Does neighborhoods and social networks matter? Exploring the process from migration to HIV sexual risk behaviors among involuntary bachelors in rural China

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Abstract: The sex ratio imbalance in China since the 1980s has resulted in a large number of involuntary bachelors in rural China. Previous studies have found an association between migration and HIV sexual risk behaviors among involuntary bachelors, but how migration affects these bachelors' HIV sexual risk behaviors remain poorly understood. Using data from a cross-sectional survey in 2017 (a sample of 740 male respondents who had rural household registration, had never been married, and were aged 28 or older), we investigated the relationship between migration and HIV sexual risk behaviors. Logistic regressions show that migration, neighborhood characteristics, and social networks were significantly associated with commercial sex and multiple sex partners, whereas only neighborhood characteristics and social networks were positively correlated with sexual partnership concurrency. Our analysis also found that neighborhood characteristics and social networks mediated the relationships of migration with commercial sex and migration with multiple sex partners. Social networks mediated the association between neighborhood characteristics and concurrency. Multiple-step analysis showed that the indirect effect of migration on commercial sex and multiple sexual partners through neighborhood characteristics and social networks was significant. Our findings suggest that further interventions should address neighborhood characteristics and social networks together.

Keywords: Migration; HIV sexual risk Behaviors; Neighborhoods; Social networks; Involuntary bachelors; China.

Introduction

Over the past 40 years, there have been highly uneven sex ratios at birth in China due to sex selective abortions and female infanticide (Cameron et al., 2017; Guilmoto, 2015; Jiang & Zhang, 2021; South & Trent, 2010). As the birth cohorts of this period reach adulthood, there will be a dramatic excess of adult males relative to adult females in China (Shripad et al., 1995; South & Trent, 2010; Yuan, 2016). Huang (2014) estimated that the total number of excess males in the marriage market will reach 30 million in 2028 and peak at 41.41 million in 2043. It is estimated that more than 10% of males born after 1980 will not be able to find a spouse (Jiang et al., 2014), suggesting that China will experience a serious male marriage squeeze for decades. In particular, poor males who belong to the lowest social strata and live in impoverished rural areas are more likely to be squeezed out of the marriage market (Jiang et al., 2014; Jiang & Sánchez-Barricarte, 2014; Wang et al., 2018), and are often called involuntary bachelors (Attané et al., 2018; Yang et al., 2015). The potential consequences of having millions of involuntary bachelors have received a great deal of attention (Cameron et al., 2017; Edlund et al., 2013; Hudson & Boer, 2002; Jiang & Sánchez-Barricarte, 2011; Liu et al., 2012; Tucker et al., 2005), and HIV transmission is a case in point. Previous studies have estimated that unmarried men were more likely than married men to engage in sexual risk behaviors (SRBs) and thereby facilitate HIV transmission (Poston & Glover, 2005; Tucker et al., 2005).

Migration has been recognized as a critical factor for HIV transmission

worldwide (El-Basse et al., 2011; Gandhi et al., 2015; Parrado & Flippen, 2014; Olawore et al., 2018). China had an estimated 380 million internal migrants by the end of the 2020, the largest number of internal migrants in the world (National Bureau of Statistics of China, 2021). During 2006-2017, HIV prevalence among migrants was 0.14%, much higher than the 0.06% among the general Chinese population (Qiu et al., 2018). There is also evidence that HIV prevalence among male migrants was even higher (0.20% – 0.95%) in geographic areas with higher HIV prevalence than in other areas (Jing et al., 2019; Luo et al., 2018). Moreover, male migrants are thought to act as "bridge populations" in the transmission of HIV (Tiruneh et al., 2015; Wang & Muessig, 2017), and those who are young and unmarried are more likely to engage in SRBs (Wang et al., 2013; Yang et al., 2015). Involuntary bachelors are leaving rural areas for China's industrial cities in search of work and marriage opportunities (Cameron et al., 2017; Liu et al., 2012; Tucker et al., 2005), and recent empirical studies confirmed that migrant bachelors engaged in SRBs more frequently than their rural counterparts (Gou et al., 2021; Xiao et al., 2020). However, it remains unclear why migration is associated with the SRBs of bachelors, and it is necessary to explore further the link between migration and SRBs among rural bachelors.

Literature Review

According to classical social disorganization theory, migration is a highly disorganizing experience (Parrado & Flippen, 2010, Thomas & Znaniecki, 1920). It disrupts established social control channels that were forged in communities of origin and exposes migrants to unfamiliar rules and patterns of behavior (Parrado & Flippen,

2010, 2014). Migrants' higher risk of acquiring HIV through sexual transmission may be attributed to changes in physical and social environments (Tiruneh et al., 2015; Yang, 2005) including the destination's neighborhood characteristics, which are generally defined as characteristics or conditions of the places where people live (Xiao et al., 2020). Previous research has demonstrated that migration often leads to changes in neighborhood characteristics (Magis-Rodriguez et al., 2009, Parrado & Flippen, 2010, 2014; Xiao et al., 2020). In addition, mounting empirical evidence suggests that neighborhood characteristics, such as neighborhood structure disadvantage, neighborhood physical disorder, and neighborhood social norms, are associated with sexual behavior and HIV transmission risk among migrants (Parrado & Flippen, 2010; Yang, 2005), men having sex with men (MSM) (Egan et al., 2011; Frye et al., 2017; Kelly et al., 2012), and urban youth (age 11-16) (Browning et al., 2008). Specifically, neighborhoods characterized by larger concentrations of recent migrants who are young and predominantly male often attract commercial establishments (Browning & Olinger-Wilbon, 2003; Magis-Rodriguez et al., 2009; Parrado & Flippen, 2014; Tucker et al., 2005), which have a direct impact on HIV transmission risk (Latkin et al., 2013a). Furthermore, although previous research has found significant associations between migration and neighborhood characteristics, and between neighborhood characteristics and HIV sexual risk behaviors, little research has tested whether neighborhood characteristics mediated the association between migration and HIV SRBs among involuntary bachelors. Thus, we propose our first hypothesis (H1): Neighborhood characteristics are associated with HIV SRBs

directly and mediate the association between migration and HIV SRBs among involuntary bachelors (path a1–b1 in Fig. 1).

