowledge scores among MASLIHAT participants who reported a positive HIV test result.

Table 3
Mixed-effects linear regression models predicting 3-month mediator scores

Predictor	HIV knowledge n = 418	Injection self-efficacy n = 417	Descriptive norms n = 417	Injunctive norms n = 417
MASLIHAT vs. TANSIHAT	5.075 (0.086) $p < .001$	1.081 (0.022) $p < .001$	3.981 (0.056) $p < .001$	3.749 (0.027) $p < .001$
Corresponding baseline score	0.821 (0.031) $p < .001$	0.896 (0.033) $p < .001$	0.897 (0.033) $p < .001$	0.876 (0.037) $p < .001$
MASLIHAT × baseline score	-0.788 (0.034) $p < .001$	-0.924 (0.047) $p < .001$	-0.928 (0.047) $p < .001$	-0.875 (0.042) $p < .001$
Network member vs. PE	-0.136 (0.099) $p = .172$	-0.004 (0.023) $p = .866$	0.007 (0.026) $p = .803$	-0.025 (0.023) $p = .281$
HIV positive	-0.445 (0.409) $p = .276$	-0.024 (0.037) $p = .516$	0.449 (0.238) $p = .059^{\dagger}$	-0.021 (0.057) $p = .718$
MASLIHAT x HIV positive	0.793 (0.409) $p = .052$	-	-	-
Monthly income (per 1,000 rubles)	-0.0004 (0.005) $p = .941$	-0.002 (0.001) $p = .048$	0.001 (0.002) $p = .629$	-0.002 (0.001) $p = .080$

Note. PE: peer educator; Values are fixed-effect estimates with robust standard errors in parentheses and p-values; Linear mixed-effects models were estimated using maximum likelihood. Models included a fixed effect for recruitment site pair and random intercept for network cluster; baseline mediator values were mean-centered; MASLIHAT was the intervention condition and TANSIHAT was the control condition.

Mediator-outcome associations

Table 4 shows the results of mixed-effects logistic regression models predicting receptive syringe sharing and other equipment sharing at 6-month follow-up. These models tested whether associations between 3-month mediator scores and subsequent sharing outcomes differed by study arm. The interaction between the intervention arm and HIV knowledge was significant for receptive syringe sharing but not for other equipment sharing. In the MASLIHAT arm, greater HIV knowledge was associated with lower odds of receptive syringe sharing (OR = 0.48, 95% CI 0.26–0.92). HIV knowledge at 3-month follow-up was not associated with equipment sharing at 6-month follow-up in either treatment condition.

INSERT Table 4 HERE

Table 4
Mixed-effects logistic regression models predicting 6-month outcomes of receptive syringe sharing and ancillary equipment sharing

Variable	RSS			Equipment sharing		
	OR [95%CI]	p-value		OR [95%CI]	p-value	
HIV knowledge (n = 418)						
Treatment Arm (MASLIHAT vs. Control)	0.04 [0.01, 0.29]	0.001	**	0.02 [0.00, 0.19]	< .001	***
HIV knowledge	1.05 [0.93, 1.17]	0.431		0.97 [0.87, 1.08]	0.563	
Treatment Arm × HIV knowledge	0.46 [0.24, 0.89]	0.020	*	0.76 [0.38, 1.49]	0.420	
Safer Injection self-efficacy (n = 417)						
Treatment Arm (MASLIHAT vs. Control)	0.03 [0.01, 0.13]	< .001	***	0.06 [0.01, 0.31]	< .001	***
Safer injection self-efficacy	0.89 [0.34, 2.31]	0.803		0.71 [0.29, 1.75]	0.461	
Treatment Arm × Safer injection self-efficacy	0.07 [0.01, 0.81]	0.033	*	0.04 [0.00, 0.58]	0.018	*
Descriptive norms (n = 417)						
Treatment Arm (MASLIHAT vs. Control)	0.58 [0.04, 8.82]	0.693		1.37 [0.10, 18.89]	0.815	
Descriptive norms	0.62 [0.36, 1.08]	0.094	†	0.59 [0.34, 1.03]	0.062	†
Treatment Arm × Descriptive norms	0.26 [0.06, 1.10]	0.068	†	0.22 [0.05, 0.90]	0.036	*
Injunctive norms (n = 417)						
Treatment Arm (MASLIHAT vs. Control)	0.004 [0.00,0.53]	0.027	*	0.02 [0.00, 1.39]	0.069	†
Injunctive norms	1.43 [0.61, 3.37]	0.414		0.92 [0.40, 2.10]	0.845	
Treatment Arm × Injunctive norms	0.58 [0.05, 6.79]	0.662		0.93 [0.08, 11.14]	0.954	

