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ORIGINAL PAPER

Young Men's Social Network Characteristics and Associations with Sexual Partnership Concurrency in Tanzania

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Abstract Social network influence on young people's sexual behavior is understudied in sub-Saharan Africa. Previous research identified networks of mostly young men in Dar es Salaam who socialize in "camps". This study describes network characteristics within camps and their relationship to young men's concurrent sexual partnerships. We conducted surveys with a nearly complete census of ten camp networks (490 men and 160 women). Surveys included name generators to identify camp-based networks. Fifty seven percent of sexually active men (n = 471) reported past year concurrency, measured using the UNAIDS method. In a multivariable model, men's individual concurrency was associated with being a member of a closer knit camp in which concurrency was the normative behavior. Younger men who had older members in their networks were more likely to engage in concurrency. Respondent concurrency was also associated with inequitable personal gender norms. Our findings suggest strategies for leveraging social networks for HIV prevention among young men.

Resumen Influencia de las redes sociales en el comportamiento sexual de los jóvenes está poco estudiado en el África subsahariana. Investigaciones previas identificaron redes de hombres en Dar es Salaam, Tanzania que socializan en "campos". Este estudio describe las características de las redes sociales de hombres jóvenes dentro de los campos y sus relaciónes con el comportamiento sexual de tener dos o más relaciones sexuales simultáneas. Hemos hecho encuestas con casi un censo completo de 10 redes de campos (490 hombres y 160 mujeres). Las encuestas incluyen generadores de nombre para identificar las redes en los campos. 57 % de los hombres que hicieron sexo (n = 471) tuvieron parejas simultáneas en el año pasado, medida por el método de UNAIDS. En el análisis multivariado, tener parejas simultáneas se asoció con ser miembro de un campo en que tener parejas simultáneas fue el comportamiento normativo de los hombres. Los hombres más jóvenes que tenían miembros de más edad en sus redes tenían mayor probabilidad de estar en parejas simultáneas. Tener parejas simultáneas también se asoció con hombres que tenían normas de género desiguales. Nuestros resultados sugieren estrategias para aprovechar las redes sociales para la prevención del VIH entre los hombres jóvenes.

Keywords Networks · Concurrency · Youth · Men · Tanzania

Introduction

In sub-Saharan Africa, young men are critical targets for HIV prevention. Although women have higher HIV prevalence rates [1], men are key to mitigating the HIV epidemic for two important reasons: men often dictate the terms of sexual relationships and, thus, control situations that facilitate transmission to women [2]; and men's poor involvement in HIV prevention is linked to their own mortality and delayed treatment [3, 4]. Targeting young

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men for intervention requires an understanding of the social factors associated with their sexual risk behaviors. The theory of social influence suggests that men may behave according to the behaviors or expectations of their social networks [5]. Empirical support for the theory among studies of male adolescents have found an association between networks and several HIV risk behaviors, including having sex with multiple partners [6], early sexual debut [7], and condomless sex [8].

Concurrency, or having at least two sexual partnerships that overlap in time, increases population risk for HIV by decreasing the time period between sexual contacts and enhancing the reach of any given actor within a population to another actor [9, 10]. Concurrency is considered a partnership-level HIV risk factor that increases the likelihood of exposure to acute infections, and the likelihood of transmitting HIV [11, 12]. Although the extent to which concurrency has contributed to the generalized HIV epidemic in sub-Saharan Africa has been challenged [13, 14], concurrency undoubtedly operates synergistically with other sexual partnership dynamics to affect HIV transmission [15, 16]. Regardless of these important debates, UNAIDS has called for research on the social factors that drive concurrent partnerships to better inform ongoing concurrency prevention programs [17].

To assess how social factors influence concurrency, we use social network analysis, which has been used in a variety of HIV prevention and treatment studies [18]. Studies have measured social network influence on concurrency among urban African-American women in Baltimore [19, 20]. Network characteristics were measured using an egocentric study design in which the respondent provided identifying information and characteristics on each of their network members or alters [21]. Several characteristics of the networks were protective against respondent concurrency, including having a large network with well-known members and higher levels of trust in their networks or sexual partner [19, 20].