Another important variable in the disorganized social context after migration is the social network, which Mitchell (1969) defined as "a specific set of linkages among a defined set of persons". Migration detaches migrants from their familiar social networks in their home areas and creates new social networks in the destination cities (Yang, 2014), which often have more tolerant social norms regarding sexual behaviors (Wang & Muessig, 2017; Yang, 2014; Yang & Yang, 2019). Additionally, social norms are considered as an important channel via which social networks influence individual behavior. Members of the same social network often share similar norms, attitudes, and levels of HIV risk behavior (Kelly et al., 2010). Social norms about sex play an important role in influencing sexual risk behavior (Yang, 2014). Previous studies have found that social norms were associated with a range of HIV-related behaviors among high-HIV risk groups, including injected-drug users (IDU) (Latkin et al., 2013b), and commercial sex male clients (CSMC) (Yang et al., 2010). Similarly, the link between social norms and HIV-related behaviors among rural-urban migrants in China, due to their economically, socially, and geographically marginalized status, has been well-documented (Wang & Muessig, 2017; Yang, 2014; Yang & Yang, 2019). Furthermore, perceived sexual risk behaviors among social network members may mediate the relationship between migration and sexual risk behavior (Yang, 2014). Therefore, we propose our second hypothesis (H2): Social networks are related to HIV SRBs directly and mediate the association between

migration and HIV SRBs among involuntary bachelors. (path a2–b2 in Fig. 1).

It is worth noting that the two mediators, neighborhood characteristics and social networks, are seen to be closely related in previous studies (Haynie et al., 2006; Kelly et al., 2012; Simons et al., 1996). The cultural transmission model, rooted in the subcultural perspective within urban and criminological theory (Anderson, 1999; Fischer, 1975; Warner, 2003; Wilson, 1996), hypothesizes that social networks in neighborhoods where social control is lax constitute a key social process through which neighborhood characteristics affect deleterious behaviors, including SRBs (Baumer & South, 2001; Browning & Olinger-Wilbon, 2003; Haynie et al., 2006; Kelly et al., 2012; Simons et al., 1996). The literature on adolescents and youth highlights the power of peers and youths' proximal friends in the transmission of norms through networks and communities (Warner et al., 2011). Disadvantaged neighborhoods breed youth peer groups that encourage early and frequent sexual activity, behavior that is transmitted to other community residents (Baumer & South, 2001). For example, Anderson (1999), in his important work on the urban underclass youth, observed ‘‘sex codes’’ among young male peer groups that encouraged higher-risk sexual activity as a sign of manhood and a source of respect (see also Browning et al., 2008; Baumer & South, 2001; Warner et al., 2011, Berg et al., 2016). These subcultural values developed in response to foreclosed opportunities for conventional success in disadvantaged neighborhoods (Browning et al., 2008; Warner et al., 2011; Berg et al., 2016). For migrants in China, whose new social networks comprise mainly peers and who are isolated from native residents in urban areas, similar

subcultural values existed (Yang & Yang, 2019). Previous studies have found that SRB was viewed positively when migrants had more friends engaging in such behavior in disadvantaged destinations (Wang & Muessig, 2017; Yang, 2014; Yang & Yang, 2019). Other research has documented that social networks (predominantly peer networks) mediated the association between neighborhood characteristics and numerous social ills, such as adolescent violence (Haynie et al., 2006), adolescent problem behavior (Simons et al., 1996), and SRBs among MSM (Kelly et al., 2012). Taken together, disorganized neighborhoods and social networks in urban areas have the potential to magnify the impact of migration on SRBs. That is, in disorganized neighborhoods in urban areas, migrants are more likely to be exposed to deviant social behaviors, which in turn increases their vulnerability to HIV and other sexually-transmitted infections (STIs). Hence, we posit our third hypothesis (H3): neighborhood characteristics and social networks simultaneously mediate the migration-HIV SRBs relationship among involuntary bachelors. (path a1–a3–b2 in Fig. 1)

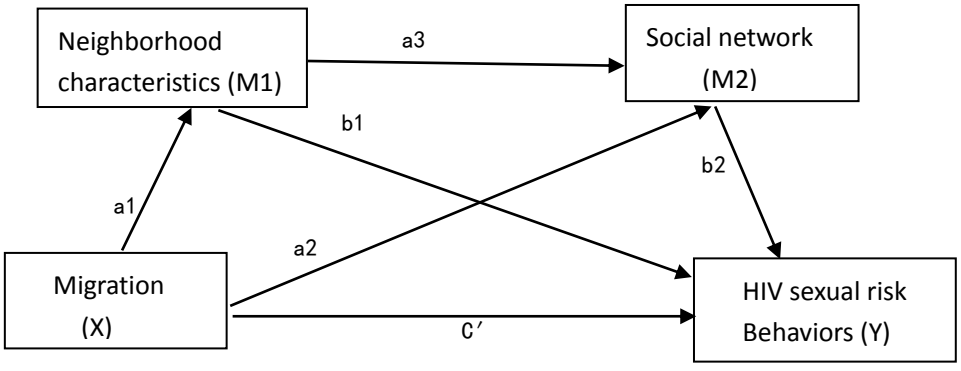

Figure 1. Conceptual model of migration and HIV sexual risk behaviors

Methods

Study setting and procedure

Data for the present study are taken from a cross-sectional survey "Mobility, Sexuality and Quality of Life of Never Married Men in Rural China" conducted from January to September, 2017. Eligibility criteria for respondents in this study were: 1) being a never-married man; 2) having rural household registration (hukou); and 3) being 28 years old or older. In rural areas, stratified multi-stage sampling was utilized to identify involuntary bachelors including those living in rural areas and those who had returned from rural to urban migration. We conducted the survey in 113 villages and bachelors were randomly selected from the name-lists provided by the village cadres.

