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Geographic mobility and potential bridging for sexually transmitted infections in Agbogbloshie, Ghana

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Abstract

Short-term mobility can significantly influence the spread of infectious disease. In order for mobile individuals to geographically spread sexually transmitted infections (STIs), individuals must engage in sexual acts with different partners in two places within a short time. In this study, we considered the potential of mobile individuals as bridge populations – individuals who link otherwise disconnected sexual networks and contributed to ongoing STI transmission. Using monthly retrospective panel data, we examined associations between short-term mobility and sexual partner concurrency in Agbogbloshie, Ghana. We also examined bridging by the location of sex acts and the location of sexual partners in concurrent triads, and whether mobile individuals from our sample were more likely to be members of geographic bridging triads. Although reported rates of sexual partnership concurrency were much higher for men compared to women, mobility was only associated with increased concurrency for women. Additionally, this association held for middle-distance mobility and short-duration trips for women. Taking into account the location of sex acts and the location of sexual partners, about 22% of men (21.7% and 22.4% for mobile and non-mobile men, respectively) and only 3% of women (1.4% and 3.3% for mobile and non-mobile women, respectively) were potential bridges for STIs over the last year. Our results highlight the gendered nature of mobility and sexual risk behavior, reflecting the normative social context that encourages women to conceal certain types of sexual behavior.

Keywords

HIV; STI; Sexual network; Partner concurrency; Circular migration

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1. Introduction

Sexually transmitted infections (STIs) such as HIV are spread through structured networks of sexual partnerships. Understanding network structure is critical in developing and implementing prevention interventions for HIV (Jenness et al., 2016). Migrants and other mobile individuals historically have been shown to connect otherwise distinct networks, thereby influence ongoing HIV transmission (Coffee et al., 2007; Decosas, 1995; Martinez-Donate et al., 2015), including in Ghana (Agyei-Mensah, 2001; Anarfi, 1993; Decosas, 1995; Oppong, 1998). Broad population movement can influence infectious disease transmission (e.g. colonization and smallpox among Native Americans); however, short-term migration and travel can also influence how individuals within and between populations form and dissolve relationships over space and time (Camlin et al., 2013; Frye et al., 2014; Schuyler et al., 2015). Sexual behavior and partnership characteristics of mobile individuals could contribute to ongoing infectious disease transmission within or across networks, or foil prevention efforts in geographically distinct sub-populations. The relationship between short-term mobility, dynamic network structures and the risk of HIV transmission can be challenging to identify and measure due to unique data requirements, and therefore requires a network-based population health approach.

Mobile individuals have the potential to bridge sexual networks, and thus provide bi-directional paths for infectious disease transmission if they engage in concurrent sexual partnerships with partners in different places. Concurrent sexual partnerships are defined as overlapping sexual partnerships where sexual intercourse with one partner occurs between two acts of intercourse with another partner (Goodreau and Morris, 2012; UNAIDS Reference Group., 2010). Although still debated (Lurie and Rosenthal, 2010; Tanser et al., 2011), most evidence suggests that concurrent sexual partnerships significantly influence HIV transmission within heterosexual populations in sub-Saharan Africa (Eaton et al., 2011; Goodreau et al., 2012; Leung and Kretzschmar 2015; Morris et al., 2009). Bridging can also occur when sexual acts with partners in a concurrent triad occur in different places or sexual partners in a concurrent triad live in different places. Therefore, if mobile individuals engage in concurrent partnerships, then the locations of the individuals in the concurrency triads will identify where the bridging occurs.

In this study, we investigate whether and how mobile individuals may act as bridge populations for STIs. We use retrospective longitudinal data on short-term mobility and sexual behaviors from our recent study of sexually active adults in Agbogbloshie, a dynamic urban resource-poor area that is a migratory hub of Ghana and the larger region of western Africa. The specific aims of this study are to: 1) examine whether mobile individuals exhibit higher levels of concurrency compared to nonmobile individuals; 2) assess which characteristics of short-term mobility explain associations with concurrency; and 3) characterize geographical bridging partnerships and concurrent triads using a network perspective. In other words; what are the partnership configurations, where do sex acts with partners occur, where do the partners live, what is the prevalence of geographical bridging triads, and do the patterns vary by mobility status and gender? This information may inform effective HIV prevention strategies and optimize treatment regimens.

1.1. Background

1.1.1. Migration, HIV and sexual risk behavior literature—Mobile individuals might be at higher risk of contracting HIV/STIs compared to non-mobile individuals because either they are selected on risky behavior tendencies, or the act of migration enables risk behavior by creating opportunities for it (Cassels et al, 2014b). Migrants often have higher rates of HIV (Nunn et al., 1995) or more risky sexual behavior (Anarfi, 1993; Brockerhoff and Biddlecom, 1999; Cassels et al., 2013; Coffee et al., 2005; Magis-Rodriguez et al., 2004; Sanchez et al., 2012; Zuma et al., 2005) compared to non-migrants. Nonetheless, in some contexts, migrants are not found to exhibit higher levels of risk behavior or HIV prevalence (Mundandi et al., 2006), or the association is complicated by a number of different variables or contexts. Indeed, general migration theory suggests that the relationship between migration and sexual risk behavior depends on the context of migration, including the type, distance, destination, duration, social context, and reason for moving (Deane et al., 2010; Mundandi et al., 2006; Voeten et al., 2010). For example, migrants may travel to places with higher HIV/STI prevalence and thus have a higher risk of exposure. Alternatively, migrants may exhibit more risk behaviors than non-migrants, but if they are in a place with lower HIV/STI prevalence, then they would not have a higher risk of exposure. It should also be noted that reverse causation is possible, wherein HIV infection causes people to migrate to seek medical care or social support (Anglewicz, 2012; Anglewicz et al., 2016).

Since HIV and STI transmission requires a network of connected individuals, other work on migration, HIV, and sexual risk behavior focuses on characteristics of migrant sexual networks, such as migrant's partnerships (Cassels et al., 2013; Rai et al., 2014), characteristics of sending and receiving populations (Sanchez et al., 2012; Strathdee et al., 2008), and connectivity of sexual networks (Martinez-Donate et al., 2015). This line of inquiry also attempts to explain the spatial distribution of infection due to migration, such as changes in rural versus urban HIV prevalence in South Africa through circular migration (Coffee et al., 2007). Out-migration can affect sexual networks in communities left behind as well. In Tanzania, the separation of couples through travel or bilocational housing increased the risk behavior of the stay-at-home spouse (Vissers et al., 2008). Out-migration can also impact the broader network structure by creating a sex ratio imbalance (Pouget et al., 2010). Lastly, the movement of people can socially or geographically connect otherwise distinct sexual networks (Aral, 2000; Butler and Hallett, 2013; Neaigus et al., 2016), which we refer to as bridging.