Network analysis remains particularly underused in low and middle income countries [22]. Previous research identified stable social networks of mostly young men in Dar es Salaam, Tanzania who socialize regularly in what they call "camps" [23]. Camps consist of between 10 and 80 members and have elected leadership, membership fees, and a physical space to meet. Camps surveyed previously had an average lifespan of 8 years and the majority of the members were not in school [24]. Men reported socializing daily at their camps, where they met and hung out with friends. Previous research showed that camps did include few women members, but women did not attend camps as regularly as men. Some camps forbade women, and others included them in leadership roles such as camp treasurer or cook [23]. A prior study demonstrated that young (15–19 years) men in camps reported substantial HIV risk behaviors: 47 % reported two or more sex partners in the past year and 21 % had at least one STI symptom in the past 4 weeks [24]. Almost half (42 %) of the sexually experienced 15–19 year olds reported having a concurrent partnership in the past 6 months [24]. This prevalence of concurrency was higher than other studies of male youth in sub-Saharan Africa [25–28]. Furthermore, qualitative research in the camps suggested that peers encouraged each other to have concurrent sexual partners [23].

Additional evidence from Sub-Saharan Africa suggests that friends' attitudes and behaviors may influence men's concurrency. A longitudinal, quantitative study in Malawi among adult married males (average age 37 years) revealed that men who perceived that their best friends engaged in extramarital partnerships were four to six times more likely to engage in an extramarital partnership themselves. In addition, those men who perceived that their friends had extramarital behaviors different from their own were more likely three years later to report changing their behaviors to be consistent with their friends [29]. These results revealed the importance of men's perceptions of their friends on men's concurrency behavior. Nevertheless, the findings were based on men's perceptions of their friends, rather than the actual behaviors of the friends themselves.

In the present study we used social network analysis to examine the influence of friends' behaviors on young men's concurrency [21]. Because camps are an important source of friendship for young men in Dar es Salaam, we used camps as the foundation for our networks [23]. To generate our hypotheses, we drew on network studies among adolescents in the United States and exploratory research from sub-Saharan Africa. We first considered structural characteristics of networks including composition (the characteristics of actors in a network) and connectedness, often measured as density (the proportion of actors who are connected to each other) [21]. A U.S. study found a significant positive association between an adolescent's number of sexual partners and the average number of sex partners in the adolescent's friendship networks [6]. Thus, we hypothesized that men's concurrency would be associated with the proportion of their network members who engage in concurrency. In addition, several studies showed that highly dense, or tightly knit, networks were more likely to have similar HIV risk perceptions and condom use behavior [30–33]. Thus, we hypothesized that a respondent from a more tightly knit camp in which concurrency is normative would be more likely to engage in concurrency. We also hypothesized that young men who occupied a central position in their networks (someone who is linked to a high proportion of other actors in the network) would also be more likely to engage in concurrency [34].

Moreover, we considered how age might interact with network structure and position. Due to developmental changes that are both social and biological in nature, adolescents may be more susceptible to peer influence at younger ages [35]. Younger adolescents are also more likely to model the behavior of their older peers. Studies among U.S. adolescents showed that adolescents with older friendship networks, compared to younger, were more likely to engage in sexual risk behaviors, such as early sexual debut [7, 36]. In previous work with young men in Dar es Salaam, the prevalence of concurrency steadily increased with age from 19, 28, 38, and 44 % for 16, 17, 18, and 19 year olds respectively, suggesting that concurrency was more common at older ages [24]. For younger men, we hypothesized that having older friends in their networks would increase their likelihood of concurrency.

Finally, we hypothesized that young men's personal gender norms would be associated with concurrency, such that those men who held inequitable attitudes towards women would be more likely to engage in concurrency. Because gender norms undergird men's power over women in sexual relationships, gender norms may also be related to men's decisions to engage in concurrent partnerships. Research from South Africa showed that young men who had concurrent partnerships had more inequitable attitudes and unequal relationships with women [27, 37]. Thus, the overall goal of this study was to identify opportunities in which young men's networks and norms could be leveraged for HIV prevention.

Methods

Our study site was Tandale, an impoverished ward in Dar es Salaam of about 44,000 people [38, 39]. HIV prevalence among young people aged 15–24 in Dar es Salaam is higher than the national average for this age group (5.3 vs 3.7 %, respectively) [40]. We chose Tandale because of reports of elevated illicit drug use and commercial sex in this ward that suggested an increased risk for HIV infections [41, 42]. Previous research in this ward applied the Priorities for Local AIDS Control Efforts (PLACE) method, a systematic sequence of procedures to identify venues where people at high risk for HIV infection meet each other [24, 43]. Semi-structured interviews with 232 community informants identified 83 venues, 57 of which were camps [24].

Ten camps from the previous PLACE data were purposively selected for inclusion in the current study. In the prior PLACE study, a subsample of all male camp members who were ages 15–19 were interviewed at each of the 57 camps [24]. The PLACE study used the UNAIDS calendar method (described below) to assess concurrency. The rate of men who reported concurrent partnerships at each camp ranged from 0 to 83 % and the inter-cluster correlation coefficient for concurrency by camp was 0.09. To sample the ten camps we first ordered the camps from lowest to highest rates of concurrent partnerships and sequentially selected every 6th camp. All members of the ten selected camps, regardless of age, were eligible and invited to complete the study.