We also surveyed migrant bachelors in urban areas of Xi'an, Shenzhen, and Dongguan city, where migrants were concentrated (National Health Commission of China,2017), from June to September in 2017. Referring to rural-urban migrant occupations in the 2010 census of China, five construction sites, one labor market, and ten factories were randomly selected. We applied cluster sampling to choose eligible respondents from each sampling site.

The CAPI (computer-assisted personal interviewing) instrument was used to ensure the privacy of the respondents and the reliability of the survey. Written informed consent was obtained from the study participants. All study protocols were approved by the Biomedical Ethics Committee of Xi'an Jiaotong University. We

obtained 744 samples by merging the data from rural and urban areas. In our analysis, we excluded four men who did not provide information on sexual behaviors. The final sample includes data from 561 migrant bachelors and 179 non-migrant rural bachelors for a total of 740 respondents from 95 counties in 20 provinces.

Measures

Commercial sex behavior

A number of studies have highlighted that commercial sex behavior increases the risk of HIV transmission (Tiruneh et al., 2015; van Veen et al., 2010; Wang & Muessig, 2017). Commercial sex was measured by asking "Have you had sexual intercourse with sex workers so far," which was coded as "1 = yes" and "0 = no".

Multiple sexual partners behavior

Multiple partnering has frequently been documented as an important HIV risk factor (Hu et al., 2006; Kalichman et al., 2011; Liu et al., 2021). Participants were asked to report their lifetime number of sex partners with the question: "How many people have you had sex with in your life?" Participants reporting more than one sex partner were coded as "1" and others were coded as "0".

Sexual partnership concurrency

Sexual partnership concurrency was defined as overlapping sexual partnerships in a given time period (Morris & Kretzschmar, 1997). (To better prevent this behavior, UNAIDS has called for more research on social factors affecting concurrency (Yamanis et al., 2016).). Participants were asked if they had at least two sexual partnerships that overlapped in a given time period. "Yes" was coded as 1, and "No"

was coded as 0.

Migration

Participants were asked if they had ever worked for at least six months in urban areas of other counties or provinces. This variable was coded as "1 = yes" and "0 = no".

Neighborhood Characteristics

In order to adequately understand neighborhood factors linked to HIV, it is important to measure key neighborhood characteristics (Latkin et al., 2013a). Previous research has documented that commercial sex was often prevalent in male-dominated environments and could facilitate HIV transmission (Magis-Rodriguez et al., 2009; Parrado & Flippen, 2010; Browning & Olinger-Wilbon, 2003). Thus, we measured neighborhood characteristics associated with exposure to HIV risk by availability of sex services and prevalence of sex trade.

Availability of sex services was measured by two items, "How many sex workers are near the village/community where you reside?" and "How many sex workers are near the village/community where you work?", on a four-point scale ranging from "0=none" to "3=many", respectively. Those answering "don't know" were coded as "0". A summary score was created with a higher score indicating a higher level of availability of sex services (ranging from 0 to 6).

To measure prevalence of the sex trade, we asked the participants "How many people do you know in the village/ community where you reside who had sexual intercourse with sex workers?" and "How many people do you know in the village/community where you work who had sexual intercourse with sex workers?".

A summary score was created with a higher score indicating a higher prevalence of sex trade (ranging from 0 to 6).

In our analysis, total neighborhood characteristic scores are calculated by summing the availability of sex services and prevalence of sex trade, with a higher score indicating a higher exposure to HIV risk in the neighborhood (scores ranged from 0 to 12). Cronbach's alpha for neighborhood characteristic measured by both the availability of sex services and prevalence of sex trade is 0.796.

Social networks

In line with the well-established name generator for discussing important matters (Burt, 1984), we used intimacy between respondents and contacts (alters) as criteria to develop a name generator. The name generator asked the respondents to "list the five people with whom you interacted most frequently over the last six months, excluding your parents or siblings".

We assessed the social network of the bachelors from the perspective of social norms. Three questions about attitudes toward commercial sex, purchasing commercial sex and communication on sexual life/sexual experience were used to assess social norms. First, to measure attitudes toward commercial sex, participants were asked if each of their social network contacts approved of the behavior of having sex with female sex workers (FSWs) (4-point response scale, 1= strongly disagree /4= strongly agree). Each response to the question was dichotomized as "1=agree" and "0=disagree". A composite score was calculated by adding responses on their five social network contacts, so the range of summed scores was 0 to 5, with a higher

score reflecting greater approval of commercial sexual behaviors in the network. Next, to measure purchasing commercial sex, respondents were asked if each of their contacts had sex with female sex workers. Each response to the question was coded as "1=yes" and "0=no". A composite score was obtained by summing responses on their five social network contacts, ranging from 0 to 5, with a higher score indicating more engagement in commercial sex in the network. Moreover, to measure communication on sexual life/sexual experience, participants were asked if they ever talked with a contact in the social network about sexual life and sexual experience. Each response was coded as "1=yes" and "0=no", and a composite score was calculated by adding responses on their five social network contacts, ranging from 0 to 5, with a higher score indicating more communication about sexual life and sexual experience in the network.

Total social networks scores were calculated by summing scores for attitudes toward commercial sex, purchasing commercial sex, and communication on sexual life/sexual experience, with a higher score indicating a higher exposure to HIV risk in social networks (ranging from 0 to 15). Cronbach's alpha for these three items was 0.723, indicating high internal reliability.

Control variables

In previous studies, demographic background characteristics are suggested as important determinants in HIV transmission (El-Bassel et al., 2011; Tiruneh et al., 2015), and alcohol use may increase HIV sexual risk (Jennifer et al., 2020; Kalichman et al., 2011; Tiruneh et al., 2015). Demographic background characteristics included

in our model are age, education level (primary school and below, middle school, high school and above), monthly income (below 3,000 yuan (RMB), between 3,000 and 5,000 yuan, above 5,000 yuan), and occupation (farmer, worker/employee, civil servant and manager, freelance and other). In addition, alcohol use was assessed by asking "In the past 12 months, have you experienced excessive drinking (or being drunk)?" Response was coded as "0 = never", "1 = sometimes" and "2 = often".

