Concurrency and HIV spread in sub-Saharan countries: biases from self-reported data and their implications for HIV prevention

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Abstract

Background: Multiple concurrent partnerships (MCP) of men have been described as the "key driver" of generalized HIV epidemics.
Objectives: To test the hypothesis that reducing MCP among men will disconnect the sexual networks that fuel HIV transmission.
Methods: We conducted a sexual network study in 7 villages of Likoma Island (Malawi). All inhabitants aged 18–35 were asked to identify up to 5 of their most recent sexual partners. Population-level sexual networks were constructed by linking reports of sexual partnerships to village rosters, assuming that a sexual relationship existed if it was reported by at least one partner. We estimate the prevalence and correlates of MCP, and infer sexual mixing patterns according to network data and compare these results to estimates derived from self-reported data only.
Results: The prevalence of MCP was significantly higher in all population groups according to network data. Self-reported data overestimated gender differences in MCP among unmarried respondents, but underestimated these differences among older ever-married age groups. The prevalence of HIV was not significantly higher among respondents in MCP according to network data, but several risk factors for HIV transmission were more common in MCP omitted by self-reported data. The infectivity of women in MCP maybe substantially higher than the rest of the population. Contrary to self-reported data, network data suggests that married men with MCP are likely to partner with women who are themselves in MCP.
Conclusions: Self-reports of MCP collected during surveys of sexual behaviors misrepresent the role of men in connecting sexual networks among the general population of Likoma Island. Interventions promoting behavioral change related to MCP should not solely focus on the behaviors of men.

Keywords: concurrency, survey data, sexual behaviors, HIV transmission, HIV risk factors, Malawi.

1 Introduction

Multiple concurrent partnerships (MCPs)—defined as having 2 or more sexual partnerships that overlap in time—can accelerate the transmission of sexually transmitted infections (including HIV) in a population (Morris & Kretzschmar 1995; Kretzschmar & Morris 1996; Potterat *et al.* 1999; Koumans *et al.* 2001) and have been described as the "key driver" behind the generalized epidemics of southern Africa(Shelton 2007). Declines in HIV prevalence in several African countries have been associated with concomitant declines in multiple partnerships (e.g., Gregson *et al.* 2006; Stoneburner & Low-Beer 2004; Hallett *et al.* 2006), and an intensification of partner reduction campaigns in generalized epidemics has been advocated (e.g., Shelton 2007; Wilson & Halperin 2008).

However, little is known about ways to promote partner reduction systematically in sub-Saharan settings. Survey data on sexual behaviors document large gender differences in MCP (e.g., Gregson *et al.* 2006; Potts *et al.* 2008; UNAIDS 2007; Halperin & Epstein 2004), and several analysts have thus suggested to focus prevention efforts on the MCPs of men (Wilson & Halperin 2008). Indeed, the sexual mixing patterns implied by such data are likely "disassortative" or "star-like" (e.g., Morris & Kretzschmar 2000; Anderson & May 2001): men with MCP are frequently partnering with women in single partnerships, and thus play a central role in connecting the sexual networks that fuel HIV transmission.

The evidence for such star-like patterns in sexual networks has been scanty and has been based on self-reports of sexual behaviors. Much research has warned against under-reporting and social desirability biases affecting these data (e.g., Cleland *et al.* 2004; Nnko *et al.* 2004). On the other hand, sexual network studies that incorporate partner tracing are much less vulnerable to under-reporting of sexual relationships because one's relationship(s) are potentially reported not only by the respondent him/herself, but also by his/her sexual partner(s). In this paper, we compare measures and correlates of partnership concurrency derived from self-reported data to measures and correlates derived from a partner tracing study describing the sexual networks of a small island on Lake Malawi (Helleringer & Kohler 2007). Our results suggest that the promotion of partner reduction should extend beyond the MCP of men.