Note: RSS: receptive syringe sharing; OR: odds ratio; CI: confidence interval based on robust standard errors. Models adjusted for participant type, HIV status, monthly income per 1,000 rubles, and site pair, with a random intercept for network cluster; MASLIHAT was the intervention condition and TANSIHAT was the control condition; mediator variable values are mean centered; †p< .10. *p < .05. **p < .01 ***p < .001

For safer injection self-efficacy, the interaction between MASLIHAT assignment and safer injection self-efficacy was significant for both receptive syringe sharing and other equipment sharing. Among MASLIHAT participants, higher safer injection self-efficacy was associated with lower odds of subsequent receptive syringe sharing (OR = 0.059, 95% CI 0.006–0.556), and equipment sharing (OR = 0.027, 95% CI 0.002–0.359). The intervention arm effect remained significant when adjusted for safer injection self-efficacy. For descriptive norms, the interaction between intervention arm and descriptive norms was significant for other equipment sharing (p<.05) and marginal for receptive syringe sharing. Among MASLIHAT participants, safer descriptive peer norms were associated with lower odds of receptive syringe sharing (OR = 0.163, 95% CI 0.042–0.632) and equipment sharing (OR = 0.129, 95% CI 0.035–0.472). The intervention arm effect was non-significant for both outcomes after adjusting for descriptive peer norms. Injunctive peer norms at 3-month follow-up were not associated with either outcome.

Figure 2. Predicted probability of 6-month syringe and ancillary equipment sharing outcomes by intervention arm and safer injection self-efficacy (mean centered) at 3-month follow-up

Figures 2 and 3 show marginal predictions of syringe and equipment sharing estimated from adjusted mixed-effect logistic regression models with a random intercept for network cluster. As shown in Fig. 2, higher injection self-efficacy at 3-month follow-up was associated with substantially lower predicted probabilities of both receptive syringe sharing and other equipment sharing among MASLIHAT participants at 6-month follow-up. In contrast, predicted probabilities of sharing were relatively flat across injection self-efficacy scores among TANSIHAT participants, consistent with the significant interaction between intervention arm and injection self-efficacy shown in Table 3. The wide confidence intervals reflect model extrapolation beyond the observed data.

In Fig. 3, Panel A shows marginal predictions of receptive syringe sharing, and Panel B shows other equipment sharing at 6-month follow-up by descriptive norms at 3-month follow-up. Safer descriptive norms were associated with lower probabilities of sharing in both treatment conditions, with a larger effect in the MASLIHAT condition. Again, wide confidence intervals reflect model extrapolation beyond the observed data.

Figure 3. Predicted probabilities of 6-month syringe and ancillary equipment sharing outcomes by intervention arm and descriptive safer injection peer norms (mean centered) at 3-month follow-up

Causal mediation analyses

Figure 4 presents the estimated average causal mediation effects (ACME) for 6-month syringe and equipment sharing outcomes. The effects are in probability scale (absolute percentage change), that is they indicate how much the predicted probability of the outcome is expected to change due to the mediator. Additional causal mediation plots displaying ACME and ADE estimates separately for the control and treatment groups are provided in Appendix B (Supplemental File S1). The results indicate that HIV knowledge did not significantly mediate the effects of MASLIHAT on receptive syringe sharing or equipment sharing. The estimated mediating effect of safer injection self-efficacy was significant for both receptive syringe sharing (ACME avg = -0.191, p=.010), and other equipment sharing (ACME avg = -0.270, $p < .001$). The estimated mediating effect of descriptive norms was also significant for both receptive syringe sharing (ACME avg = -0.548, $p < .001$), and other equipment sharing (ACME avg = -0.592, $p < .001$).