Statistical analysis

Both independent sample t-tests and Pearson's chi-squared tests were used to compare socio-demographic profiles, neighborhood characteristics, social networks, and SRBs among migrant and non-migrant bachelors. Four logistic regression models were employed to assess the role of migration experience, neighborhood characteristics, social networks, and the confounding effect of neighborhood characteristics and social networks on the three types of SRB dependent variables – commercial sex, multiple sexual partners and sexual partnership concurrency. Models 1 tested the associations between migration experiences and the three types of SRBs. The role of neighborhood characteristics in the associations between migration and three types of SRBs were tested in models 2 by adding neighborhood characteristic variables to models 1. The role of social networks in the associations between migration and the three types of SRBs were tested in models 3 by adding social network variables to models 1. The confounding effect of neighborhood characteristics and social networks in the association between migration and the three types of SRB dependent variables were tested in models 4 by adding social network variables to models 2. The above

analyses used Stata 15 software. Finally, because we hypothesized that there are three mediation pathways through which migration influences HIV SRBs, we applied the bias-corrected bootstrapping approach advocated by Preacher and Hayes (2008) to conduct mediation analyses with the PROCESS procedure. If the 95% confidence interval for an estimate of a coefficient does not include zero, that indirect effect is considered significant. In addition to calculating indirect effects, PROCESS also calculates the unstandardized path coefficients for all paths in the model (Turan et al., 2017). In all of the analyses, we controlled demographic background characteristics, and alcohol use.

Results

Table 1. Comparison of sample characteristics among bachelors by migration status

	Non-migrant bachelors (N=179)	Migrant bachelors (N = 561)	t / $\chi 2$	p value
HIV sexual risk behaviors				
Commercial sex behaviors	23 (12.85%)	151 (26.92%)	14.93	0.000
Multiple sex partners	67 (37.43%)	318 (56.68%)	20.16	0.000
Sexual partnership concurrency	11 (6.15%)	57 (10.16%)	2.62	0.105
Neighborhood	0.84 (1.25)	2.51 (2.58)	-9.03	0.000
Social network	1.45 (2.08)	2.36 (2.69)	-4.17	0.000
Age	34.55 (4.81)	33.05 (4.38)	3.90	<0.001
Education			31.53	<0.001
Primary school and below	78 (43.58%)	124 (22.10%)		
Junior high school	55 (30.73%)	240 (42.78%)		
Senior high school and above	46 (25.70%)	197 (35.12%)		
Monthly income			24.74	<0.001
<3,000 yuan	100 (55.87%)	205 (36.54%)		
3,000-5,000 yuan	47 (26.26%)	256 (45.63%)		
>5,000 yuan	32 (17.88%)	100 (17.83%)		
Occupation			81.19	<0.001
Farmer	81 (45.25%)	97 (17.29%)		
Worker/employee	38 (21.23%)	303 (54.01%)		

Civil servant, manager	21 (11.73%)	35 (6.24%)		
Freelance and other	39 (21.79%)	126 (22.46%)		
Alcohol use			8.31	0.016
Never drunk	38 (21.13%)	71 (12.66%)		
Sometimes drunk	120 (67.04%)	427 (76.11%)		
Often drunk	21 (11.73%)	63 (11.23%)		

Table 1 compares characteristics of bachelors by migration. There are significant differences in utilization of commercial sex and multiple sex partners between the two sub-samples. Among migrant bachelors, 26.92% had utilized commercial sex, while this percentage was 12.85% among non-migrant bachelors. 56.68% of the migrant bachelors had had multiple sex partners, while this percentage was 37.43% among non-migrant bachelors. For sexual partnership concurrency, although the difference between the two types of samples was not significant, 10.16% of the migrant bachelors had experienced this behavior, while among the non-migrant group the proportion was 6.15%. There were significant differences in neighborhoods and social networks between the two groups. Compared to non-migrant bachelors, the neighborhoods of migrant bachelors had more sex services available and the sex trade was more prevalent. The social networks of migrant bachelors were more tolerant of commercial sex, with more network members purchasing commercial sex services, and with more communication on sexual life/sexual experience. For the control variables, all the comparisons show significant differences between the two groups (p value < 0.05). Migrant bachelors were younger, a higher percentage were workers or company employees, they had higher educational achievement and a higher average monthly income, and they were more likely to have been drunk than their non-migrant counterparts.

Table 2. Logistic regression models for engaging in commercial sex

	commercial sex			
	Model 1	Model 2	Model 3	Model 4
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Age (years)	0.02 (0.02)	0.02 (0.02)	0.03 (0.03)	0.04 (0.03)
Education (primary and below for reference)				
Middle school	-0.42 (0.23)+	-0.48 (0.25) +	-0.37 (0.26)	-0.41 (0.27)
Higher school and above	-0.50 (0.28)+	-0.56 (0.31)+	-0.49 (0.31)	-0.49 (0.32)
Monthly income (3,000 and below for reference)				
3,000-5,000 yuan	0.19 (0.22)	0.27 (0.25)	0.44 (0.25) +	0.46 (0.26)+
>5,000 yuan	0.52 (0.29)+	0.52 (0.32)	0.70 (0.32) *	0.69 (0.34)*
Occupation (farmer for reference)				
Worker/employee	0.08 (0.28)	0.05 (0.31)	-0.23 (0.31)	-0.19 (0.33)
Civil servant, manager	0.60 (0.41)	0.45 (0.46)	-0.14 (0.46)	-0.05 (0.48)
Freelance and other	0.23 (0.29)	-0.10 (0.33)	-0.03 (0.32)	-0.25 (0.34)
Alcohol use (never drunk for reference)				
Sometimes drunk	0.75 (0.32)*	0.55 (0.34)	0.45 (0.34)	0.32 (0.35)
Often drunk	1.45 (0.38)***	0.78 (0.43)+	1.10 (0.41) **	0.59 (0.44)
Migration	1.02 (0.26)***	0.11 (0.29)	0.76 (0.28) **	0.15 (0.30)
Neighborhood		0.47 (0.05) ***		0.36 (0.05)***
Social network			0.37 (0.04) ***	0.27 (0.04)***
Constant	-3.39 (0.96)***	-3.67 (1.05) ***	-4.27(1.06) ***	-4.37 (1.10)***
Pseudo R2	5.76	19.80	18.54	24.90
LL	-380.36	-323.70	-328.78	-303.11
N	740	740	740	740