2 Data and Methods

2.1 General approach

Our knowledge of the extent and correlates of partnership concurrency in sub-Saharan populations is almost exclusively based on self-reports of sexual behaviors collected in various contexts. These data are often inaccurate because respondents may not report stigmatized behaviors (e.g., Cleland *et al.* 2004; Mensch *et al.* 2003): for example, if respondent A in Figure 1a reports only one his/her relationship and omits the other and respondent E reports only one of his four relationships, then neither individual A nor E would be classified as engaged in a MCP based on self-reported survey data. Women, in particular, may be more likely to under-report the extent of their sexual networking (e.g., Nnko *et al.* 2004), and in this context the relative role of men in connecting sexual networks may be overestimated.

In network studies based on partner tracing designs (see Morris 2004), respondents are not sampled but rather every member of the network of interest is systematically enrolled and asked to nominate sexual partners. Nominated partners are then matched to existing population rosters (e.g., Helleringer & Kohler 2007; Bearman *et al.* 2004), and all data are linked. The number of sexual partners nominated by a respondent during a sexual network survey is the "outdegree" (Wasserman & Faust 1994), which corresponds to the self-reported number of partners in conventional surveys. The number of times a respondent is nominated by other survey respondents is the "indegree", and the "total degree" of a respondent is a combination of his/her outdegree and indegree. If self-reports of sexual behaviors were perfectly accurate, outdegree, indegree and total degree would be equal for each member of the network. In the presence of under-reporting, the measures diverge. The ability of sexual network data to obtain a respondent's total degree by combining a respondent's self-reported data (outdegree) with the respondent's partners' reports (indegree) effectively reduces measurement error due to under-reporting of sexual relationships. In this paper, we systematically compare inferences about sexual networks made on the basis of outdegrees only to inferences made on the basis of total degrees.

In Figure 1a, for example, both A's and E's outdegrees are 1, while their total degrees are 2 and 4 respectively. On the other hand, network data can correctly identify A as being involved in a MCP, even though A's self-reports include only one sexual partner (Figure 1b). We refer to respondents with outdegree ≤ 1 as having "self-reported serial partnerships" (SR-SP), and respondents with outdegree ≥ 2 as having "self-reported multiple concurrent partnerships" (SR-MCP). Finally, we refer to respondents who self-reported being engaged in at most one sexual relationship (outdegree ≤ 1), but were nominated by at least one other respondent (total degree ≥ 2), as having "network-reported MCPs" (NR-MCP). Respondents with network-reported MCPs would not be identified as having concurrent partnerships according to self-reported data since their outdegree is equal to one.

2.2 Data

Our analysis is based on the Likoma Network Study (LNS), which traced the sexual networks of young adults on Likoma, a small island in the northern region of Lake Malawi (Helleringer & Kohler 2007; Helleringer *et al.* 2006). During November 2005 and February 2006 the LNS implemented a sexual network survey that was based on three steps. First, in November 2005, we completed a household census during which we enumerated all inhabitants of the island. The main aim of this census was to constitute rosters of potential sexual network members. Second, from January to mid-February 2006, we conducted a sexual network survey with all inhabitants aged 18–35 in seven villages of the island. Respondents were asked to provide the names (along with other identifying information such as residence, occupation ...) of up to 5 of their recent sexual partners during computer-assisted interviews. They were also asked to answer questions about the context of their relationships with these partners (e.g., duration and timing), and relationship-specific risk factors for HIV transmission (e.g., condom use). Interviews were conducted using audio computer-assisted self-interviewing techniques (ACASI), which have been shown to significantly increase the validity of reports of stigmatized behaviors in other contexts (Mensch *et al.* 2003). The network of sexual relationships was then constructed by tracing all nominated partners and linking, where possible, nominated partners to survey respondents and individuals included in the household roster. More than 80% of partners residing on Likoma were traced. Third, during March 2006, study participants were tested for HIV infection using two rapid tests as suggested by the Malawi Ministry of Health.