We obtained consent from the camp leader to invite members of their camps to participate. Each leader provided us with a membership roster from their camp. All leaders were cooperative and willing to give us the membership lists. To ensure that there were no imposters, we obtained the name, nickname and age of each camp member from the camp leader and verified these identifiers during the interview process.

The ten camps selected for this study had an average of 68 members per camp (range 50–82 members). Out of 662 members total, we interviewed 650 members (a 98 % response rate). These members included 490 men and 160 women. Women ranged from 17 to 38 % of each camp's membership.

Survey Procedure

We asked each member if he or she would be willing to complete a one-time hour-long structured survey with a study interviewer. Those members who were interested were asked to provide written informed consent to participate. Those who could not write were allowed to sign with a thumb print. After consent camp members were interviewed in a quiet, pre-identified location close to their camp. The survey was completed on paper by the interviewers. All participants were given a drink and a snack for their participation, as well as a referral card with local health resources. Participants were asked a variety of demographic questions, including their age, level of education, and what type of work they do. Data collection occurred in 2011. Ethical approvals were obtained by the Institutional Review Boards of Duke University and Muhimbili University of Health and Allied Sciences.

Outcome Variable

The outcome variable was having a concurrent partnership in the past year. We focused on men's concurrency because we were interested specifically in how social network norms influence men's behavior in this context. To assess concurrency, we used the method recommended by UNAIDS [17]. Each respondent is asked the names of their three most recent partners from the past 12 months, how long ago (in terms of days, weeks and months) he last had sex with each partner and how long ago he initiated the

sexual relationship. Partnerships classified as concurrent met the following criteria: (a) the date of first sex with one partner preceded the date of last sex with another partner; and (b) sex occurred at least twice with one of the partners. The UNAIDS measure was highly correlated ($\rho = 0.86$) with the direct measure of concurrency, when respondents were asked directly whether any of these partnerships were ongoing at the same time [17]. We chose to use the UNAIDS method to generate the outcome variable because it was likely more precise and conservative than the direct method.

Gender Norms

Gender norms were assessed using four items from the Gender Equitable Norms Scale by Pulerwitz and Barker [44]. In a previous paper on attitudes and concurrency among South African men, men who engaged in concurrency were more likely than men who were not engaged in concurrency to endorse positive attitudes towards having multiple sexual partners. We therefore included a measure of attitudes in this analysis as well, specifically focusing on men's decision-making in sexual relationships. The items were previously used with a similar population of young men [24] and demonstrated good reliability. We asked each individual whether they agreed (1), partially agreed (2), or disagreed (3) with four statements: "It is the man who decides what type of sex to have"; "Men need more sex than women do"; "A man needs other women, even if things with his wife are fine"; and "If a woman cheats on a man, it is okay for him to hit her". The items were summed so that higher scores indicated greater endorsement of gender inequality; the range of sum scores was four to twelve. The alpha for the items was 0.79.

Social Network Characteristics

Participants were asked to name up to five alters in each of three different social domains: friends with whom they discussed problems (problems network), friends with whom they socialized (socialized network), and friends with whom they had worked in the past 30 days (work network). For each of the alters named, participants were asked to provide the person's name, age and whether the friend was in the same camp as the respondent. After removing duplicate names ($n = 274$), 3099 alters were named who also shared the same camp as the respondent.

A SAS 9.2 algorithm (Soundex) was used to identify close spelling matches between respondents (egos) and alters using the individuals' last names, first names, and ages. Of the 3099 alters in the same camp as a respondent, the SAS program matched 2791 (83 %). The remaining 308 unmatched names were visually inspected for matches in the list of camp respondents. Matches were identified for 233 of the 308, for a total match rate of 98 %. When correctly matched, the alter was linked to their unique case ID in our dataset. 80 % of the camp-based friends mentioned by the respondents were male. Nevertheless, we used both male and female camp members in our assessment of all network characteristics.

There was a significant amount of overlap between alters mentioned in each social domain (problems, socialized and work), so we grouped the alters together to create the network variables. The percentages of duplicated ties between networks ranged from 32 to 72 %, with the highest amount of overlap between alters named in the socialized and problems networks (72 %) and the lowest amount of overlap between the work and problems networks (32 %). For each network (problems, socialized, work), the number of people named ranged from 0 to 5. For all ties, the number of unduplicated names ranged from 1 to 7. Very few people (2 %) named five contacts within any given network.