1.1.2. The bridging hypothesis and conceptualization—The bridging pathway asserts that mobile individuals link otherwise distinct subpopulations (Aral, 2000; Cassels et al., 2014b). The bridging hypothesis for STIs claims that mobile individuals will also engage in high-risk sexual behavior that can promote the spread of STIs between populations. The UNAIDS definition of a bridge population is a population that connects high prevalence groups with individuals who would otherwise be at a low risk of infection. Population bridging may help explain past population-level changes in HIV prevalence in rural versus urban areas in a number of countries in sub-Saharan Africa, including South Africa (Coffee et al., 2007; Lurie et al., 2003), Kenya (Brockerhoff and Biddlecom, 1999), Uganda (Nunn et al., 1995), and Zimbabwe (Coffee et al., 2005). Other work has identified how individuals can bridge socially distinct populations and promote transmission of disease between them, such as between commercial sex workers and the general population (Morris et al., 1996), between populations with different sexual orientation (Cassels et al., 2010; Gorbach et al., 2009), and between high-risk and low-risk networks (Aral, 2000; Gorbach et al., 2005). Our paper addresses the bridging of geographically separate populations through partnership patterns associated with short-term mobility.

Mobile individuals – often mobile men – historically have been viewed as bridge populations, but evidence for this association mostly stems from studies conducted in the early phases of epidemics when clearly defined clusters of infection occurred (Lurie et al., 2003). Only recently have women been the focus of studies on migration and sexual risk behavior as well (Camlin et al., 2014). For example, the bridge hypothesis has been tested for men in South Africa, where male rural residents travel for work to an urban area with higher HIV prevalence, become infected there, and bring the infection back to their lower prevalence village (Lurie et al., 1997). Rates of HIV between countries and within countries in sub-Saharan Africa still vary widely (UN Joint Programme on HIV/AIDS, 2014), and geographical bridging can link these places. However, geographical bridging could influence the spatial trajectory of an epidemic even if it does not connect high-prevalence and low-prevalence groups (as defined by UNAIDS). Human mobility can link populations with other levels of risk, such as coverage of anti-retroviral therapy (ART) –higher coverage of ART in a population significantly lowers risk of transmission within that population. Thus, it is important to understand contemporary region-specific forms of geographic bridging for men and women within sub-Saharan Africa to identify from or to where infections might be occurring, or how human mobility might impact local interventions, such as ART coverage as prevention.

In this paper, we extend the conceptualization and test the bridging hypothesis in a number of ways. First, we use sexual partnership concurrency as our outcome of interest. Sexual partner concurrency is when an individual is involved in two or more sexual relationships that overlap in time, and is associated with a higher risk of STI or HIV transmission at a population level. Using this measure, as opposed to a measure of individual-level risk, explicitly specifies the potential pathway for bridging. Second, we include the locations of sex acts and sexual partners. In addition to the geographic mobility of an individual, it is important to consider the location of the exposure event (i.e. sex acts) and mobility of sexual partnerships when identifying bridge populations. The location of the sexual partner's residence can identify where ongoing transmission risk may occur. Geographic bridging, by definition, requires a mobile person, but not all mobile individuals engage in concurrent sexual partnerships. Using a dyadic perspective, or one that considers the connections between individuals, allows us to consider whether migrants are more or less likely to be in geographic bridging triads. Third, with this perspective, we can identify bridging partnerships even from the perspective of a non-mobile individual who has a sexual partnership with someone who lives elsewhere. Lastly, we are able to test the bridging hypothesis separately for men and women.

We hypothesize that mobile individuals are more likely to have concurrent sexual partnerships compared to non-mobile individuals. Secondly, mobile individuals will be more likely to engage in sexual acts in different geographic locations, and also have sexual partners who live in different geographic locations. Third, we assume that these general associations will hold for both men and women, but that the patterns and magnitude of association between mobility and concurrency will vary significantly by gender.

2. Data and methods

2.1. Study setting

We used data from the Migration & HIV in Ghana (MHG) study, a cross-sectional study of sexually active adults within Agbogbloshie, Ghana during 2012. Agbogbloshie is a densely settled, resource-poor setting in central Accra. In 2012, the population of Agbogbloshie was estimated at 8305 (54% female and 46% male), of whom 5466 were aged 15–49 (same gender distribution) (Ghana Statistical Service, 2012).

Agbogbloshie was chosen as a study site because its residents come from many regions in Ghana and represent a wide range of ethnicities, and it also attracts seasonal migrants, partly because it is home to Ghana's largest commercial fresh produce market (Oberhauser and Yeboah, 2011). Internal migration is very common in Ghana (Ackah and Medvedev 2012; Ghana Statistical Service, 2008; Ghana Statistical Service (GSS) 2009), and more than half of all internal migrants live in the Greater Accra and Ashanti regions (Rokicki et al., 2014). A substantial proportion of the Agbogbloshie population are migrants (Awumbila and Ardayfio-Schandorf, 2008; Oberhauser and Yeboah, 2011), and the migrants living in Agbogbloshie are quite mobile as well. Reasons for short-term mobility include circular labor migration to acquire or process goods to sell in Accra's central markets, travel for holidays and festivals, and to spend time with family outside of Accra. Many women from our study went to their parents' home to give birth to their children before returning back to Agbogbloshie.

HIV prevalence in Ghana has been declining and is currently near 1.4%, with more women infected compared to men (57% women, 43% men) (Ghana AIDS Commission, 2015). The majority of HIV-positive cases are found in the Ashanti (3.0% prevalence in 2010), Eastern (3.2%), and Greater Accra (2.6%) regions, while HIV prevalence is lowest in the Northern Region (0.7%0 (Dako-Gyeke et al., 2012). Utilization of antiretroviral therapy (ART) varies significantly by region and gender as well (Dako-Gyeke et al., 2012). Overall uptake of ART has increased dramatically since its introduction in 2003. However, less than 40% of people living with HIV in Ghana received ART in 2010, and men were much less likely to initiate ART compared to women. Reasons for gender and geographic disparities in ART uptake include stigma, rural barriers to HIV testing and treatment, and gender differences in routine health care and attitudes toward health (Ampofo, 2009; Dako-Gyeke et al., 2012).

2.2. Study design

The sampling scheme, survey methods, weighting scheme, and details about completion and response rates have been described in detail elsewhere (Cassels et al., 2014a). Briefly, the MHG used a two-stage cluster randomized sampling scheme to obtain a probability sample of the target population. Given a census of the area residences, we first selected households at random with probability proportional to estimated household size, and then randomly selected one adult household member to participate. Given differences between estimated and actual household sizes, we used a weighting scheme to address differential selection probabilities. Eligibility criteria were current residence in the selected household, age 18–49 years, and ever having consensual sexual intercourse. The Institutional Review Boards of the University of Washington and University of Ghana approved these study procedures.

The study involved a standardized survey administered by trained field staff and a diagnostic HIV-1/2 test, although for this analysis we only consider survey data. The survey was organized into sections with structured questions for demographics, summary travel, and sexual behavior, and also an event history calendar for detailed travel and sexual history for each month over the past year. A series of structured questions captured lifetime and recent migration, and short-term mobility patterns including the place of birth, length of time living in Agbogbloshie, number of residences within Accra, and summary measures of number of overnight trips and reasons for that travel. Structured partnership questions queried the lifetime history of sexual activity as well as number of past-year partners. Partners were defined as persons with whom the subject had engaged in consensual vaginal or anal intercourse.