Table 5 presents the causal mediation results for receptive syringe sharing and other equipment sharing by treatment group, and average direct effects. ACME(treated) represents the estimated indirect effect under the MASLIHAT intervention condition. It includes the portion of the effect where the mediator's influence depends on the treatment level. ACME(control) represents the difference in expected outcome due to the mediator without treatment. It represents the part of the effect due to mediation alone, independent of any interaction between the treatment and the mediator [38]. Additional results are available in Appendix C (Supplemental File S1).

INSERT Table 5 HERE

Discussion

The Migrants' Approached Self-Learning Intervention in HIV/AIDS for Tajiks (MASLIHAT) is a network-based, peer educator training intervention developed to reduce risky drug, alcohol, and sexual behavior among male Tajik migrants in Moscow who inject drugs. The intervention trains participants to discuss HIV-related risk and prevention with their injection networks, and to promote and model risk reduction behaviors. In a previous paper we reported that the MASLIHAT intervention was successful in reducing injection and sexual HIV-related risk behavior among both peer educators and their network members [28]. Similar interventions have reported success in reducing HIV-related risk behavior among people who inject drugs in the U.S., Russia, and other countries [2, 3, 6, 39, 40]. However, few studies have reported

changes in perceived behavioral norms or safer injection self-efficacy, and we have not found any that have taken the next step to demonstrate whether or to what extent these changes actually mediated the intervention effects.

The present analysis shows that the MASLIHAT intervention significantly increased HIV knowledge and safer injection self-efficacy, and shifted behavioral norms toward safer injection practices. Safer injection self-efficacy and safer descriptive peer norms at 3-month follow-up, but not injunctive peer norms, were associated with less risky injection behavior at 6-month follow-up. Causal mediation analyses suggest that the effects of the intervention on injection behavior were mediated by changes in self-efficacy and perceived behavioral norms. Changes in safer injection self-efficacy were estimated to account for 27–39% of the total effect. The estimates for descriptive peer norms should be interpreted cautiosly due to almost complete separation of the distributions of the mediator between the two conditions. Significant mediation effects therefore may partly reflect model assumptions rather than empirical support. This situation may indicate a violation of the positivity assumption for the mediator [41], i.e. that any observed level of the mediator should have a non-zero probability of occurring across each treatment group.

The absence of any effect of safer injection self-efficacy at 3-month follow-up on syringe and ancillary equipment sharing behavior at 6-month follow-up in the TANSIHAT control group was unexpected, since the pre-intervention measures were correlated in both conditions (i.e. greater self-efficacy was correlated with a lower probability of sharing syringes or equipment). Syringe and equipment sharing increased over time in the TANSIHAT condition, which may have weakened the prospective association between earlier self-efficacy and later behavior. In contrast, descriptive peer norms for safer injection were associated with less risk behavior in both groups, but the effect was stronger in MASLIHAT condition.

Finding significant causal mediation effects in the treatment condition but not in the control condition indicates that the effect of the mediator on the outcome is conditional on receipt of the treatment. This treatment-by-mediator interaction indicates that the causal mechanism is only active under the treated condition. These results suggest that the MASLIHAT intervention not only shifted behavioral norms and increased self-efficacy for safer injection, but also strengthened the relationship between these social cognition variables and risk behavior. Peer support for safer injection likely has a synergistic effect with self-efficacy, increasing the possibility of implementing safer practices. While perceived self-efficacy indicates a belief that one is capable of performing the requisite behavior [42], it is more likely to be translated into action in the context of a supportive social environment [43, 44].