Two variables measured network characteristics at the camp level:

1. *Closeness*: network density, the proportion of actual ties among all possible ties in a network (average outdegree scaled by population size), is often used as a measure of closeness. However, density is sensitive to network size [45]. Because the camps differed in size, we used average outdegree as an alternate measure to density [45]. We calculated the average outdegree for each camp, or the average number of alters named by a camp's members, as our measure of camp closeness.
2. *Concurrency as normative behavior among men in the camp*: the number of men in the camp who engaged in past year concurrency, measured via the UNAIDS method [17], was divided by the total number of men in the camp. We considered this an indicator of the social norm for concurrency among male camp members. We dichotomized this variable to indicate whether concurrency was normative. Among the ten camps the mean proportion of men who were engaged in concurrency was 55 %. A value of "1" indicated that more than 55 % of men in the camp engaged in concurrency whereas a value of "0" indicated that less than 55 % of men in the camp engaged in concurrency. A similar indicator has been used to measure peer influence [46] or social cohesion [47] on smoking.

Two network characteristics were computed using respondents' ego networks as the reference. Ego networks were defined as outdegree, the number of camp-based alters named *by* the respondent, plus indegree, the number

of camp-based alters who *named* the respondent as a friend. Ego network characteristics included:

1. *Popularity*: indegree centrality measured the number of camp-based alters who named the respondent as a friend. This indicator has been used in other research to assess popularity of the respondent (higher indegree centrality = greater popularity) [34].
2. *Average age of ego network*: the average age of alters in the respondent's ego network.

Analysis

We assessed associations between social network (camp and ego) characteristics, gender norms and concurrency among men who had at least one partner in the past 12 months. Although we did not include women in the outcome variable, we included female alters who were named as part of men's ego networks and women were included in the whole camp network variable of average outdegree. Because only 19 men in our sample had never had sex, we did not have sufficient data to accurately convey how networks influenced the choice to become sexually active, which may be a step along on the pathway towards concurrency. Therefore in the models we restricted the sample to men who reported ever having sex (n = 471; 96 %).

First we calculated descriptive statistics for concurrency and network characteristics. Univariate and multivariate methods were used to estimate correlates of concurrency. Because of the dependency of observations among our social network data, we used generalized estimating equations (GEE) with a logit link to account for the clustered design. GEE is designed to obtain reasonable estimates of coefficients and robust standard errors for dependent data by averaging over the random effects [48]. GEE has been used in other network studies of HIV risk behavior [49, 50]. Complete data were missing for 18 people, or 4 % of the sexually active sample, and these were excluded in the multivariate model. We treated camp as the cluster variable and specified an independent correlation matrix. The multivariate model included all factors significantly associated with the outcome at a level of $\alpha = 0.10$ in the univariate analysis. In the multivariable model, all continuous variables were centered to interpret interaction effects. To assess our hypothesis that more close-knit networks in which concurrency is the normative behavior for men would be associated with respondent concurrency, we included an interaction term combining the average degree variable with the variable indicating whether concurrency was normative at the camp. We also examined the interaction of respondent's age and average age of network members. Only the significant interactions are presented in the final model and plotted using an online calculator [51]. All analyses were completed in Stata 13.0.

Results

Table 1 describes characteristics of the sample of men who had ever had sex (n = 471). The average age of the men was 22.23, with a standard deviation of 3.36 (range 15.00–33.00). The majority of men were not in school (69 %) and still living at home with their parents (55 %). The men reported an average of four and a half years as a camp member and 98 % (n = 462) reported being a member of only one camp. Most of the men were not currently in school and most had not yet reached Form 4 (equivalent to Grade 11). The majority of men visited the camp at least two to three times per week (79 %). Respondents' average score on the gender norms scale was 10 with a range of 4-12.

Sexual Partners

Men were asked about their sexual behaviors and three most recent sexual partners in the past 12 months. They had an average of 2.3 partners, and 98 % of their partners were women. More than half (57 %) of the men reported concurrent sexual partnership in the past 12 months. Forty-six percent of the men reported giving money to at least one sexual partner in exchange for sex. Paid sex was moderately correlated with concurrency ($\rho = 0.40$). The proportion of men who exchanged money for sex increased as men's age increased: 32 % of 16–19 year old men, 48 % of 20–24 year old men, and 51 % of 25–33 year old men gave money to a partner in exchange for sex in the past 12 months ($\chi^2 = 8.57$, $p < 0.014$). Substantively, we know that as men age, they have more financial resources to pay for sex. Therefore, we elected to include age in our final model, and exclude paid sex.