Individual-level risk factors for HIV transmission elicited by the LNS were self-reported symptoms of STI, last time sought treatment for STI, last time received an injection, general health, recent symptoms indicative of infection with *plasmodium falciparum* and HIV testing behavior. Symptoms of STI, last time sought STI treatment and last time received an injection were all ascertained over the year prior to the survey and were coded "1" if the respondent experienced these events during that time span, and zero otherwise. Symptoms of STI which were assessed included painful urination, ulceration of the genital area or discharge from the penis/vagina. The variable was coded "1" if the respondent experienced any of these symptoms, and 0 otherwise. General health was assessed on a continuous scale ranging from 1 (excellent) to 5 (poor), and for these analyzes we created an indicator variable taking value 1 when the respondent reported general health levels equal to or below 4. HIV testing behavior was measured by a variable describing whether a respondent had ever been tested for HIV infection prior to the study. Condom use is described by two variables: having ever used a condom with a current partner and consistency of use with all partners. Condom use was defined as consistent when a respondent reported "always" using a condom with a given partner.

Concurrency is defined by the temporal overlap between two sexual relationships (Morris & Kretzschmar 1997). In most studies, it is either measured indirectly by asking respondents about the start and end dates of their partnerships (Morris 2004; **?**), or directly by asking them whether they have had two or more sexual relationships during a specified—and generally short—period of time (e.g., Halperin & Epstein 2004). We measure concurrency directly at the time of the survey, that is, by counting how many sexual partnerships a respondent was involved in at the time of the interview according to both his own reports (outdegrees) and reports of his/her potential partners (total degrees, see section 2.1).

3 Methods

We compare the prevalence of MCP by gender in the study population according to self-reported and network data using standard techniques of bivariate analysis. We also conduct comparisons of these estimates by marital status of the respondents.

We examine the association between MCP and HIV status/HIV risk factors, by fitting logistic regression models with concurrency (measured by self-reported or network data) as an independent variable. We examine associations separately for men and women, and models include controls for age group and marital status (never married vs. ever married). We further assess differences in HIV risk factors between in MCP by fitting models that include SR-SP, SR-MCP and NR-MCP as different levels of an independent categorical variable (with SR-SP as the reference category). We conduct Wald tests to assess whether the odds ratios of SR-SP vs. SR-MCP, and SR-SP vs. NR-MCP were homogeneous (Agresti 1990). Standard errors of the estimates are adjusted for the clustering of observations within study villages.

Network assortativity refers to the probability that a sexual relationship connects two partners who are otherwise engaged in other concurrent partnerships. Patterns of assortativity are important for disease spread, because they have very different implications for the emergence of dense network components when the average number of partners in a population is low (**?**): when the partners of a respondent with MCP are unlikely to have MCPs themselves (disassortative network), sexual networks are generally small and HIV transmission limited; on the other hand, when a respondent's partners' also have other partners (assortative network), robust networks emerge rapidly and rates of transmission increase. We assess the extent of network assortativity, by estimating the odds ratio of a sexual relationship connecting partners who are both engaged in MCP. Because each respondent may be involved in several relationships, we use generalized estimating equations with a binomial distribution of the dependent variable and a logit link (Agresti 1990) to account for clustering of observations by respondents. The odds ratio derived from GEE estimation are population-averaged and thus account for the relative availability of partners with multiple partners in the population. These analyzes are restricted to the pool of relationships having taken place between surveys respondents ("in-sample relationships").

4 Results

4.1 Descriptive statistics

923 respondents participated in the sexual network survey. Table **??** describes characteristics of these respondents and the sexual relationships they were involved in at the time of the survey. 36.9% of women and 52.3% of the men interviewed had never been married, and 10.8% of women were widowed or divorced. 23.1% of women and 26.8% of men reported not being involved in a relationship at the time of the survey (outdegree=0). However, 43 of those were nominated by other respondents (indegree ≥ 1). The proportion of respondents with 2 or more partnerships ongoing at the time of survey was systematically higher according to network data (total degrees). In total, Female respondents were involved in a total of 466 relationships, while male respondents were in involved in 407 relationships; 180 of these relationships were reported jointly by both partners. Table **??** describes characteristics of these relationships. More than 80% of partners nominated during the sexual network survey were traced in the rosters of the Island population, and over 60% of these partners were themselves interviewed during the sexual network survey. Among 282 relationships potentially reported by both partners ("in-sample"), more than 12% were reported by the woman only and 19% by the man only. When considering only in-sample non-marital relationships, these proportions were raised to 21.9% and 39.9% respectively.