Limitations

The large effects observed in the MASLIHAT condition may raise questions about social desirability effects. Although sensitive survey questions were self-administered, peer educators and their network members in the MASLIHAT condition may have responded to questions about HIV-related risk behaviors according to their perceptions of what was expected of them. As reported previously, biological testing was uninformative as there were no new HIV-positive test results over the 12-month follow-up, and an equal number of new hepatitis C virus infections across conditions [28].

Causal mediation analysis requires certain assumptions to produce valid inferences. A key assumption is sequential ignorability [29, 41]. This assumption requires that there are no unmeasured confounders affecting any of the causal pathways [29, 45]. The assumption in regard to treatment-outcome and treatment-mediator confounding (ignorability of the treatment) is met by random assignment to treatment condition. However, the assumption in regard to mediator-outcome confounding (ignorability of the mediator) is not testable using observed data. We were not able to conduct sensitivity analysis in R to address this issue due to the multilevel structure of our data.

The large effects on HIV knowledge and peer norms in the MASLIHAT condition resulted in ceiling effects, low within-group variability, and little overlap in variable distributions between groups. Low within-group variability and limited overlap between groups may have affected the estimation of counterfactual outcomes, as the model must extrapolate beyond the

observed data. The estimates of the mediation effects, particularly for descriptive peer norms, should be interpreted cautiously.

Conclusion

The results indicate that the MASLHAT intervention had strong effects on HIV knowledge, safer injection self-efficacy, and descriptive and injunctive peer norms for safer injection, and that changes in safer injection self-efficacy and descriptive peer norms were associated with reductions in injection risk behaviors. Self-efficacy for safer injection was estimated to account for 27% to 39% of the intervention effect on injection risk behaviors. Descriptive peer norms were also identified as having a mediating role, however the estimates may be unstable because of low variability in the treated group distribution and limited overlap in distributions between conditions.

Table 5
Causal mediation analysis for MASLIHAT intervention effects on receptive syringe sharing and ancillary equipment sharing

Outcome / Mediator	ACME (control)			ACME (treated)			ADE avg			Prop. mediated (avg)
	ACME	95% CI	*p*	ACME	95% CI	p	ADE	95% CI	*p*	
RSS										
HIV knowledge	0.025	[-0.055, 0.097]	0.500	-0.406	[-0.684, 0.036]	0.084	-0.529	[-0.769, -0.329]	< .001	0.296
SISE	-0.021	[-0.142, 0.084]	0.726	-0.373	[-0.615, -0.078]	0.012	-0.534	[-0.708, -0.363]	< .001	0.273
Peer norms	-0.306	[-0.633, 0.019]	0.074	-0.790	[-0.929, -0.263]	0.012	-0.184	[-0.452, 0.034]	0.124	0.779
Equipment										
HIV knowledge	-0.022	[-0.124, 0.065]	0.718	-0.220	[-0.645,0.087]	0.484	-0.573	[-0.781, -0.299]	< .001	0.154
SISE	-0.054	[-0.187, 0.062]	0.418	-0.487	[-0.680, -0.209]	< .001	-0.433	[-0.599, -0.277]	< .001	0.390
Peer norms	-0.351	[-0.640, 0.005]	0.052	-0.833	[-0.929, -0.475]	< .001	-0.112	[-0.337, 0.083]	0.312	0.861

Note: Values are estimates with quasi-Bayesian 95% confidence intervals and p-values from causal mediation analyses using 1,000 simulations. RSS: receptive syringe sharing; SISE: Safer injection self-efficacy; Peer norms: descriptive peer norms for safer injection; ACME: average causal mediation effect; ADE: average direct effect

Abbreviations

HIV: Human Immunodeficiency Virus

MASLIHAT: Migrants' Approached Self-Learning Intervention in HIV/AIDS for Tajiks

PE: Peer educator

PWID: People who inject drugs

TANSIHAT: Targeted Application of Network and Social Intervention on Health Assistance for Tajiks

Declarations

Competing interests:

The authors have no competing interests to declare.