Social Network Characteristics

We first report camp network characteristics. Average outdegree by camp, a measure of camp closeness, was 2.99 (range: 2.17–3.62). The average proportion of male members at a camp who were engaged in concurrency was 55 % (range 26–73 %).

Figure 1a, b depict network graphs of two camps. Figure 1a depicts the camp at the minimum average outdegree and Fig. 1b depicts the camp at the maximum average outdegree among all camps. The colors represent concurrency or no concurrency, and the vertex sizes are indegree, which is how many people named that person as a friend. The squares are men and the triangles are women. The colors of the arrows indicate whether or not the friend engaged in concurrency.

Ego networks (outdegree plus indegree) [52] consisted of an average of 5.97 camp members (range 1–18) among

Table 1 Description of the population of sexually experienced male members of 10 camps in Dar es Salaam, Tanzania, 2011 (n = 471)

Characteristic	Median* (range) or % (N)
Demographic characteristics	
Age (years)	22 (16–33)
16–21	48 % (224)
22–33	52 % (245)
Currently a student	31 % (142)
Education completed	
Standard 7 or less	36 % (163)
Form 1–3	29 % (132)
Form 4 or higher	35 % (161)
Ever married	
Currently married	14 % (64)
Was married but not currently married	5 % (22)
Never married	81 % (381)
Sexual partners	
Number of partners in past 12 months	2 (0–12)
1 partner	32 % (151)
2 partners	35 % (163)
3+ partners	32 % (148)
Had concurrent partners in past 12 months	57 % (270)
Gender norms	
Gender norms (summed responses to 4 items)	10 (4–12)
Camp network characteristics	
Average number of camp members	65 (50–82)
Average proportion male camp members	75 % (62–82)
Average outdegree	3 (2–4)
Average proportion of male members engaged in concurrency	55 % (26–73)
Ego network characteristics	
Popularity in ego network (indegree centrality)	3 (0–10)
Average age of ego network members	22 (17–30)

*Unless stated otherwise

all respondents. 47 % of the ego networks comprised 6–10 camp members, 47 % comprised 1–5 members, and 6 % comprised 10+ members. Among all respondents, the average indegree and average outdegree was 2.99 alters; outdegree ranged from 0 to 9 alters, and indegree ranged from 0 to 10 alters.

The average indegree centrality score among all respondents was 3.13 (standard deviation 1.97). Average age of alters in ego networks was 22.28 (std. dev. 2.60; range 17.50–30.00).

Models

Using a multivariable GEE model, we assessed the relationship between social network characteristics, gender norms, and respondent concurrency in the past 12 months among sexually experienced male members of the ten camps. We first examined bivariate associations with each variable of interest (Table 2) and then included significant variables ($\alpha \leq 0.10$) in an adjusted model. We tested all variable times variable interaction terms; only the significant terms are reported in the adjusted model. Marital status, completed education and popularity were not significant in the unadjusted models and were dropped from the adjusted model.

In terms of individual level factors, the adjusted model demonstrated a positive association between age (years) and concurrency (OR 1.15; 95 % CI 1.01–1.32). There was also a positive association between inequitable gender norms and concurrency such that those respondents who reported more inequitable gender norms were more likely to have had a concurrent partnership (OR 1.42; 95 % CI 1.30–1.56). We also observed a protective effect for being currently a student (OR 0.67; 95 % CI 0.40–1.14).

We interacted the measure of closeness in the camp, average outdegree, with the dichotomous variable indicating whether concurrency was normative (greater than the mean