Standard errors in parentheses +p< 0.1，*p< 0.05，**p< 0.01，***p< 0.001

Table 2 presents the results of logistic regressions for the risk of engaging in commercial sex. Model 1 examined the association between migration and engaging in commercial sex, while controlling age, education level, monthly income, occupation, and alcohol use. Compared to non-migrant bachelors, migrant bachelors were more likely to engage in commercial sex. In Model 2 we added the neighborhood characteristics to Model 1 to examine the effect of neighborhood characteristics on commercial sex. Neighborhood characteristics were significantly associated with a higher risk of engaging in commercial sex ($p < 0.001$), indicating that with greater availability of sex services and the prevalence of the sex trade in

urban areas, migrant bachelors are more likely to engage in commercial sex. However, after adding the neighborhood characteristics variable, the correlation between migration and commercial sex was not significant, which indicates that the association between migration and commercial sex may be mediated by neighborhood characteristics. In Model 3, we added the social network variables to Model 1 to examine the effect of social networks on commercial sex. The social network variables were associated with a significantly higher risk of engaging in commercial sex ($p < 0.001$). Bachelors who communicated about sexual life/sexual experiences within their social networks, and who perceived that more network alters purchased commercial sex services and approved of commercial sex, were significantly more likely to engage in commercial sex. After adding the social network variable, although the correlation between migration and commercial sex remained significant, it decreased substantially, indicating that the association between migration and commercial sex may be mediated by the social network. Finally, in Model 4 we added the social network variable to models 2 to test the confounding effect of neighborhood characteristics and social networks on commercial sex. Social networks were significantly associated with a higher risk of engaging in commercial sex ($p < 0.001$), but the correlation between migration and commercial sex remained nonsignificant. However, after adding the social network variable, although the correlation between neighborhood characteristics and commercial sex remained significant, it decreased substantially, indicating that the association between neighborhood characteristics and commercial sex may be mediated by the social network. For the control variables,

monthly income above 5,000 Yuan was positively associated with a higher risk of engaging in commercial sex.

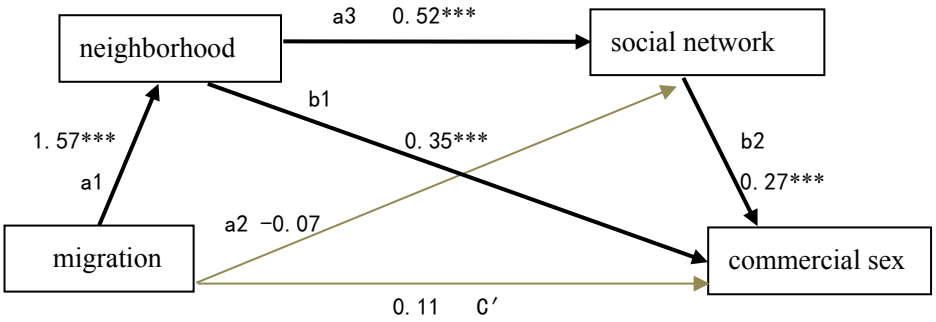

Figure 2. Multiple-step mediation analysis for commercial sex.
+p< 0.1，*p< 0.05，**p< 0.01，***p< 0.001

To test the mediating effects of neighborhood characteristics on the association between migration and commercial sex (path a1–b1 in Fig. 1), we used 5,000 bootstrap samples to obtain the bias-corrected 95% confidence interval for the indirect effect (i.e., mediated effect). The indirect effect of migration on commercial sex through neighborhood characteristics was significant [coefficient = 0.74, SE = 0.10, CI (0.5500, 0.9470)], as this confidence interval did not include zero. Therefore, hypothesis H1, namely that neighborhood characteristics are associated with commercial sex directly and mediate the association between migration and commercial sex among involuntary bachelors, is supported. Next, we tested the mediating effects of social networks on the association between migration and commercial sex (path a2–b2 in Fig. 1). The indirect effect of migration on commercial sex through social networks was significant [coefficient = 0.27, SE = 0.08, CI (0.1163, 0.4366)]. Hypothesis H2, that social networks are associated with commercial sex and mediate the association between migration and commercial sex,

is also confirmed. Finally, to test the multiple-step mediating effects of neighborhood characteristics and social networks (path a1–a3–b3 in Fig. 1), we used 5,000 bootstrap samples to obtain the bias-corrected 95% confidence intervals for the total indirect effect (i.e., total mediated effect) and the specific indirect effects. The total indirect effect of migration on commercial sex was significant [coefficient = 0.77, SE = 0.12, CI (0.5366, 0.9990)]. The indirect effect of migration on commercial sex through neighborhood characteristics and social networks was also significant [coefficient = 0.22, SE =0.04, CI (0.1441, 0.3192)]. This confirms that a multiple-step mediation is present. Again, the indirect effect of migration on commercial sex through neighborhood characteristics was also significant [coefficient = 0.57, SE =0.10, CI (0.3852, 0.7639)]. However, the indirect effect of migration on commercial sex through the social network was not significant [coefficient = -0.02, SE =0.05, CI (-0.1251, 0.0744)]. After controlling the three indirect individual paths, the direct effect of migration on commercial sex was not significant [coefficient = 0.11, SE =0.29, CI (-0.4538, 0.6735)]. Thus hypotheses H3, that neighborhood characteristics and social networks simultaneously mediate the migration-HIV SRBs relationship, is confirmed (see Fig 2).