Compliance with Ethical Standards:

Study procedures were reviewed and approved by the Institutional Review Boards of the University of Illinois Chicago, PRISMA Research Center in Tajikistan, and the Moscow Nongovernment Organization “Bridge to the future.” All participants provided written informed consent. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

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Authors’ contributions:

JAL and MEM contributed to the study conception and design. Material preparation and data collection were performed by JJ. Data analysis was conducted by MEM and JP. The first draft of the manuscript was written by MEM and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data Availability:

The datasets supporting the findings of this study are available in the Open Science Framework repository. Project: MASLIHAT Randomized Controlled Trial [DOI 10.17605/OSF.IO/7G3YH. Data link: https://osf.io/ws5mp/].

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Figures

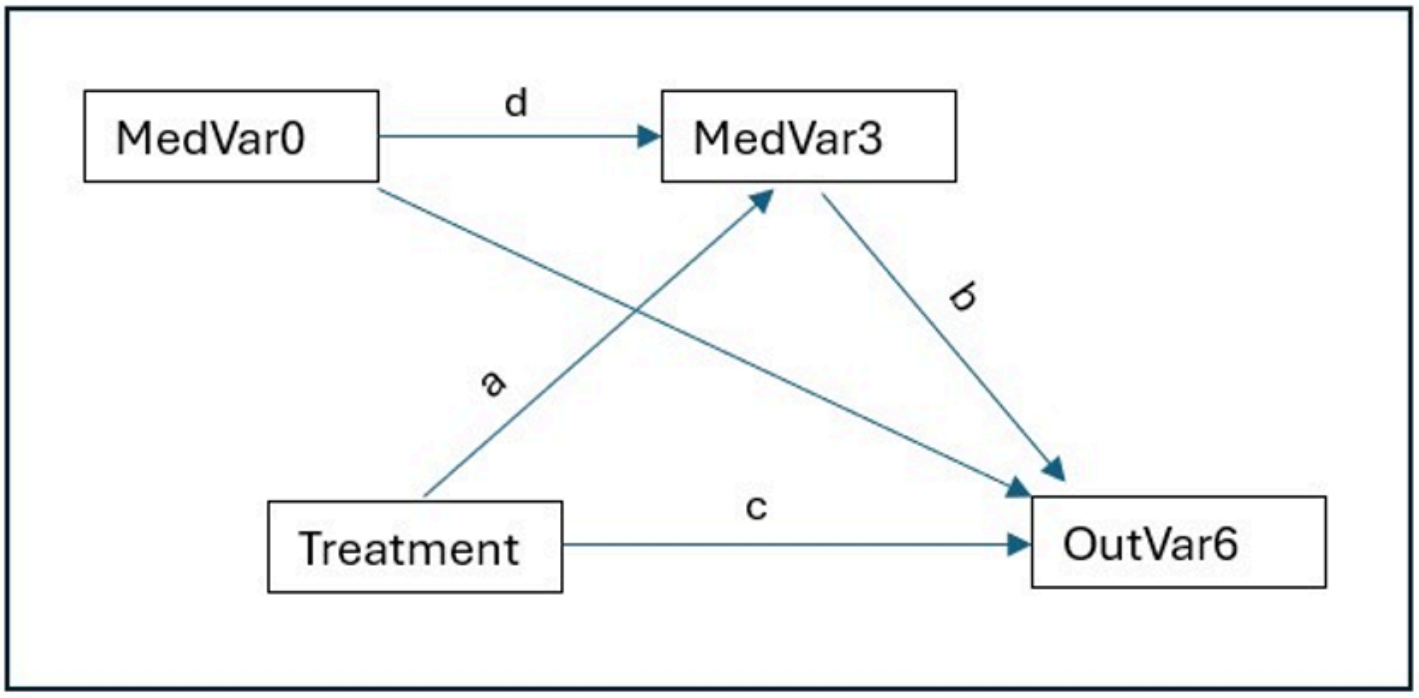


Figure 1

Directed acyclic graph of mediation model with 3-month mediator and 6-month outcome and baseline mediator as a covariate