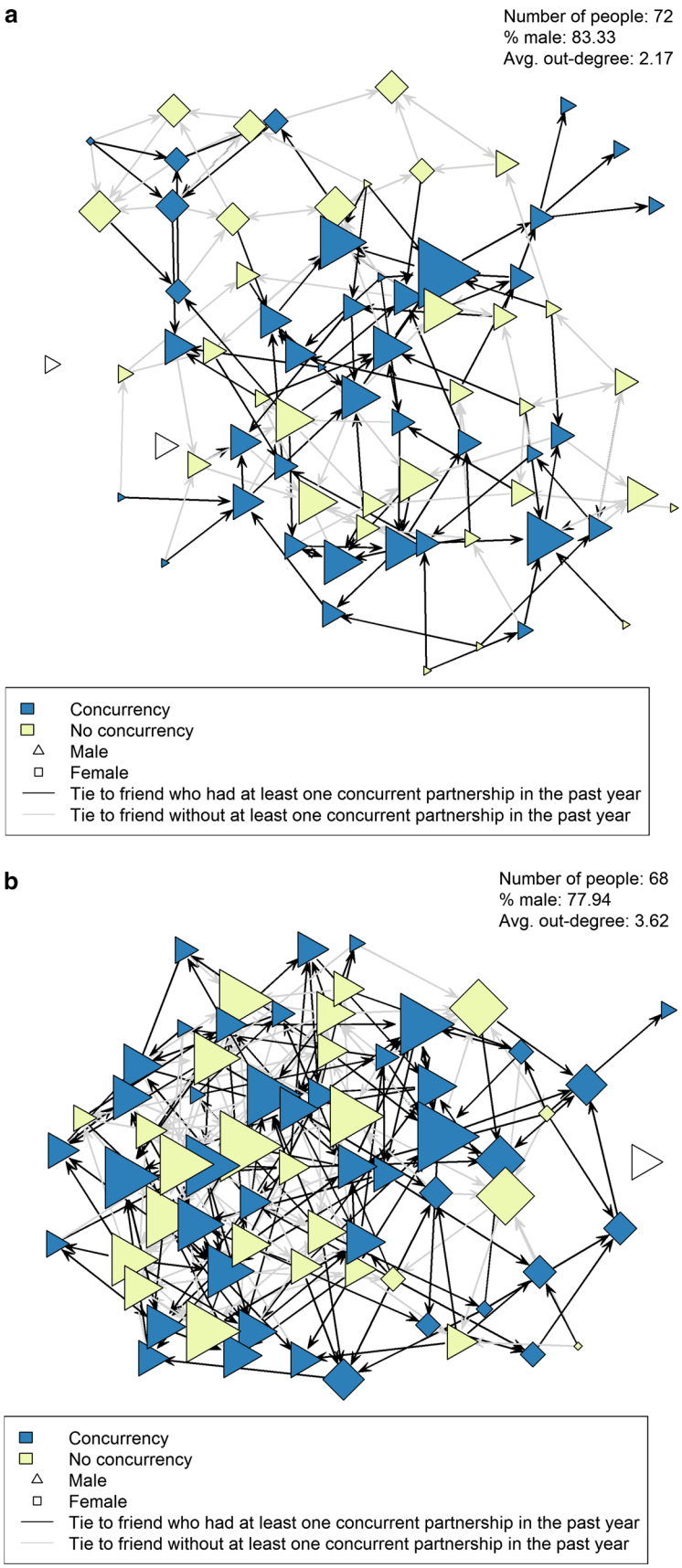

Fig. 1 **a** Sociocentric network graph of camp with minimum average outdegree among sample of 10 camps in Dar es Salaam, 2011. **b** Sociocentric network graph of camp with maximum average outdegree among sample of 10 camps in Dar es Salaam, 2011 (Color figure online)

Table 2 Factors associated with concurrency among sexually experienced male members of 10 camps in Dar es Salaam, Tanzania, 2011 (n = 453 in full model)

	Unadjusted model		Adjusted model	
	Odds ratio (95 % CI)	*p*	Odds ratio (95 % CI)	*p*
Demographic variables				
Age of respondent	1.10 (1.04–1.17)	0.00	1.15 (1.01–1.32)	0.03
Currently married or ever married[a] (reference: never married)	1.10 (0.68–1.76)	0.71		
Currently a student[a] (reference: not currently a student)	0.51 (0.34–0.76)	0.00	0.67 (0.40–1.14)	0.14
Education completed[a] (reference: standard 7 or less)				
Form 1–3	1.11 (0.70–1.77)	0.52		
Form 4 or higher	0.94 (0.61–1.46)	0.79		
Inequitable gender norms (individual)	1.40 (1.29–1.52)	0.00	1.42 (1.30–1.56)	0.00
Camp network characteristics				
Closeness (average outdegree)	1.44 (1.04–2.00)	0.03	0.37 (0.17–0.84)	0.00
Concurrency as normative behavior among men in camp (>55 % of men engage in concurrency)[a]	2.34 (1.62–3.41)	0.00	3.14 (1.77–12.66)	0.00
Ego network characteristics				
Popularity (indegree centrality)	1.05 (0.96–1.16)	0.27		
Average age of ego network	1.11 (1.03–1.19)	0.01	1.00 (0.85–1.19)	0.96
Interaction effects				
Closeness * concurrency as normative behavior among men	N/A		4.71 (1.75–12.66)	0.00
Age * average age of ego network	N/A		0.97 (0.94–0.99)	0.01

[a] Binomial or categorical variable; all other variables are continuous

proportion of 55 %) among men in the camp. The interaction of camp closeness and normative concurrency was significantly associated with respondent concurrency (OR 4.71; 95 % CI 1.75–12.66). The plot of this interaction term is found in Fig. 2 to assist with interpretation. In Fig. 2, average outdegree is on the X axis and probability of respondent concurrency is on the Y axis. The dotted line indicates that concurrency was normative among male camp members and the solid line indicates that concurrency was not normative among male camp members. The difference between the two lines reveals that at low levels of camp closeness, whether concurrency was normative in the camp did not have a strong effect on respondent concurrency. However, the large difference between the two lines at high levels of camp closeness indicates that a respondent was much more likely to engage in concurrency behavior when there was a high level of camp closeness in his camp and concurrency was normative among his camp's male members.