For the event history calendar, questions and responses were addressed interactively with the subject, with the events over the year entered into the survey tool in order of recall related to key milestones (e.g., childbirth and holidays). Fig. 1 shows the event history scheme with a hypothetical response to demonstrate how mobility episodes, concurrent partnerships, and geographic characteristics of sexual behavior were recorded. Responses were obtained for each of the 12 months prior to the survey to obtain retrospective longitudinal data. Sexual data here were limited to the last three partners (Morris, 2004), including the duration and type of the partnership, month-by-month information on the type of the partnership, the frequency of protected and unprotected sexual activity within the partnership, geographic location of sexual activity, and where the partner lived within Ghana. Short-term mobility data included month-by-month information on each overnight episode, destination (city and region), duration of mobility episode, and reason for travel. Mobility data were geocoded to the city level using the ggmap software package in R (Kahle and Wickham). The distance between Agbogbloshie and each geocoded city was measured using data on the road networks, the most common mode of transportation in our study sample.

2.3. Measures

2.3.1. Concurrency—The main outcome in the analysis was sexual partnership concurrency per person/month, measured as having more than one ongoing partnership at any point during the month. For months in which concurrency could not be verified (only 8 out of 500), such as months with multiple short-duration (less than one month) partnerships or transitional partnerships in which one ends and a new partnership begins within the month, we conservatively assumed that an overlap in partnerships did not occur.

2.3.2. Mobility—Short-term mobility was measured as overnight travel away from Agbogbloshie regardless of duration or distance. International travel, although rare, was included. A night away from home but within Agbogbloshie, such as a night spent at a place of work or partner's house, was not counted as a mobility episode. Characteristics of the mobility episodes were used to define three additional short-term mobility measures: frequency, distance, and duration.

2.3.3. Mobility frequency—Our mobility frequency measure represented the number of unique trips an individual traveled in each month. The values for mobility frequency ranged from 0 to 3, with no respondents reporting greater than three trips in a month. We hypothesize that the more frequent an individual travels, the more opportunity they would have to engage in additional concurrent partnerships.

2.3.4. Mobility distance—Distance represented how far away from home, or geographically separated, a mobile individual was. The mobility distance did not always mean that the particular distance was actually traveled in that month if, for instance, a trip spanned an entire month. Therefore, we did not use the measure to represent the act of traveling; rather, it was a proxy for how geographically separated an individual is from Agbogbloshie. We hypothesize that individuals who travel to more geographically separate destinations would have more concurrent partnerships, especially for women, due to the ability to behave in a private or confidential way.

Destination was recorded for each unique trip taken in the last 12 months. For individuals who traveled more than once per month, we used the maximum distance of all the trips traveled within the month. The final categories of mobility distance for the analysis were: non-migrant, <10 km representing trips within Accra (e.g. Adabraka, Dansoman), 10–100 km which capture destinations within the Greater Accra Region (e.g. Tema) and closer places in bordering regions (e.g., Koforidua in the Eastern Region and Agona Swedru in the Central Region), and >100 km which includes destinations such as Kumasi, Cape Coast, Takoradi, and the northern regions of Ghana. In the descriptive analysis, we also constructed a map based on the region of travel destination, as opposed to a measure of distance.

2.3.5. Mobility duration—For each month, the duration of a mobility episode could range from 1 night to 30 nights, or the entire month. We wanted to identify individuals who were gone the entire month, thus not physically bridging two places within a month. Therefore, the categories were: non-migrant, 1–7 days, 8–29 days, and >29 days.

2.3.6. Geographic bridging triads—Geographic bridging triads are a subset of concurrent partnerships. Respondents were asked where sex acts occurred and where their partners lived. Both variables were coded as 1) within Agbogbloshie, 2) within the Greater Accra region but outside of Agbogbloshie, or 3) within Ghana but outside of the Greater Accra region. An individual was categorized as engaged in a *geographic bridging triad* if within that month they had >1 active partnership (i.e. degree 2 or higher), and engaged in a sex act outside of Agbogbloshie or had at least one partner who lived outside of Agbogbloshie. An individual was categorized as engaged in a *linked geographic bridging triad* if they also engaged in a sex act within Agbogbloshie or had a partner who lived within Agbogbloshie as well. We categorize linked geographic bridging triads for two reasons. First, we want to distinguish triads that connect an individual from Agbogbloshie with concurrent partners in different geographic locations (all potential geographic bridging triads) from those that exhibit clear links back to sexual partners in Agbogbloshie (linked geographic bridging triads). Second, we want to examine the location of sex and location of partners in concurrent triads by the sex of the respondent. The difference between an individual in a linked geographic bridging partnership is that the individual also had sexual intercourse within Agbogbloshie, or also had a sexual partner who lived inside of Agbogbloshie. Therefore, the definition of a linked geographic bridging partnership ensures that the risk is geographically linked back to Agbogbloshie.

2.3.7. Controls—The models were stratified by gender to show male-female differentials in effect. All models accounted for confounding variables that were thought *a priori* to influence both migration and risk of concurrency, including age (continuous in years), marital status (never married, cohabiting, married, or widowed/separated/divorced), ever having a child, religion (Christian, Muslim, or other), and income (categorized into quartiles). The 6 individuals who reported polygamous union were coded as married.

2.4. Analytical strategy

The analysis was split into three general sections. First, we used descriptive statistics to explore differences in sexual partnership concurrency and mobility by gender, both at the individual level with summary measures over the last year and at the level of person-month. Second, we assessed evidence for the association between short-term mobility and sexual partner concurrency using pooled ordinary least squares logistic regression models, with cluster-robust standard errors, stratified by gender. The clustered standard error technique is appropriate since the data contain a large number of clusters (individuals) and are balanced within individuals (mostly 12 months per person). We tested bivariate relationships with prevalence of sexual partnership concurrency within a month, then ran a series of multivariate models to test whether any short-term mobility in a month was associated with sexual partnership concurrency, independent of potentially confounding variables. Then, we analyzed which characteristics of mobility drove the associations with sexual risk behavior for men and women. We ran the same logistic models, stratified by gender, with three different mobility measures: distance, frequency, and duration of travel, as defined above.

In the third section, we described the characteristics of the potential geographic-bridging partnerships and concurrent triads using a network perspective. We explored the distribution of partnership formations, where partners live, and where sex occurred. Lastly, we presented a cascade of bridging risk to assess how prevalent geographic bridging partnerships were, and who was involved in the bridges. The bridging risk cascade represents the proportion of individuals who were in an ongoing partnership, those that were engaged in a concurrent partnership, and those that engaged in a geographic or linked geographic-bridging triad during the last 12 months, stratified by gender and mobility status. The cascade represents individuals and their cumulative behavior over the course of a year. Each category is a subset of the previous category.

3. Results

We recruited 484 study subjects, comprised of 202 men and 282 women, which yielded 5808 person-months of data. However, some individuals moved to our study site within the 12 months prior to the interview. We therefore dropped 175 person-months prior to their move to Agbogbloshie since we could not ascertain which mobility episodes were away from “home.” These personmonths were contributed by 30 individuals (minimum 1 month per person, maximum 11 months per person, mean 5 months living in AG). The final sample size for the analysis was 5633 person months: 202 men contributed 2383 person-months and 282 women contributed 3250 person-months.