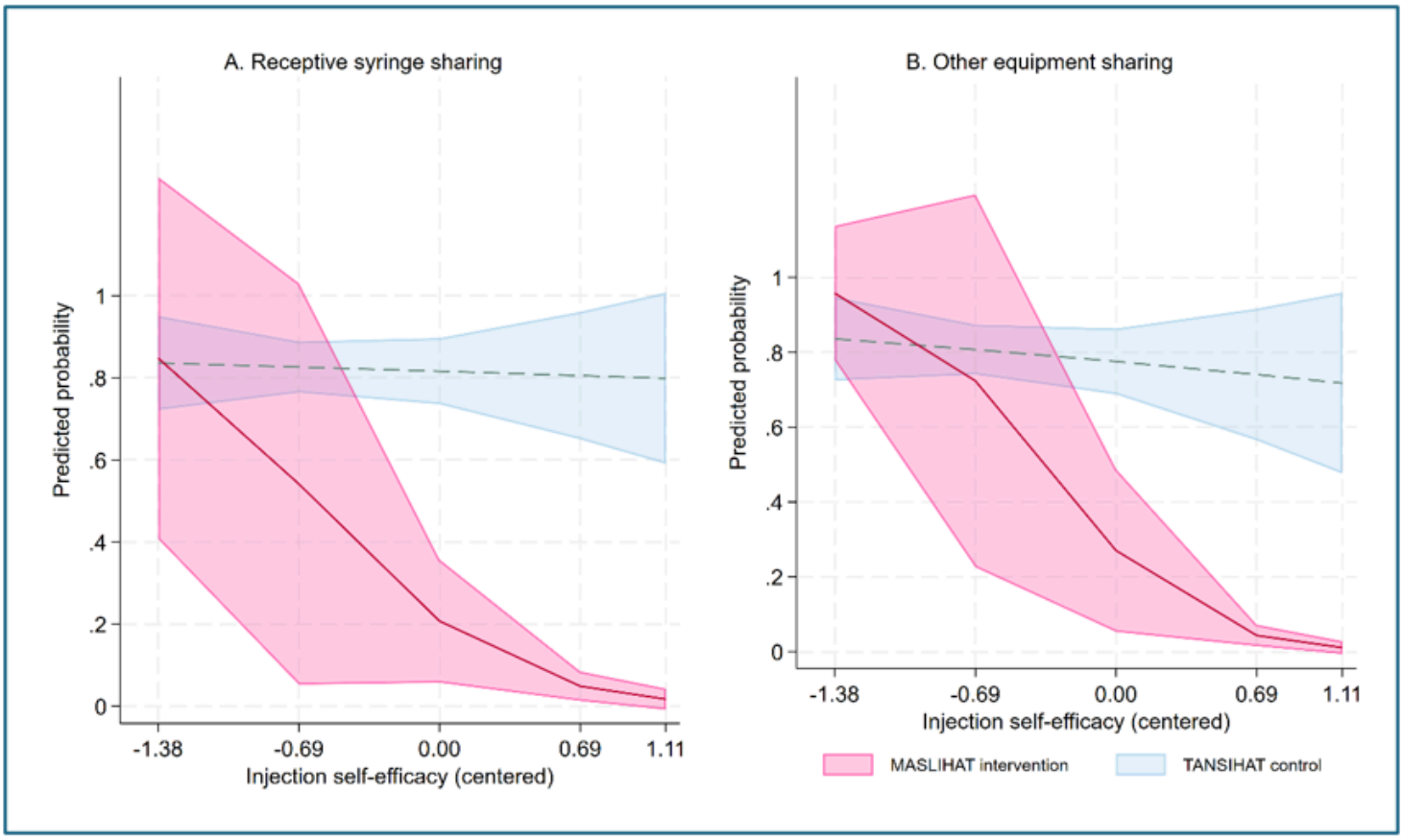


Figure 2

Predicted probability of 6-month syringe and ancillary equipment sharing outcomes by intervention arm and safer injection self-efficacy (mean centered) at 3-month follow-up