Table 3. Logistic regression models for having multiple sexual partners

	multiple sexual partners behavior			
	Model 1	Model 2	Model 3	Model 3
	Coefficient SE	Coefficient SE	Coefficient SE	Coefficient SE
Age (years)	0.00 (0.02)	-0.00 (0.02)	0.01 (0.02)	0.01 (0.02)
Education (primary and below for reference)				
Middle school	0.04 (0.21)	0.06 (0.22)	0.09 (0.22)	0.09 (0.22)
Higher school and above	0.10 (0.24)	0.16 (0.26)	0.12 (0.26)	0.15 (0.26)
Monthly income (3,000 and below for reference)				
3,000-5,000 yuan	0.53 (0.19)**	0.60 (0.20)**	0.73 (0.20) ***	0.73 (0.21)***
>5,000 yuan	0.22 (0.25)	0.19 (0.27)	0.37 (0.27)	0.33 (0.27)
Occupation (farmer for reference)				
Worker/employee	0.59 (0.24)*	0.57 (0.25)*	0.40 (0.25)	0.45 (0.25)+
Civil servant, manager	1.32 (0.39)**	1.26 (0.40)**	0.90 (0.41) *	0.97 (0.41)*
Freelance and other	0.69 (0.25)**	0.52 (0.26)*	0.57 (0.26) *	0.47 (0.27)+
Alcohol use (never drunk for reference)				
Sometimes drunk	0.90 (0.23)***	0.76 (0.24)**	0.73 (0.25) **	0.67 (0.25)**
Often drunk	1.66 (0.33)***	1.31 (0.35)***	1.46 (0.35) ***	1.27 (0.36)***
Migration	0.55 (0.20)**	0.04 (0.21)	0.38 (0.21) +	0.07 (0.22)
Neighborhood		0.34 (0.05) ***		0.24 (0.05)***
Social network			0.29 (0.04) ***	0.21 (0.04)***
Constant	-2.10 (0.83)*	-2.10 (0.86) *	-2.64 (0.87) **	-2.50 (0.88)**
Pseudo R2	8.31	14.90	14.79	17.45
LL	-469.75	-435.96	-436.57	-422.94
N	740	740	740	740

Standard errors in parentheses +p< 0.1，*p< 0.05，**p< 0.01，***p< 0.001

The estimates from logistic regression for multiple sexual partners are presented in Table 3. Model 1 shows that migrant bachelors were more likely to have multiple sexual partners, which suggests that migration increases the risk of having multiple sexual partners. After adding neighborhood characteristics in Model 2, the association between neighborhood characteristics and a higher risk of having multiple sexual partners was significant ($p < 0.001$). However, in Model 2 the correlation between migration and multiple sexual partners was not significant, suggesting that the association between migration and multiple sexual partners may be mediated by

neighborhood characteristics. Again, in Model 3, when social network variables were added to Model 1, they were associated with a significantly higher risk of having multiple sexual partners ($p < 0.001$). Although the correlation between migration and multiple sexual partners remained significant, ($p < 0.1$), the correlation coefficient decreased substantially, indicating that the association between migration and having multiple sexual partners may be mediated by the social network. Finally, in Model 4 we added social networks variables to models 2 to test the confounding effect of neighborhood characteristics and social networks on the association between migration and having multiple sexual partners. Social networks were significantly associated with a higher risk of engaging in multiple sexual partners ($p < 0.001$). The correlation between migration and multiple sexual partners remained nonsignificant, but after adding the social network variables, although the correlation between neighborhood characteristics and multiple sexual partners remained significant, the correlation coefficient decreased substantially, indicating that the association between neighborhood characteristics and multiple sexual partners may be mediated by the social network. For the control variables, monthly income between 3,000 and 5,000 yuan, being drunk and frequent drunkenness, and being a civil servant or a manager were positively associated with a higher risk of having multiple sexual partners.

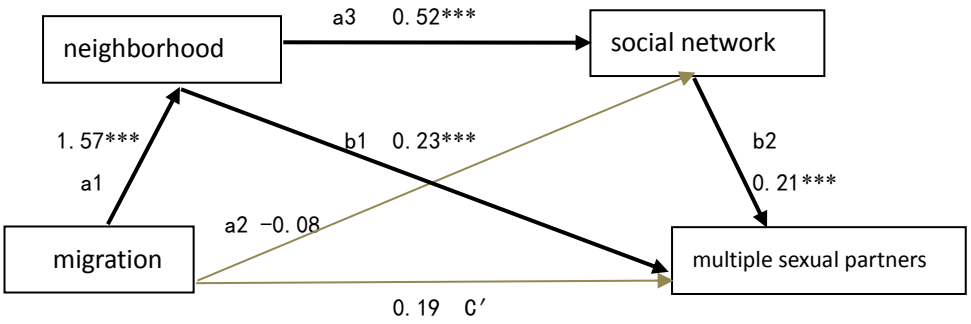

Figure 3. Multiple-step mediation analysis for multiple sexual partners.

+p< 0.1，*p< 0.05，**p< 0.01，***p< 0.001

Next, we conducted the same mediation analyses as described above but replaced the commercial sex with having multiple sexual partners. First, to test the mediating effects of neighborhood characteristics on the association between migration and having multiple sexual partners (path a1–b1 in Fig. 1), we used 5,000 bootstrap samples to obtain the bias-corrected 95% confidence intervals for the indirect effect (i.e., mediated effect). The indirect effect of migration on having multiple sexual partners through neighborhood characteristics was significant [coefficient = 0.52, SE = 0.09, CI (0.3711, 0.7101)], as this confidence interval did not include zero. Therefore, hypothesis H1, that neighborhood characteristics are associated with having multiple sexual partners directly and mediate the association between migration and having multiple sexual partners, is supported. Second, we tested the mediating effects of social networks on the association between migration and having multiple sexual partners (path a2–b2 in Fig. 1). The indirect effect of migration on having multiple sexual partners through social networks was significant [coefficient = 0.22, SE = 0.07, CI (0.0935, 0.3608)]. Hypothesis H2, namely that social networks

are associated with commercial sex and mediate the association between migration and social networks, is also confirmed.