3.1. Descriptive results

In the weighted descriptive analysis (Table 1), 42% of the population was male and over half were aged 29 or younger (54%). The majority of the population was either never married (42.5%) or currently cohabiting (18.8%) and 5.5% tested positive for HIV. The majority of respondents reported only one sexual partner over the past year, but 30% of men and 5.5% of women reported a concurrent sexual partnership at some point within the year prior to the survey.

Mobility was common in our study population. In the preceding 12 months, 77% of men and 81% of women reported at least one overnight trip away from home, with women reporting 8 unique trips in the last year, compared to 6 trips reported by men on average. The main reasons for short-term mobility for men were to visit family or friends, for work or farming, and for funerals or holidays. For women, the main reasons for mobility were for education or health reasons, to visit family and friends, and for funerals and holidays.

Table 2 shows monthly short-term mobility and sexual behavior data for the sample, in person-months. Twenty-three percent of observed person-months involved at least one overnight trip: 21% of male person-months (p-m) and 24% of female p-m. Although both men and women were highly likely to engage in short-term mobility, the characteristics of the mobility episodes varied (see Table 2). Women were more likely to have short- and medium-distance overnight trips compared to men. Women were more likely to travel within the Greater Accra region (14% of p-m) compared to men (9% of p-m), and men were more likely to travel to more distant regions such as the Upper East and Upper West regions (see Fig. 2). However, travel to other regions was common as well; 15% of p-m involved travel outside the Greater Accra region (respondents could report travel to >1 region within a month). Women were slightly more likely to travel within a month, slightly more likely to take only one trip per month, and more likely to be gone for a short amount of time per month compared to men.

Men were more likely to have person-months involving a concurrent sexual partnership (16.7% of person-months for males vs. 2.9% for females) (Table 2). The location of sex acts and where sexual partners live (for any sex partner, regardless of concurrency status) varied by the gender of the respondent. Women were much more likely to have sex acts outside of Agbogbloshie compared to men (24.5% vs. 15.3% p-m).Women were more likely to have sexual partners located within Agbogbloshie compared to men (47.1% vs. 43.3% p-m), and men were twice as likely to have a sexual partner living far away, outside of the Greater Accra region.

3.2. Bivariate analysis

For men, age was positively associated with increased risk of concurrency, but the relationship was negative for women. Marital status was highly associated with increased concurrency among women, with those never married much more likely to engage in concurrent partnerships compared to any other category. The odds of having a concurrent partnership were two times higher for men who had ever had a child compared to men who had never had a child, whereas the odds of a concurrent partnership were lower for women who had ever had a child, but not statistically significant.

Any short-term mobility, in this case defined as any overnight travel outside of Agbogbloshie regardless of distance or time away from home, was associated with increased risk of sexual partnership concurrency in that month for women but not men (see Table 3). In fact, no measure of short-term mobility (distance, frequency, or duration) was associated with increased risk of concurrency for men. Men who were away from home for an entire month had significantly lower odds of engaging in concurrent partnerships during that month compared to men who were not mobile. For women, almost every measure of mobility was associated with increased odds of having a concurrent partnership. Notably, the frequency of travel was associated with increased risk of concurrency for women (odds ratio [OR] =1.77 for 1 trip, and OR =3.53 for 2 or more trips). Only women who traveled >100 km from home, and women who were mobile for longer durations (longer than a week) did not have significantly higher odds of a concurrent partnership.). There were no person-months in which a woman was away for the entire month and had a concurrent partnership.

3.3. Multivariate analysis

Findings in the multivariate analysis confirmed the bivariate analysis. No significant associations emerged between any category of mobility and sexual partnership concurrency for men after controlling for standard sociodemographic measures (see Table 4). Any short-term mobility was associated with higher odds of having a concurrent partnership for women independent of age, marital status, ever having a child, religion, and income. After accounting for sociodemographic confounders, only short-term mobility to slightly more distant destinations (10–100 km) was associated with higher odds of concurrency compared to non-mobile women. Middle-distance, frequent, and shorter-duration trips were associated with higher odds of concurrent partnerships for women.

3.4. Triad-level descriptive analysis

As shown in the descriptive and multivariate analyses, men and women were equally likely to engage in short-term mobility and men were more likely to have concurrent partnerships than women, but mobility was highly associated with concurrency only for women. However, mobile individuals engaging in concurrent partnerships was only one way in which bridging could have occurred. Geographic bridging also can occur when sexual partners in a concurrent triad live in different places. Therefore, this next section will address concurrent partnership triads, places of residence for partners, places of sex acts, and whether these patterns vary by migrant status and gender with a bridging cascade.

3.4.1. Location of partner—Table 5 contains descriptive statistics from the 492 person-months (398 with men as ego, 94 with women as ego) that involved a concurrent partnership. The geographic patterns of partnership locations within concurrent triads varied significantly by gender. Only 1.1% of women's concurrent triads involved both partners living within Agbogbloshie, and thus were not geographical bridging triads, compared to almost a quarter of men's triads. More than 4 out of 10 female concurrent triads were bridges connecting Agbogbloshie (n = 39, 41.5%), with one partner living in Agbogbloshie and the other living outside of Agbogbloshie, while more than half of all male concurrent triads were bridges connecting Agbogbloshie (n = 228, 57.3%). However, the majority of concurrent triads for women were distant bridges, with both partners living outside of Agbogbloshie (n = 54, 57.5%), compared to only 20.4% of male concurrent triads.

3.4.2. Location of sex—The patterns of sex act locations within concurrent triads was also significantly different between men and women. First, more than half of all sex acts (n =224, 56.3%) with both partners in male concurrent triads took place within Agbogbloshie, compared to only 7.4% of sex acts (n =7) for women, representing no geographic bridging. Women were much more likely to be in distant bridging triads; greater than 61% of sex acts with both partners occurred outside of Agbogbloshie for women, compared to only 9% of sex acts for men. Nearly 30% of concurrent triads bridged with Agbogbloshie, involving sex acts with one partner in Agbogbloshie and the other partner elsewhere outside of Agbogbloshie, for both men and women.

3.4.3. Bridging risk cascade—At some point in the last year, men and women were equally likely to be in an ongoing partnership (87.6% and 83.0% respectively) (Fig. 3). The pattern of the bridging risk cascade diverges for men and women after this first stage. Almost one-third of men had a concurrent partnership in the last year compared to 5.7% of women. Twenty-five percent of men engaged in a geographic bridging triad, and 22.3% in a linked geographic bridging triad. For women, 5.3% engaged in a geographic bridging triad and 2.8% in a linked geographic bridging triad.

The direction of the relationship between bridging risk and mobility was different for men and women. Mobile men were equally likely to be sexually active compared to non-mobile men. However, men who were not mobile engaged in just as much, if not more, concurrent partnerships compared to those who were mobile. Men who were not mobile within a month still engaged in geographic bridging partnerships, possibly more so than men who were mobile. There was no difference in the proportion of men in linked geographic bridging partnerships by mobility status. For women, mobility was associated with higher levels of concurrent partnerships (7.1% vs. 1.4%) and geographic bridging triads (6.6% vs. 1.4%). The difference was less clear for linked geographic bridging triads (3.3% vs. 1.4% for mobile and non-mobile women, respectively). The drop in the proportion of mobile women engaging in a linked geographic bridging triad was due to the added requirement of having sex acts or a sexual partner both within and outside of Agbogbloshie. Many of the mobile women engaged in sexual acts with concurrent triads only outside of Agbogbloshie.