4.2 Prevalence of MCP on Likoma Island

Among this population, the proportion of respondents engaged in MCP was 4.6% among females and 12.1% among males ($p < 0.001$) according to self-reported data. Concurrency was however significantly more common according to network data: the proportions of women and men engaged in MCP increased to 11.1% and 18.8% respectively. The relative increase in the estimated proportion of respondents involved in MCP between the two research designs was 55.4% for males and 142.3% for females. Biases in measures of concurrency according to self-reports further varied by gender and marital status (Figure 2). Among never married women, the relative difference in proportion engaged in MCP between self-reported and network data was 189.1%. Among never married men however, the relative increase was only 22.2%. Whereas self-reports of sexual behaviors highlight large gender differences in MCP in this population, network data indicate that never married women were as likely to be engaged in MCP at the time of the survey as their male counterparts ($p = 0.716$). Among ever-married respondents, on the other hand, self-reported data underestimated gender differences in MCP: 4.1% of ever-married women and 11.9% of ever-married men self-reported being involved in MCP at the time of the survey, but these figures were raised to 8.5% and 22.9% for women and men respectively, according to network data.

Table 1: Characteristics of relationships identified during the sexual network interview. Ongoing relationships.

	Women	Men
Respondents' characteristics	$N = 501$	$N = 422$
Marital status		
Never married	36.9%	52.3%
Currently married	52.3%	44.9%
Widowed or divorced	10.8%	2.8%
Outdegrees		
0	23.1%	26.8%
1	72.3%	61.0%
2	4.4%	9.5%
3	0.2%	2.6%
Total Degrees		
0	17.9%	22.8%
1	70.9%	58.4%
2	9.6%	15.4%
3	1.6%	3.3%
In-sample relationships†	$N = 282$	
Proportion reported by		
Woman only	12.5%	
Man only	19.1%	
Both man and woman	68.4%	
In-sample Non-marital relationships	$N = 123$	
Proportion reported by		
Woman only	21.9%	
Man only	39.9%	
Both man and woman	38.2%	

Notes: †Relationships involving two survey respondents. Relationships between a survey respondent and an inhabitant of Likoma who refused to participate in the survey or was absent at the time of the survey are not included in these calculations.
‡Proportion of jointly reported relationships in which both partners reported the same answer on survey items listed below.
* When partners disagree, women more frequently report behavior under consideration.
** When partners disagree, men more frequently report behavior under consideration.

4.3 Risk factors for HIV transmission in Multiple Concurrent Partnerships

4.3.1 Prevalence of HIV among MCP

While MCP were significantly more common according to network data, the prevalence of HIV did not vary significantly between respondents in serial relationships and respondents having MCP according to both self-reported and network data. Among women, the proportion of infected respondents was above 10% and did not vary by concurrency status. Among men, HIV prevalence was significantly lower (around 5%), and we could not detect differences in HIV prevalence between men in serial relations and men with MCPs. However, the sample sizes available for analysis were small ($N = 597$) and participation in HIV testing was related to partnership concurrency. In particular, men involved in a MCP were significantly more likely to have refused participation in HIV testing during the study (OR = 0.62, 95% CI: 0.37, 1.05) and no cases of HIV infection were detected among network-reported MCPs.