Finally, we conducted a multiple-step mediation analysis to test the mediating effects of neighborhood characteristics and social networks (path a1–a3–b3 in Fig. 1). As the confidence interval for this indirect model did not include zero, the total indirect effect of migration on having multiple sexual partners was significant [coefficient = 0.52, SE = 0.10, CI (0.3396, 0.7156)]. The indirect effect of migration on having multiple sexual partners through neighborhood characteristics and the social network was also significant [coefficient = 0.17, SE =0.04, CI (0.1025, 0.2710)], which suggests that there is multiple-step mediation. The indirect effect of migration on having multiple sexual partners through neighborhood characteristics was significant [coefficient = 0.36, SE =0.09, CI (0.2095, 0.5431)], although the indirect effect of migration on having multiple sexual partners through the social network was not [coefficient = -0.02, SE =0.04, CI (-0.1036, 0.0627)]. After controlling the three indirect paths, the direct effect of migration on having multiple sexual partners was not significant [coefficient = 0.19, SE =0.20, CI (-0.2058, 0.5876)]. Thus, hypotheses H3, namely that neighborhood characteristics and social networks simultaneously mediate the migration/multiple sexual partners relationship, is supported (see Fig. 3).

Table 4. Logistic regression models for engaging in sexual partnership concurrency

	sexual partnership concurrency			
	Model 1	Model 2	Model 3	Model 4
	Coefficient SE	Coefficient SE	Coefficient SE	Coefficient SE
Age (years)	0.02 (0.03)	0.02 (0.03)	0.02 (0.04)	0.02 (0.04)
Education (primary and below for reference)				
Middle school	-0.19 (0.34)	-0.24 (0.35)	-0.09 (0.36)	-0.15 (0.36)
Higher school and above	0.02 (0.40)	0.03 (0.40)	0.14 (0.42)	0.14 (0.41)
Monthly income (3,000 and below for reference)				
3,000-5,000 yuan	0.03 (0.32)	0.02 (0.33)	0.10 (0.34)	0.08 (0.34)
>5,000 yuan	0.13 (0.41)	-0.04 (0.43)	0.10 (0.43)	-0.03 (0.44)
Occupation (farmer for reference)				
Worker/employee	0.21 (0.41)	0.29 (0.43)	0.07 (0.43)	0.16 (0.45)
Civil servant, manager	-0.02 (0.62)	-0.11 (0.65)	-0.55 (0.67)	-0.43 (0.68)
Freelance and other	0.21 (0.42)	0.01 (0.45)	0.05 (0.45)	-0.03 (0.46)
Alcohol use (never drunk for reference)				
Sometimes drunk	0.26 (0.43)	-0.06 (0.44)	-0.01 (0.44)	-0.12 (0.40)
Often drunk	1.25 (0.49)*	0.63 (0.52)	0.85 (0.52)	0.49 (0.53)
Migration	0.51 (0.36)	-0.22 (0.40)	0.22 (0.37)	-0.22 (0.40)
Neighborhoods		0.32 (0.06) ***		0.23 (0.06)***
Social networks			0.27 (0.04) ***	0.19 (0.05)***
Constant	-3.70 (1.38)**	-3.71 (1.42) **	-2.64 (0.87) **	-4.02 (1.47)**
Pseudo R2	3.00	10.41	10.66	13.61
LL	-220.29	-203.45	-202.89	-196.19
N	740	740	740	740

Standard errors in parentheses +p< 0.1，*p< 0.05，**p< 0.01，***p< 0.001

Table 4 presents the results of logistic regressions for the risk of engaging in sexual partnership concurrency. For Model 1, the association between migration and sexual partnership concurrency was not significant, controlling for socio-demographic background characteristics and alcohol use. For Model 2, when we added neighborhood characteristics, they were significantly associated with a higher risk of engaging in sexual partnership concurrency ($p < 0.001$). For Model 3, when social network characteristics were added, they were significantly associated with concurrency ($p < 0.001$). Finally, when social network characteristics were added to

Model 2, both neighborhood characteristics ($p < 0.01$) and social networks ($p < 0.001$) were significantly associated with concurrency, and the coefficient of neighborhood characteristics was substantially reduced, suggesting that the social network may mediate the association between neighborhood characteristics and concurrency.

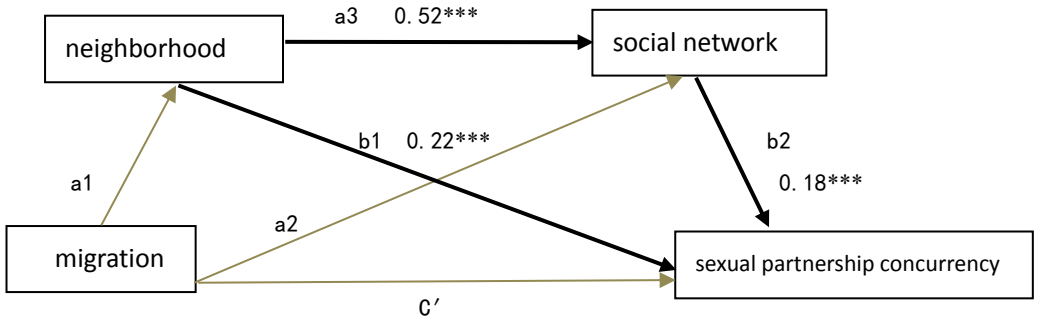

Figure 4. Mediation analysis for sexual partnership concurrency.

+p< 0.1，*p< 0.05，**p< 0.01，***p< 0.001

Although the association between migration and sexual partnership concurrency was not significant, both neighborhood characteristics and social networks were significantly associated with concurrency. Therefore, we conducted mediation analysis to test whether the social network was a mediator between neighborhood characteristics and concurrency. The indirect effect of neighborhood characteristics on concurrency was significant [coefficient = 0.09, SE = 0.03, CI (0.0397, 0.1456)], which suggests that the social network was indeed a mediator between neighborhood characteristic and concurrency. After controlling the indirect paths, the direct effect of neighborhood characteristic on concurrency remained significant [coefficient = 0.22, SE =0.06, CI (0.1076, 0.334)], suggesting there may exist other indirect paths (see Fig. 4).