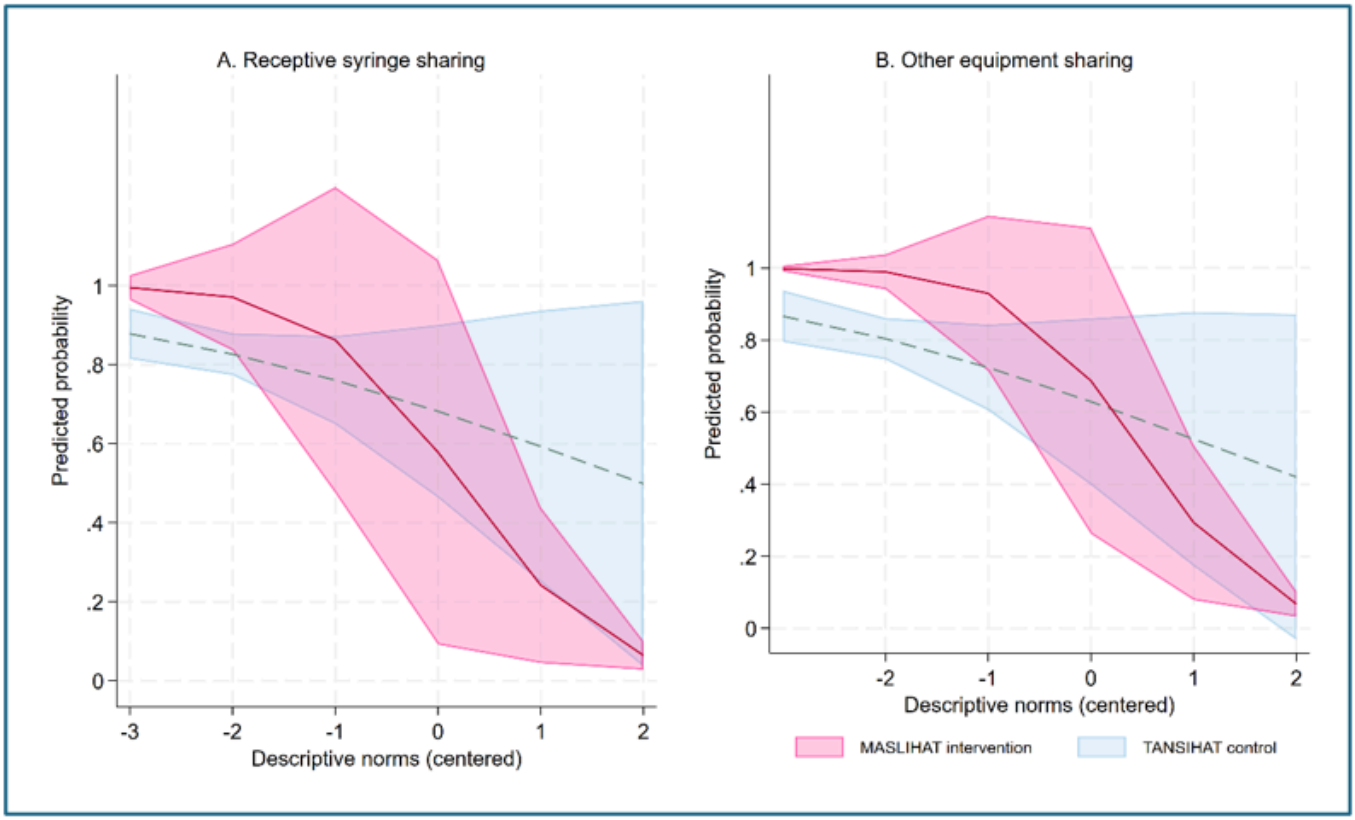


Figure 3

Predicted probabilities of 6-month syringe and ancillary equipment sharing outcomes by intervention arm and descriptive safer injection peer norms (mean centered) at 3-month follow-up