4.3.2 Prevalence of HIV co-factors among MCP

Table 2 compares the prevalence of co-factors and attitudes related to the risk of HIV transmission among MCP, according to self-reported and network data. It indicates that self-reported data may underestimate the infectivity of individuals with MCPs, among both men and women. While self-reports of MCP indicate that women with SR-MCP did not differ from the rest of population with regards to HIV co-factors, estimates derived from network data indicate otherwise: women in MCP were generally more likely to have used condoms with any of their current partners, but were significantly less likely to have done so consistently (OR = 0.35). While these findings may be due to the small number of women with SR-MCP, we did find additional evidence that the prevalence of STIs was significantly higher among women with NR-MCP relative to women with SR-MCP ($p \approx 0.09$). Among men, the prevalence of condom use was higher among MCP than among men in serial relations according to self-reported data, as was the proportion of men worrying about HIV. According to network data, however, several other co-factors enhancing HIV transmission risks were more common among men with MCP including recent use of injections and recent episodes of malaria/flu-like illnesses. In addition, men with NR-MCP were significantly less likely to be worried about HIV, but were more likely to report less consistent condom use than men with SR-MCPs, .

4.4 Assortative mixing by degree

Finally, analyses of network assortativity, i.e., of the probability that the partners of a respondent with multiple concurrent partners themselves have multiple partners, also highlight large differences between self-reported and network data. Estimates for the set of relationships connecting survey respondents are presented in table 3. Among partners of women, results from generalized estimating equations do not indicate a tendency towards assortative or disassortative mixing: women in MCP were just as likely to form partnerships with men in serial relations as with men in MCP. This lack of association was seen both in self-reported and network data. Estimates for partners of men, on the other hand, differed radically by type of data: while self-reported data indicated that sexual networks of men could be *disassortative* (i.e., that men with MCP are more likely to have partners who have just one partner), network data did not confirm the presence of

Table 2: Prevalence of co-factors of HIV transmission among respondents with MCP according to self-reported and network data. Age and marital status adjusted Odds Ratios.

	Women			Men		
	Self-reported *OR [95%CI]*	Network *OR [95%CI]*	Homogenous OR† *p-value*	Self-reported *OR [95%CI]*	Network *OR [95%CI]*	Homogenous OR† *p-value*
Self-reported STI symptoms						
Ref=No symptoms						
At least one symptom	0.97 [0.32,2.97]	1.62 [0.82,3.21]	0.09	0.88 [0.29,2.66]	0.96 [0.41,2.24]	0.66
Last Sought STI treatment						
Ref=Never sought or > 1 year ago						
Over the last year	1.10 [0.34,3.55]	0.80 [0.34,1.88]	0.51	2.11 [0.47,9.46]	1.12 [0.31,4.01]	–[a]
Last time received an Injection						
Ref=Never received or > 1 year ago						
Within last year	0.99 [0.42,2.34]	0.85 [0.36,2.01]	0.74	1.08 [0.84,1.38]	1.32 [0.96,1.81]*	0.32
Malaria symptoms						
Ref=No recent symptoms						
Recent symptoms	1.26 [0.53,3.02]	0.80 [0.45,1.44]	0.32	0.88 [0.51,2.85]	1.35 [0.96,1.89]*	< 0.01
HIV testing prior to study						
Ref=Never tested						
Ever tested	0.89 [0.35,2.23]	1.04 [0.60,1.79]	0.66	1.32 [0.68,2.58]	1.54 [0.65,3.63]	0.53
HIV risk perception						
Ref=Not worried at all						
Worried a little/worried a lot	0.76 [0.41,1.42]	1.02 [0.83,1.25]	0.35	3.25 [1.34,7.92]**	2.12 [1.17,3.86]**	0.04
Condom use						
Ref=no current use						
Used with at least one partner	1.44 [0.66,3.15]	2.66 [2.01,3.54]**	0.24	2.73 [1.45,5.15]**	3.21 [1.46,7.1]**	0.85
Consistency of Condom use†						
Inconsistent use						
Consistent use with all partners	0.40 [0.11,1.62]	0.35 [0.20,0.61]**	0.79	0.88 [0.39,2.03]	0.57 [0.21,1.57]	0.04

Notes: Figures reported in the table are Odds ratios derived from logistic regression models, adjusting for age and marital status.
†*P*-values reported in these columns are derived from tests of the null hypothesis that the odds ratios of SR-SP vs. SR-MCP and SR-SP vs. NR-MCP are equal. Low p-values indicate that the null hypothesis is rejected.
[a] No men with NR-MCP interviewed during the sexual network survey indicated having recently sought treatment for STI.
** $p < 0.05$, * $p < 0.1$.