To assess our hypothesis related to developmental differences in network influence, we interacted respondent's age with the average age of his network members. In Fig. 3, respondent's age is on the X axis and probability of respondent concurrency is on the Y axis. The solid line indicates the average age of a respondent's ego network

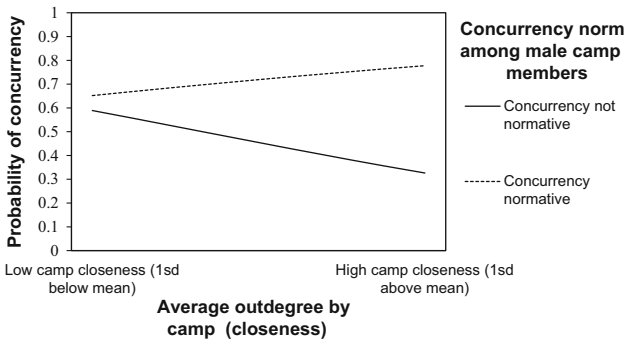

Fig. 2 Plot of interaction effect between camp closeness and camp concurrency norm on respondent concurrency

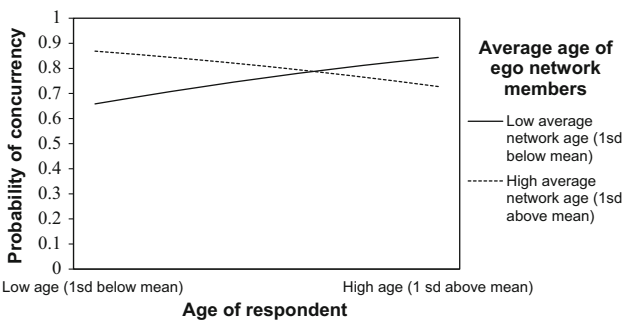

Fig. 3 Plot of interaction effect between respondent's age and average age of ego network on respondent concurrency

members that was one standard deviation below the mean network average age for all respondents. The dotted line indicates the average age of a respondent's ego network members that was one standard deviation above the ego network average age for all respondents. The difference between the two lines reveals that respondents who were younger but had older friends were more likely to engage in concurrency than younger respondents with younger friends. The difference between the two lines at older age for the respondent is not as large indicating that for older respondents there was less influence of network members' ages on respondent concurrency.

Discussion

This study finds support for the theory that social networks influence young men's concurrency behavior. In Dar es Salaam we surveyed 98 % of the membership of ten social networks called camps, including 490 men and 160 women. Actual behavioral data from the network members, rather than perceptions of network members' behaviors, were used to generate the network characteristics, and the UNAIDS method was used to assess concurrency. Consistent with the social influence theory, we observed a positive effect of network closeness and normative behavior on respondent concurrency. The men in our study were more likely to have engaged in concurrent partnerships if they were in close knit camps where concurrency was reported by the majority of male members. Theoretically, members of more closely knit networks are more likely to report making decisions about HIV risk behaviors that are in line with their network members' behaviors [53]. Prior studies have also found a positive effect of network closeness and norms on condom use, HIV risk perceptions and drug using behaviors [30–33]. Targeting social norms for concurrency in tightly knit camps may be fruitful as an intervention strategy to reduce concurrency.

We showed that age was positively associated with concurrency. Studies from Tanzania have shown older men may have an easier time attracting sexual partners because of an improved economic situation that comes with older age and because women will be attracted to them as a means for gaining material and financial support [54]. We also found that younger men in the camps who had older, rather than younger, friends in their networks were more likely to engage in concurrency. This finding is consistent with other studies showing that adolescents with older friendship networks are more likely to engage in sexual risk behaviors [7, 36]. Several studies from Tanzania have shown that young men engage in concurrency to prove their success with women to their peers and contribute to the norm that young men need multiple partners to satisfy their sexual needs [23, 54]. One intervention implication of this finding may be to train older men to mentor their younger network members on HIV prevention. Another strategy may be to "rewire" the network by connecting younger members to network outsiders who will have a positive influence on them [22]. In any case, reaching younger men during a stage of life when their expectations about sexual behavior are still developing is likely a productive intervention strategy [55].