4. Discussion

Geographic bridging of STIs is occurring in Agbogbloshie, with almost one quarter of men engaging in sexual partnerships that potentially bridge. However, the association between short-term mobility and geographic bridging was different for men and women in our study. Mobile men did not behave differently than non-mobile men, but the small amount of bridging initiated by women was significantly associated with mobility. All geographic bridging must involve mobility by someone; therefore, the geographic bridging associated with non-mobile men in our sample depended on mobile women outside of our sample.

Although our definition of geographic bridging is slightly different than Rai et al. (2014) study –migrant men who reported casual sex at destination and were married, or if unmarried also reported casual sex at original during return visits –our results are remarkably similar. In their sample of male migrants in India, ~27% were defined as traditional bridge groups, compared to 22.4% of mobile men in our sample. However, one of our key findings is that a similar proportion of non-migrant men also engaged in geographic bridging triads.

Similar to many recent studies in sub-Saharan Africa (Beguy et al., 2010; Camlin et al., 2014), we found that women were participating in short-term mobility just as much, if not more, than men. The increasing feminization of mobility, identified as an important trend in Ghana many years ago (Anarfi, 2001), will significantly affect how STIs bridge geographic space, since women's sexual behaviors appear to be different when they are away from home. About one in five non-mobile men in our study engaged in geographically bridging triads, which means, by definition, that they had a female sexual partner who did not live in Agbogbloshie. Women in other parts of Ghana may be similar to the women in our sample, and may have a higher proportion of sex acts outside of their residential setting compared to men. Since our findings suggest that females behave differently when away from home, sexual behavior by mobile women may be a key component to geographic bridging. Sexual risk behavior for mobile women should garner more attention and be the focus of future research.

Attitudes and behavioral norms toward the acceptability of sexual partner concurrency could explain the gendered differences in our findings. Distance traveled was significantly associated with concurrency for women. Not onlywere mobile women significantly more likely to engage in concurrent partnerships, but the majority of the concurrent triads for women took place completely outside of Agbogbloshie. Women exhibited different sexual risk behaviour when they were away from home, but men behaved the same regardless of whether they were mobile. In other settings, the amount of reported sexual partner concurrency was associated with being exposed to norms that support multiple partnerships (Carter et al., 2007; Mulawa et al., 2016; Yamanis et al., 2016). Common social norms that tolerate men having multiple concurrent partnerships, but condemn women who do so in a densely populated urban setting like Agbogbloshie could have a different influence on sexual behaviors – enabling men's concurrency, but driving women's concurrency behavior to distant places. In our findings, distance from home may equate with anonymity, and thus women who travel far enough from home may be able to engage in additional sexual partnerships without stigma.

Concepts of human mobility and sexual partnership concurrency, when considered in tandem, can improve our understanding of the geographical patterns of STIs and HIV by linking concepts of space and time. Concurrency amplifies STI/HIV transmission in three ways, all related to timing and sequence: it increases the number of transmission paths including "backward paths", it speeds up existing transmission paths, and it increases exposure during periods of high infectiousness (Goodreau and Morris, 2012). To date, most empirical and theoretical studies of concurrency have not incorporated space. However, our findings show that human mobility can be an important driver of STI bridging, especially because patterns of sexual behavior may differ over space. Additionally, other characteristics of places connected by human mobility, such as the prevalence of HIV, also significantly determines the spatial scale in which concurrency amplifies disease transmission.

Our findings have some policy implications. First, unintuitively, prioritizing mobile men to receive behavioral or biomedical interventions may not be more effective than prioritizing non-mobile men. On the other hand, prioritizing mobile women could have far-reaching impacts. For example, providing HIV treatment for HIV-positive women or pre-exposure prophylaxis for HIV-negative women could prevent geographical spread of HIV, given that they are more likely to have concurrent partnerships while away from home. Second, any behavioral or educational campaigns to reduce STI or HIV transmission in this setting should incorporate information about sexual networks. A sexual concurrency reduction intervention, "Know Your Network", has been shown to be feasible and acceptable in Kenya (Knopf et al., 2014). The goal of this intervention was to start community discussions about concurrency, and to provide the knowledge, motivation, and skills to create normative and behavioral change. A concurrency reduction intervention targeted at men with mobile partners or mobile women could be very effective in reducing the geographical spread of STIs and HIV in this community. Partner notification, especially if linked to geographically diverse HIV testing and treatment facilities, could also be an effective intervention. Lastly, community randomized-controlled trials of STI/HIV interventions need to consider gendered patterns of mobility and sexual risk behavior in order to reduce contamination between intervention and control areas.

4.1. Limitations

Many of our conclusions are based on a small number of person-months in which women reported concurrent partnerships; the 94 person-months were produced from just 16 women. Despite little variation in our outcome variable (2.9% of person-months), statistically significant results confirm a positive relationship between short-term mobility and increased risk of concurrency for women. On the other hand, the findings presented on gender-based differences in geographic bridging triads were based solely on this small sample and should be interpreted with caution. Moving forward, the framework that we developed to examine short-term mobility and geographical bridging of sexual partnerships will be useful to examine these issues further with larger datasets.

Any study that relies on self-reported behavior must consider the possibility of reporting error or bias (Chae, 2016), and ours is no different. With our data, we must consider two main types of bias: recall bias and social desirability bias. We designed the questionnaire and trained our interviewers with the goal to reduce these errors. To reduce recall bias, respondents first worked with the interviewer to populate their event history calendar with landmarks to anchor the past 12 months in time. Interviewers also established rapport with the study participant, to help fill in “typical” and “non-typical” months, not always in a linear way, over the past 12 months. Social-desirability bias may have led to underreported levels of concurrency for women. Indeed, the same cultural norms that encourage women to hide their sexual practices by traveling elsewhere may have also led to under-reporting in our sample. It is interesting to note the disparate levels of reported 12-month concurrency prevalence in our sample compared to the 2008 Ghana DHS: 30% vs. 6.3% for men; 5.5% vs. 0.5% for women, but the study populations are also vastly different. Our findings may also be biased if our survey design was unable to capture mobile individuals who did not have a stable household presence in Agbogbloshie, although ultimately less than 4% of eligible respondents were unable to be recruited due to long-term travel.

In order to unequivocally assess whether an individual linked two separate sexual networks, one would need to assess whether a pathogen was successfully transmitted from one individual to another. Our approach was to assess whether an individual had a concurrent sexual partnership that would provide a potential transmission pathway, but we were not able to confirm whether an STI was transmitted. We explored the possibility of only considering concurrent partnerships in which unprotected sexual intercourse took place with both partners. However, we did not have sufficient power to support this approach, especially when stratifying by gender and combining partnerships into triads. However, condom use was not common in our sample. On average, individuals in the sample engaged in 4.7 sex acts per month and 4.3 of those (90%) were unprotected.