Table 3: Odds ratios of assortative mixing by degree.

	Women		Men	
	Never Married	Ever Married	Never Married	Ever Married
Self-Reported Data	0.88 [0.28,2.75]†		0.42 [0.08,2.21]†	
Network Data	1.05 [0.64,1.73]†		0.89 [0.42,1.89]	2.28 [1.01,5.19]**

Notes: Figures reported in the table are population-averaged odds ratios, adjusted for age. Estimates are derived from generalized estimating equations (GEE) assuming a binomial distribution of the response variable, and a logit link function. Estimates of standard errors are adjusted for clustering within respondents, using an exchangeable correlation matrix.
†The best-fitting models did not include an interaction term between respondent's concurrency status and marital status. Goodness-of-fit was assessed on the basis of Wald Statistics

star-like patterns centered around men with MCP. Quite to contrary, estimates based on network data suggest that (at least regions of) the sexual networks of men could be *assortative*: partners of married men in MCP were almost 3 times more likely to be themselves involved in MCP than the partners of men in serial relations.

5 Discussion

In this small sub-Saharan population, the systematic comparison of partner-reported network data and self-reported sexual partnership data highlighted several important biases in self-reported sexual behavior data. First of all, self-reported data underestimated the proportion of men and women engaged in MCP by 55% and 143% respectively. Second, self-reports of MCP overestimated gender differences in partnership concurrency among never-married respondents, but underestimated gender differences in MCP among ever married respondents. Third, several cofactors potentially enhancing the transmission of HIV during sexual intercourse were more common among respondents with NR-MCP than among the rest of the population. Finally, inferences drawn from self-reported about the population-level data suggested that sexual networks in this population could be disassortative

The findings presented here thus agree with findings from several other studies having documented large and systematic under-reporting of sexual relationships sub-Saharan populations, particularly among younger unmarried women (e.g., Cleland *et al.* 2004; Nnko *et al.* 2004; Mensch *et al.* 2003; Dare & Cleland 1994; Gregson *et al.* 2004), and among older married respondents (e.g., Dare & Cleland 1994). While these studies have been conducted at an aggregate level (Nnko *et al.* 2004; Zaba *et al.* 2004) or have been limited to comparisons of different modes of data collection (e.g., Mensch *et al.* 2003; Gregson *et al.* 2004; Mensch *et al.* 2008), we were able to quantify the extent of bias in self-reported sexual behavior data at the individual level. We were thus able to identify the characteristics of the relationships omitted during sexual behavior surveys, as well as the characteristics of respondents who under-reported the extent of their recent sexual networking. While HIV was not more prevalent among respondents in a MCP, several risk factors affecting the risk of onward HIV transmission were significantly more common in concurrent relationships misclassified by self-reported data and among respondents involved in these relationships. For example, condom use was less less consistent during non-reported concurrent partnerships of women and men. Women with NR-MCP were also more likely to present recent symptoms of STIs than women in serial relations, and because co-infection with STIs act as an important amplifier of HIV transmission risks (e.g., Cohen *et al.* 1997; Krieger *et al.* 1995), their infectivity could thus be significantly increased. Men with NR-MCP were more likely to report having recently experienced symptoms indicative of malaria or a flu-like illness than men in serial relations. Because systemic co-infection (in particular with *Plasmodium falciparum* malaria)is another important amplifier of HIV transmission risk (Kublin *et al.* 2005; **?**), men misclassified by self-reported data may thus also be more infectious than the rest of the population. Men who did not disclose ongoing concurrent sexual relationships during the sexual network survey were also much less likely to have consistently used condoms with their partners, but were significantly less likely to be infected with HIV.