We also found a direct association between inequitable gender norms and concurrency. Addressing gender norms during interventions with men may have an effect on concurrency behavior, and likely would have an indirect effect on other sexual risk behaviors [2, 56]. In addition, being in school was negatively associated with concurrency among the men in our sample, replicating the finding of a prior study in Dar es Salaam [24]. The consistency of this finding suggests that perhaps keeping men in school would have a similar positive effect on preventing HIV transmission as keeping girls in school [57].

Because the camps are social networks in and of themselves, future research that assesses relationships among all camp members may generate more accurate measures of closeness and popularity, rather than limiting each member to fifteen social contacts. In this study, there was a significant amount of overlap between the networks, and very few people named the upper limit of five camp members for any network domain, so it is unlikely that the upper limit impacted our results. In a current intervention trial with 54 camps in Dar es Salaam [58], camp members are asked to identify whether *each* of their fellow camp members is a friend, acquaintance, someone they don't get along with, or someone they don't know. The collection of longitudinal network data during the intervention will allow for uncovering network mechanisms that changed behavior over time.

Due to the cross-sectional design of this study, we cannot assess the direction and magnitude of social influence effects. For example, concurrency practices may lead to personal gender norms or to socializing with older friends rather than vice versa. Young men may have sought to replicate the concurrency behavior they observed among their peers. Alternatively, it is possible that respondents' attitudes were influenced by their peers' behavior, with indirect effects on concurrency. We cannot rule out the possibility that the associations we observed are due to homophily, the tendency for people to socialize with others who share similar behaviors to their own [59]. Furthermore, our cross-sectional study limits our ability to evaluate recall bias regarding concurrency. Among those who had at least two partners in the past 12 months, the proportion who reported concurrency was quite high at 87 %, although this proportion was not very dissimilar from a

prior study (78 %) among men aged 15–19 in the camps [24]. To minimize this bias we used the conservative UNAIDS method to assess concurrency and included detailed questions about each of the three most recent sexual partners. However, men still may have exaggerated their number of sexual partners [60].

We note that the odds ratios we present in this paper should not be interpreted as prevalence ratios since the outcome of concurrency in this study is not rare [61, 62]. Because of our clustered and dependent network data we elected to use GEE as our modeling strategy. GEE has also been used in other network studies of HIV risk behavior [49, 50].

Nevertheless, the associations that we observed between network characteristics and concurrency suggest that further research is warranted. If the effects hold in longitudinal research, several intervention strategies may be appropriate. For example, creating ongoing opportunities within men's networks to openly discuss the consequences of concurrency, or to discuss strategies for avoiding concurrent partnerships, could change men's perceptions that concurrency is a positive or normative behavior [31]. Another strategy could be to bring in outsider role models to the network, such as lay health advisors, who could provide new information to network members about preventing concurrency and HIV [63].

This is the first study to apply network data to sexual risk behavior among young Tanzanian men. Understanding how networks are linked with sexual risk behavior over time is a first step towards the development of intervention strategies that may more effectively target and change social norms. A recent systematic review of HIV prevention interventions for young people in sub-Saharan Africa found that few interventions were effective in part because social norms for sexual behavior were overlooked [64]. A lack of attention to social norms and concurrency was implicated in the failure of a recent adolescent HIV prevention trial in Tanzania to reduce HIV and STI incidence [65, 66].

Using network data to examine social influence on HIV risk behavior has received substantial attention among U.S. adolescents, but is a nascent line of inquiry in sub-Saharan Africa. Nevertheless, the magnitude of the HIV epidemic in the region requires large scale interventions to address HIV. Sexual health education is not systematically available in Dar es Salaam's secondary schools [67]. Thus networks may serve as a conduit for spreading information about sexual health for the city's young people [22]. Network interventions in which participants receive prevention information and then spread it to their social contacts, resulting in indirect effects, can maximize intervention reach, compared to interventions focused solely on individuals [18].

Conclusion

This study assessed social network characteristics associated with sexual partnership concurrency among young men. The findings provide additional evidence of the importance of men's social networks in sustaining men's sexual risk behaviors. The stable and organized camps in Dar es Salaam offer a unique, important opportunity to assess the influence of networks on young men's behaviors and leverage their networks for HIV prevention. Assessing network effects on HIV risk behavior through longitudinal or intervention research can illuminate the role of social influence in bringing about behavior change; assess the direction and magnitude of the association between networks, norms and risk behaviors; and assess spillover or indirect effects [18]. Further network studies of HIV risk behavior could be particularly useful for developing interventions attuned to social context and in high prevalence settings where the magnitude of the HIV epidemic requires maximizing intervention reach.

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