Future work on mobility and sexual risk behaviors should account for reason for mobility, as the reasons for travel likely drives not only where, when, and with whom individuals travel, but also the opportunities to engage in sexual activity while traveling. Our study included some descriptive data on reasons for travel, but our statistical analyses did not show any insightful patterns probably due to limitations in the way in which we collected the data.

4.2. Conclusions

Our findings highlight the gendered nature of mobility and sexual risk behavior, and suggest how cultural norms may affect women's sexual behavior that could lead to geographically bridged sexual networks. Our network perspective allowed us to assess alternate paths in which bridging could occur, including bridging triads from the perspective of a non-mobile individual. This approach may be useful for future work in which sexual risk behavior is a function of partners' characteristics as well as the characteristics of networks and communities more broadly. Information on spatially-explicit sexual networks and bridging can support policy to identify and disrupt STI transmission chains in low-resource settings, or alternatively, to exploit connected sexual networks to disseminate positive prevention messages.

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<tr><td>C16</td><td>Mobile (region, town, nights)</td><td></td><td>CE (Cape Coast, 7)</td><td></td><td></td><td>AS (Kumasi 20)</td><td>AS (Kumasi 15)</td><td></td><td>GA (Tema, 2)</td><td></td><td></td><td></td><td></td></tr>
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</table>

AS: Ashanti, GA: Greater Accra, CE: Central

*Responses are not applicable in shaded areas

Fig. 1.

Event history calendar scheme. Partial responses from a hypothetical individual depict an individual with mobility episodes and a concurrent partnership.

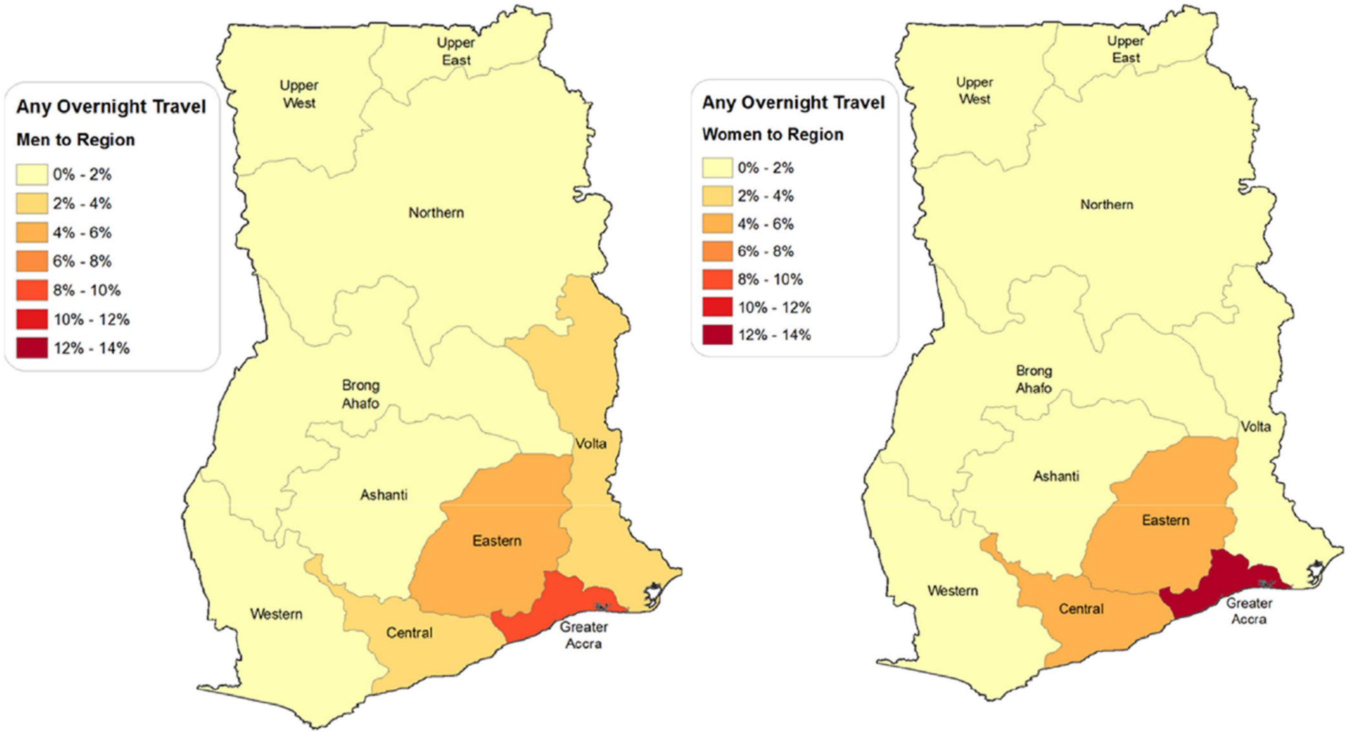

Fig. 2.

Map of short-term mobility destination per person-month of MHG survey respondents, by gender.