Discussion

This study developed and empirically tested a conceptual model to better understand how migration shapes the HIV sexual risk behaviors of involuntary bachelors. We examined two critical migration-related factors jointly: neighborhood characteristics and social networks. Several of our findings deserve to be highlighted.

First, we examined the effects of migration on HIV sexual risk behaviors. Compared to their non-migrant counterparts, migrant bachelors made greater use of commercial sex and more often had multiple sex partners, which is consistent with previous research on migrants (Hu et al., 2006; Parrado & Flippen, 2014). For sexual partnership concurrency, the difference between the two groups was not significant, which is consistent with results of a study of the migrant population in Honduras (Gandhi et al., 2015) and may be attributed to migrants' disadvantage in the sexual partnership market and their lower socioeconomic status. Our findings echo and support some of the previous concerns that migration may increase the risk of HIV transmission among involuntary bachelors (Liu et al., 2012; Tucker et al., 2005). With a growing number of involuntary bachelors and their massive numbers of migrants, the Chinese government should pay more attention to these bachelors who are more vulnerable to the risk of HIV transmission.

Second, we found evidence that neighborhood characteristics were associated directly with commercial sex, having multiple sexual partners, and sexual partnership concurrency. They also mediated the association between migration and both using commercial sex and having multiple sexual partners. These are important findings

because they reveal a possible mechanism for how migration influences HIV sexual risk behaviors. Consistent with previous research suggesting that available targets (sex workers and sex venues) (Browning & Olinger-Wilbon, 2003; Latkin et al., 2013a; Parrado & Flippen, 2010; Yang et al., 2020b) in a neighborhood increased the likelihood of engaging in HIV SRBs, our findings suggest that availability of commercial sex in urban neighborhoods indeed induces migrant bachelors to engage in HIV SRBs.

Third, our results confirm previous findings that social networks were associated with higher HIV sexual risk (Wang & Muessig, 2017; Yang, 2014; Yang & Yang, 2019). Bachelors who communicated about sexual life/sexual experiences within their social networks and perceived that more network alters had purchased commercial services and approved of utilizing commercial sex were significantly more likely to engage in commercial sex and have multiple sex partners. These findings suggest that migrant bachelors are at a particularly high risk of HIV transmission after migration due to their involvement with deviant social networks. Additionally, we found that social networks mediated the association between migration and commercial sex and multiple sexual partners, providing empirical evidence that social networks may mediate the relationship between migration and SRBs (Yang, 2014).

Most importantly, we found that social networks mediate the association between neighborhood characteristics and HIV SRBs, and a multiple-step mediation exists in the process from migration to HIV SRBs. These results are consistent with previous findings that neighborhood characteristics and social networks interact (Kelly et al.,

2012; Latkin et al., 2013a), and that the social network is an important pathway through which neighborhoods influence risky sexual behaviors and HIV SRBs (Browning & Olinger-Wilbon, 2003; Kelly et al., 2012). The combined effect of neighborhood characteristics and social networks, which has often been overlooked in the previous literature (Carpiano et al., 2011; Kelly et al., 2012; Latkin et al., 2013a), is critical for HIV-related prevention and intervention. To our knowledge, our research is the first that explicitly examines the combined effect of neighborhoods and social networks in the migration-HIV SRBs relationship, and reveals the whole pathway through which migration can influence involuntary bachelors' SRBs. Thus we have extended the classic social disorganization theoretical framework and cultural transmission models, which have been applied to risky sexual behaviors among immigrants, especially MSM and adolescent youth, to involuntary bachelors who have suffered from the severe marriage squeeze in rural China.

There are, however, several limitations of the present study. First, in terms of methodology, we cannot draw definitive conclusions regarding causality, as the data are cross-sectional. Second, in terms of theory, we have mainly considered the facilitating effects of neighborhood characteristics and social networks on migration-HIV SRBs relationship. However, it is worth noting the hindering effects of neighborhood characteristics and social networks on the migration-HIV SRBs relationship, such as through neighborhood regulations or informal control dynamics such as collective efficacy (Sampson et al., 1997). Further research may explore the migration-HIV SRBs process across multiple dimensions including the regulatory

influence of collective efficacy (Browning et al., 2008; Parrado & Flippen, 2014; Sampson et al., 1997) or family bonds (Yang &Yang, 2020a). Third, although a CAPI instrument was used to protect the privacy of the participants, SRBs may have been underreported because of their association with stigma and discrimination. In spite of these limitations, our study does capture pathways through which the effects of migration on HIV risky behaviors might operate, and which may also be useful for policy proposals.

Conclusions

This study highlights the importance of neighborhood characteristics and social networks in the migration-HIV SRBs relationship among involuntary bachelors. By quantifying the multiple-step mediating role of neighborhood characteristics and social networks between migration and HIV SRBs, our study reveals the whole pathway via which migration influences HIV SRBs among involuntary bachelors. Our findings suggest that the Chinese government should conduct more effective interventions to interrupt the potential HIV transmission linkage by simultaneously targeting migrant bachelors' neighborhood characteristics and social networks. Due to the increased availability of commercial sex in neighborhoods in urban areas, commercial sex has become an important way for involuntary bachelors to satisfy their sexual need. However, since commercial sex is regarded as morally deviant and not legal in China, it is difficult for sex workers and their clients to access formal HIV advice and care. Becoming more tolerant and properly regulating commercial sex could be beneficial to curb the risk of HIV transmission among migrant bachelors

given the serious gender imbalance and massive internal migration. In addition, although network-based interventions have been widely used in HIV prevention, they seldom consider neighborhood factors directly (Latkin et al., 2013a). Hence, in urban neighborhoods where migrants and commercial sex are heavily concentrated, it is crucial to change social norms among migrant bachelors by promoting risk awareness and improving HIV-related knowledge within social networks. It is also possible to improve the migration-related risk environment: by removing policy barriers to migration with their families, involuntary bachelors would have increased social support, both material and emotional, which could reduce their vulnerability to HIV risk.

Conflicts of interest

None.

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