Our findings thus have important implications for HIV control in sub-Saharan populations. study thus indicates that the concurrent relationships omitted during sexual behavior surveys based on self-reported data may be more likely to present high risks of HIV transmission. Population-based studies of the factors determining HIV spread (e.g., Lagarde *et al.* 2001; Boerma *et al.* 2003) may thus have largely under-estimated the contribution of partnership concurrency to local epidemics. These findings may strengthen the claim that concurrent partnerships are the "key driver" of generalized HIV epidemics. They are also important in light of the renewed emphasis on HIV interventions promoting partnership reduction (Shelton 2007; Potts *et al.* 2008): while self-reported data on MCP would identify the behaviors of men as the main "culprit" in establishing generalized HIV epidemics, MCP are also common among women in particular at younger ages. While the few existing examples of partner reduction programs such as Uganda's "zero grazing" (e.g., Stoneburner & Low-Beer 2004) had a strong gender bias, partner-reported network data suggests that such interventions should be more broadly targeted and aim at addressing the concurrent relationships of women as well.

Our study suffers from several limitations. First, while the true impact of concurrency is measured among partners' of an index case (Morris 2001), we were not able to directly assess the impact of partnership concurrency on the *transmission* of HIV. Instead, we were only able to show that factors favoring HIV transmission were more common in MCP that were omitted by self-reported data. This limitation stems from the fact that our sample size is small, that our data are cross-sectional and the biomarkers of HIV infection we used were limited to the detection of HIV antibodies (and thus did not allow identifying recent acute HIV infection). Studies having estimated precisely the impact of concurrency on the transmission of a pathogen in a population were either based on prospective research designs (Potterat *et al.* 1999) or were able to classify connected cases of a disease by stage of infection (Koumans *et al.* 2001).

Second, the impact Second, network data improves on estimates of sexual behavior parameters derived from self-reported data only insofar as the partners of respondents are also enrolled in the study. The reduction in bias afforded by partner-reported data thus varies with levels of(*i*) survey non-response among members of the study villages, and (*ii*) sexual mixing with partners residing outside of the study area. Non-response was limited for the sexual network survey as only 11% of eligible participants declined to be interviewed or were absent at the time we visited them. Sexual relationships with partners residing outside of the study villages were on the other hand much more common and presented significant HIV risks **?**. If inhabitants of the sampled villages were more likely to under-report partnerships they engaged in with residents of the mainland or of other villages of Likoma, then our estimates of the prevalence of MCP in this population may still be biased downwards.

Third, our results based on partner-reported data may also be affected by over-reporting of sexual relationships. Indeed, several studies have argued that some respondents (especially younger men) could "swagger" during surveys and exaggerate the number of partnerships they were involved in (Nnko *et al.* 2004; Mensch *et al.* 2003). Other studies have pointed out that women may exaggerate the duration of their relationships and may report particular relationships as ongoing even though the man considers their relationship as over (Nnko *et al.* 2004). Such patterns of sexual behavior reporting could lead to over-estimating concurrency levels among inhabitants of Likoma.

There are however several strong indications that these biases do not affect our data. While it is easy to swagger when asked about the number of sexual partners one has had, it is much more complicated to do so when asked to name (and provide locating information about) these partners. On the other hand, women misclassified by self-reported data were also more than twice more likely to present symptoms of STIs than women in serial relations. suggesting that they may indeed have taken more sexual risks than their reports of sexual partnerships suggest. Similarly, only in 27 relationships did partners disagree on whether or not the partnership was still ongoing at the time of the survey. In 14 of these relationships, the man reported that the relationship was still ongoing. When these relations were excluded from the analyzes, estimates of MCP prevalence based on linked records declined only slightly and the correlates of concurrency described in table 2 remained unchanged. Finally, of 31 extra-marital relationships between a man and a married woman reported during this study, 23 (74.2%) were reported jointly by both partners. On the other hand, among the 59 non-marital relationships between a man and a never married woman, only 20 (33.4%) were reported jointly by both partners. The difference in proportions was significant at the .05 level, indicating that younger (unmarried) women may be more likely to be secretive about their relationships than younger men to be "swaggering" about theirs (Nnko *et al.* 2004).