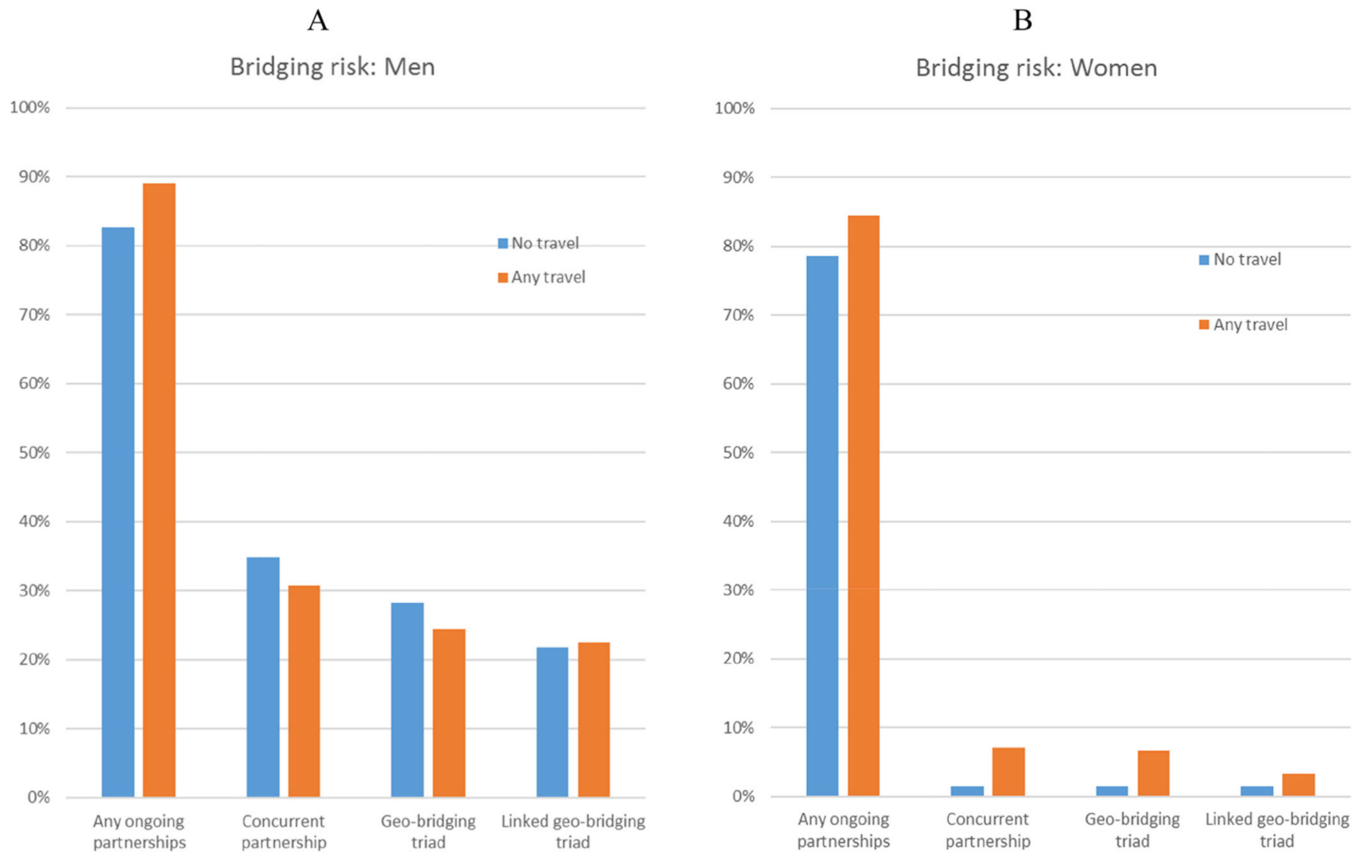

Fig. 3.

The proportion of individuals who had any ongoing partnership, had a concurrent partnership, a geographical or a linked geographically bridging concurrent partnership in the last year, by mobility and gender.

Notes: These figures represent individuals and their cumulative behavior over the course of one year. Each subsequent category is a subset of the previous category.

Any ongoing partnership represent an individual that had a sexually active partnership at any time in the last year.

Concurrent partnership represents whether the individual had an overlapping partnership at any point in the last year.

Geographic bridging triad are individuals in a concurrent triad and either had sexual intercourse outside of Agbogbloshie or had a sexual partner who lived outside of Agbogbloshie at any point in the last year.

Linked geographic bridging triad are individuals in a geographic bridging triad who also had sexual intercourse within Agbogbloshie or had a sexual partner who lived inside Agbogbloshie.

Table 1

Demographic, behavioral and epidemiologic characteristics of adults in Agbogbloshie, Accra, Ghana, 2012 (n = 484 individuals).

	Total		Men		Women	
	%/mean	*95% CI*	*%/mean*	*95% CI*	*%/mean*	*95% CI*
Sociodemographic characteristics						
Gender						
Male	41.6	36.3–47.1				
Female	58.4	52.9–63.7				
Age						
18–29	54.4	48.9–59.8	52.9	44.7–61.0	55.5	48.2–62.6
30–39	28.8	24.1–33.8	31.5	24.3–39.8	26.8	21.1–33.3
40–49	16.8	13.1–21.3	15.5	10.4–22.5	17.7	12.8–24.0
Ever had a child						
Yes	70.3	64.9–754–.2	64.6	56.5–71.9	74.4	66.8–80.7
Marital status						
Never married	42.5	37.1–48.0	43.6	35.8–51.8	41.7	34.6–49.3
Cohabiting	18.8	14.6–23.9	17.9	12.1–25.7	19.4	13.8–26.5
Married	29.1	24.4–34.3	31.6	24.3–40.0	27.3	21.4–34.0
Widowed/separated/divorced	9.6	7.1–13.0	6.9	4.1–11.3	11.6	7.9–16.7
Religion						
Christian	77.0	71.9–81.4	68.0	60.0–75.2	83.4	76.8–88.4
Moslem	13.7	10.1–18.3	14.1	9.0–21.6	13.4	8.9–19.8
Traditional/no religion	9.3	6.7–12.8	17.8	12.6–24.7	3.2	1.5–7.0
Income						
Mean (in Ghana Cedi)	1960	1755–2165	2560	2188–2933	1523	1319–1728
Median (Ghana Cedi)	1500		1908		1200	
Sexual behavior and health characteristics						
HIV-1 Infection						
Infected	5.5	3.3–9.1	2.8	1.1–6.9	7.2	3.9–12.9
Any concurrent sexual partnership						
Yes	15.7	12.2–20.1	30	23.0–38.2	5.5	3.2–9.6

	Total		Men		Women	
	%/mean	***95% CI***	***%/mean***	***95% CI***	***%/mean***	***95% CI***
Migration and mobility						
Short-term mobility[a]						
Any overnight trip away from home1	79.4	74.6–83.4	77.3	69.4–83.7	80.8	74.7–85.7
Number of overnight trips (mean)	7.3	4.1–10.5	6.1	2.1–10.1	8.1	3.5–12.8

[a] In the last 12 months, how many times have you been away from home for one or more nights?.

Table 2

Monthly concurrency and characteristics of short-term mobility among adults in Agbogbloshie, Accra, Ghana, 2012 (n = 5,633 person-months (p-m)).[a]

	Total		Men		Women		X2 test
	n (p-m)	***%***	***n (p-m)***	***%***	***n (p-m)***	***%***	
Migration and mobility							
Short-term mobility[b]							
Any overnight trip	1,295	23.0%	501	21.0%	794	24.4%	p = 0.003
Maximum distance of mobility							
no travel	4,338	77.0%	1,882	79.0%	2,456	75.6%	
<10 km	217	3.9%	44	1.8%	173	5.3%	
10–100 km	421	7.5%	159	6.7%	262	8.1%	
>100 km	657	11.7%	298	12.5%	359	11.0%	p < 0.001
Frequency of overnight trips (>3km)							
no travel	4,338	77.0%	1,882	79.0%	2,456	75.6%	
1 trip away from home	1,131	20.1%	426	17.9%	705	21.7%	
2 or more trips	164	2.9%	75	3.1%	89	2.7%	p = 0.004
Total duration of mobility[c]							
no travel	4,338	77.0%	1,882	79.0%	2,456	75.6%	
1–7 nights	750	13.3%	273	11.5%	477	14.7%	
8–29 nights	416	7.4%	185	7.8%	231	7.1%	
>29 nights	125	2.2%	41	1.7%	84	2.6%	p < 0.001
Sexual behavior and location							
Concurrency							
no	5,141	91.3%	1,985	83.3%	3,156	97.1%	
yes	492	8.7%	398	16.7%	94	2.9%	p < 0.001
Location of most distant sex act[d]							
No sex within the month	1,554	27.6%	651	27.3%	903	27.8%	
Within Agbogbloshie	2,917	51.8%	1,368	57.4%	1,549	47.7%	
Within Greater Accra, outside Agbogbloshie	936	16.6%	278	11.7%	658	20.2%	
Within Ghana, outside Greater Accra	226	4.0%	86	3.6%	140	4.3%	p < 0.001
Location of most distant partner[e]							

	Total		Men		Women		X2 test
	n (p-m)	***%***	***n (p-m)***	***%***	***n (p-m)***	***%***	
No ongoing partnerhip within the month	1,233	21.9%	505	21.2%	728	22.4%	
Within Agbogbloshie	2,562	45.5%	1,031	43.3%	1,531	47.1%	
Within Greater Accra, outside Agbogbloshie	1,239	22.0%	496	20.8%	743	22.9%	
Within Ghana, outside Greater Accra	599	10.6%	351	14.7%	248	7.6%	$p < 0.001$
Total	**5,633**		**2,383**		**3,250**		

[a]Unadjusted for clustering within individual.