In brief, the findings presented here indicate that the role of MCP in the diffusion of HIV within sub-Saharan populations may have been underestimated in comparative studies of the determinants of HIV risks. Self-reported data are not well-suited to estimate the prevalence of MCP in local populations and assess the contribution of partnership concurrency to the uneven spread of HIV. The design and evaluation of behavioral interventions targeting partnership concurrency should rely on sexual network data, that includes partner tracing.

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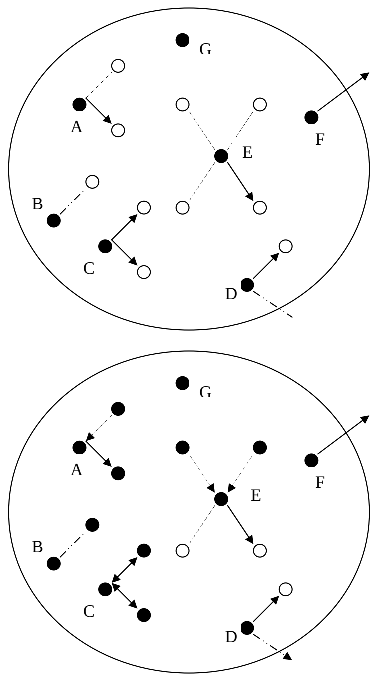

Figure 1: Comparison of self-reported sexual behavior data and partner-reported network data.
In panel A, individuals A,B,C,D,E,F,G are sampled from the population and are asked to report their sexual relationships.
In panel B, the same individuals are interviewed as are their partners as part of the complete network survey. In panel B, if individual A does not disclose his/her relationship with any of his/her partner, A may still be classified as involved in a concurrent partnership if the partner(s) report this relationship.
Solid black circles represent individuals interviewed during a survey. Solid arrows represent the nominations made by a respondent during a sexual behavior survey. Dotted lines represent relationships of a respondent that he/she did not disclose during the sexual behavior survey. We consider that a sexual relationship took place between two respondents as long as at least one of the two partners reported it during the survey

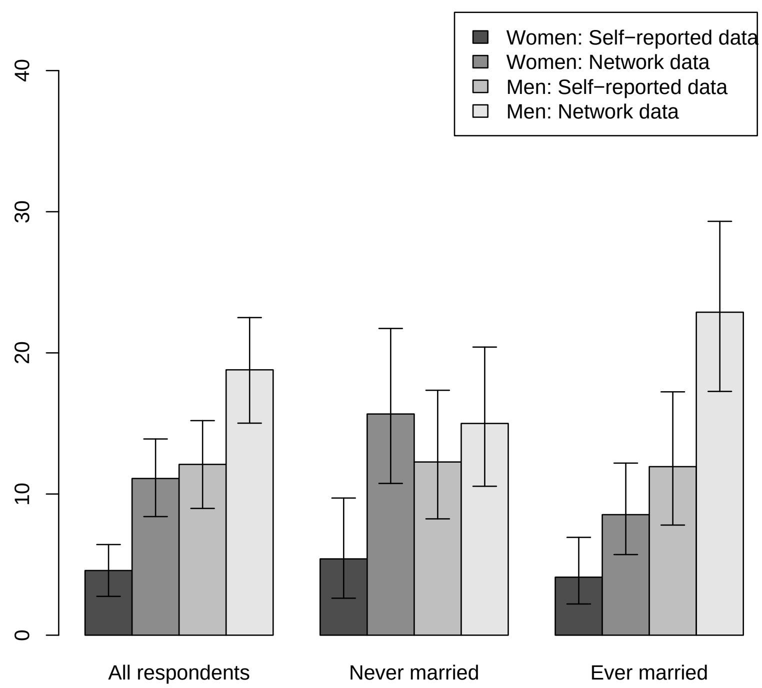

Figure 2: Prevalence of Multiple Concurrent partnerships among inhabitants of Likoma Island according to different data collection methodologies.