[b]Short-term mobility defined as any overnight trip outside of Agbogbloshie.

[c]4 person/months of travel are missing duration.

[d]Among all sex acts in the month, the most distant location of sex.

[e]Among all ongoing sexual partnerships within the month, the geographical location of the most distant partner.

Table 3

Bivariate logistic regression analysis, with robust standard errors adjusted for clustering, to examine factors independently associated with sexual partnership concurrency in a given month(OR = odds ratio, unadjusted). Unit of analysis is person-months.

	Men			Women		
	OR	*SE*	p-value	*OR*	*SE*	p-value
Short-term mobility						
Any overnight trip						
No (reference)	1			1		
Yes	1.02	0.27	0.927	1.96	0.56	0.018
Maximum distance of overnight trip						
No travel (reference)	1			1		
<10 km	0.79	0.50	0.712	2.54	1.27	0.063
10–100 km	1.52	0.72	0.378	2.69	1.27	0.036
>100 km	0.82	0.19	0.408	1.18	0.36	0.575
Frequency of overnight trips						
No travel (reference)	1			1		
1 trip away from home	1.05	0.26	0.832	1.77	0.49	0.040
2 or more trips	0.86	0.65	0.843	3.53	2.47	0.071
Total duration of overnight trips						
No travel (reference)	1			1		
1–7 nights	1.04	0.23	0.848	2.48	0.72	0.002
8–29 nights	1.25	0.68	0.676	1.68	1.12	0.440
>29 nights[a]	0.13	0.13	0.043	–		
Sociodemographics						
Age (continuous)	1.04	0.02	0.051	0.91	0.03	0.004
Marital status						
Never married (reference)	1			1		
Cohabiting	1.03	0.47	0.950	0.345	0.309	0.235
Married	1.17	0.61	0.200	0.098	0.104	0.029
Widowed/separated/divorced	0.77	0.48	0.669	0.033	0.036	0.001
Ever had a child						

	Men			Women		
	OR	***SE***	**p-value**	***OR***	***SE***	**p-value**
No (reference)	1			1		
Yes	1.95	0.71	0.066	0.39	0.23	0.117
Religion						
Moslem (reference)	1			1		
Christian	0.96	0.49	0.941	0.63	0.60	0.630
Traditional/no religion	1.03	0.62	0.964	1.25	1.68	0.867
Income (quartiles)[b]						
First	0.51	0.25	0.176	2.41	1.87	0.259
Second	1.57	0.68	0.295	1.32	1.16	0.754
Third	0.72	0.32	0.463	1.03	1.06	0.977
Fourth (reference)	1			1		

[a] No women who traveled >29 days in a given month reported concurrent sexual partnerships in that month.

[b] Income quartiles were separetely calculated for each gender.

Table 4

Multivariate logistic regression analysis, with robust standard errors adjusted for clustering, to examine factors associated with sexual partnership concurrency in a given month, comparing different measures of mobility characteristics. (AOR = adjusted odds ratio).[a]

	Model 1						Model 2						Model 3						Model 4					
	Men			Women			Men			Women			Men			Women			Men			Women		
	AOR	SE	p-value	AOR	SE	p-value	AOR	SE	p-value	AOR	SE	p-value	AOR	SE	p-value	AOR	SE	p-value	AOR	SE	p-value	AOR	SE	p-value
Short-term mobility																								
Any overnight trip																								
No (reference)	1			1																				
Yes	1.09	0.28	0.729	1.99	0.69	0.047																		
Maximum distance of overnight trip																								
No travel (reference)							1			1														
<10 km							0.86	0.72	0.862	2.20	1.14	0.130												
10–100 km							1.62	0.81	0.336	2.77	1.47	0.054												
>100 km							0.88	0.20	0.569	1.26	0.39	0.458												
Frequency of overnight trips																								
No travel (reference)													1			1								
1 trip away from home													1.11	0.27	0.650	1.18	0.61	0.076						
2 or more trips													0.97	0.80	0.968	3.19	2.22	0.095						
Total duration of overnight trips																								
No travel (reference)																			1			1		
1–7 nights																			1.11	0.03	0.647	2.68	0.99	0.008
8–29 nights																			1.26	0.70	0.680	1.70	1.27	0.476
>29 nights[b]																			0.19	0.20	0.105	–		

[a] All models are adjusted for the sociodemographic variables listed in Table 3: age, marital status, ever having a child, religion, and income.

[b] No women who traveled >29 days in a given month reported concurrent sexual partnerships in that month.

Table 5

Triad-level concurrent partnership bridging, defined by location of sex and location of partners at the level of person-month.

Location 1	Location 2	Proportion of triads: Total n	Total %	Men n	Men %	Women n	Women %
Location of partner							
Within Agbogbloshie	Within Agbogbloshie	90	18.3%	89	22.4%	1	1.1%
Within Greater Accra, outside Agbogbloshie	Within Greater Accra, outside Agbogbloshie	74	15.0%	37	9.3%	37	39.4%
Within Ghana, outside Greater Accra	Within Ghana, outside Greater Accra	12	2.4%	10	2.5%	2	2.1%
Within Greater Accra, outside Agbogbloshie	Within Ghana, outside Greater Accra	49	10.0%	34	8.5%	15	16.0%
Within Agbogbloshie	Within Greater Accra, outside Agbogbloshie	184	37.4%	157	39.4%	27	28.7%
Within Agbogbloshie	Within Ghana, outside Greater Accra	70	14.2%	59	14.8%	11	11.7%
Within Agbogbloshie	>1 partner outside of Agbogbloshie *	13	2.6%	12	3.0%	1	1.1%
Location 1	Location 2	Total n	Total %	Men n	Men %	Women n	Women %
Location of sex act							
No sex act in month		9	1.8%	9	2.3%	0	0.0%
Within Agbogbloshie	Within Agbogbloshie	231	47.0%	224	56.3%	7	7.4%
Within Greater Accra, outside Agbogbloshie	Within Greater Accra, outside Agbogbloshie	91	18.5%	35	8.8%	56	59.6%
Within Ghana, outside Greater Accra	Within Ghana, outside Greater Accra	1	0.2%	1	0.3%	0	0.0%
Within Greater Accra, outside Agbogbloshie	Within Ghana, outside Greater Accra	2	0.4%	0	0.0%	2	2.1%
Within Agbogbloshie	Within Greater Accra, outside Agbogbloshie	135	27.4%	108	27.1%	27	28.7%
Within Agbogbloshie	Within Ghana, outside Greater Accra	20	4.1%	19	4.8%	1	1.1%
Within Agbogbloshie	>1 partner outside of Agbogbloshie *	3	0.6%	2	0.5%	1	1.1%
TOTAL		492		398		94	

*This category includes individuals with 3 overlapping partnerships, who engaged with more than one of the partners outside of Agbogbloshie

LEGEND

No geographical bridging

Distant bridging, between other places

Bridging connecting Agbogbloshie