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Egocentric Networks and HIV in Pregnant and Breastfeeding Women Attending Antenatal Care in Lusaka, Zambia

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Abstract

Human immunodeficiency virus (HIV) has a disproportionate effect on pregnant and breastfeeding women in sub-Saharan Africa. This study used egocentric social network analysis (SNA) to compare the social and sexual networks of HIV-negative and HIV-positive women attending an antenatal care (ANC) clinic in Lusaka, Zambia. In order to assess risk and protective factors for HIV acquisition and transmission, variables included self (ego) sociodemographic characteristics, main partner characteristics, features of the relationship between ego and her main partner, alter attributes, alter-ego ties, and alter-alter ties. Associations between the independent variables and ego HIV status were identified using bivariate tests. Logistic regression analyses were performed to assess the relationship between predictors and ego HIV status when multiple variables were included in the same model. Overall, 219 participating women (69 HIV-positive, 150 HIV-negative) nominated 1095 alters. Compared to HIV-negative egos, HIV-positive egos were older, had main partners who were more likely to consume alcohol before sex, disclosed their HIV status to fewer alters, had fewer alters with whom they had daily interactions, and had more alters who were HIV-positive or HIV-unknown. Number of alters who were HIV-positive or HIV-unknown and non-disclosure of HIV status were the greatest risks (with the effect of HIV-positive or HIV-unknown being of a slightly greater magnitude than non-disclosure of HIV status), which places breastfeeding women, their partners and their infants at risk of preventable HIV infection.

Keywords: Social Network Analysis, HIV Prevention, Pregnancy, Sub-Saharan Africa, Zambia, Egocentric Networks

Introduction

The disproportionate impact of the HIV epidemic on pregnant and breastfeeding women involves various biological, social, behavioural, cultural, economic and structural elements [1-3]. In sub-Saharan Africa (SSA), women face constraints on the navigation of sexual safety, and factors operating across the socioecological arena at multiple levels (e.g., individual, partnership, peers and communities, societal) influence not only women's HIV vulnerability, but also that of their male partner [4,5]. Additionally, fear of stigma, loss of social capital, gender inequality, discrimination and

potential violent reactions causes many women in SSA to avoid HIV disclosure [6]. The disproportionate impact of HIV on pregnant and breastfeeding women is evident in urban populations in Zambia, where more than 60% of new HIV infections occur within marriage or cohabiting relationships [7]. Despite several programmatic efforts to address HIV risks, many of the influences on the risk behaviours of pregnant and breastfeeding women are poorly understood, leaving many women, their partners, and their infants at continued risk of acquiring HIV [8,9].

Behaviours perceived as normative within social networks are adopted by individuals to reinforce a sense of identity and belonging to a group [10]. Thus, social network analysis (SNA) may be useful in understanding the influences on pregnant and breastfeeding women's HIV protective behaviours and vulnerability. However, few have studied women's social and sexual networks during pregnancy and breastfeeding, or how these networks contribute to HIV risk, prevention and transmission.

Egocentric SNA is a methodological tool used to understand the structure, function, and composition of network ties around an individual. Egocentric sampling is designed for the collection of network data from the index individual (known as the ego) about the people in their social network (known as alters) without recruitment or direct observation of the alters. It is particularly useful for the collection of sensitive data regarding sexual behaviors, substance and alcohol use and gambling [11-13]. SNA generally can reveal how individual, behavioral, and social network factors influence engagement in risk behavior and specifically how such factors shape pregnant and breastfeeding women's HIV-related behaviors and beliefs [14-18].

In Zambia, as in much of SSA, accessing healthcare is considered a predominantly female domain, and it is therefore often challenging to recruit male study participants [19]. Taking a pragmatic view of this gender norm, we opted to use an egocentric approach to analyse pregnant/breastfeeding women's social networks to reveal previously unobservable links to HIV risk and protective behaviours, not only for the women themselves but also for the men in their networks. We hypothesized that a woman's social and sexual networks during pregnancy and breastfeeding contribute to continued HIV risk. In addition, we hypothesized that the patterns of relationships within the sexual networks of HIV-negative and HIV-positive women exhibit direct and indirect ties that affect HIV risk behaviour.

Materials and Methods

Site and Population

Study staff recruited pregnant and breastfeeding women attending mother and child health care visits at Chipata Level 1 Hospital, a government health facility run by the Lusaka District Health Office (LDHO) in Lusaka, Zambia. Serving a population of over 100,000, the mother and child clinic has an average of 400-450 new patients and 900-1000 return visits each month, and an HIV prevalence of ~15%. The study was conducted from December 2019 to March 2020. We planned to recruit a convenience sample of 300 participants similar to other published SNA studies however, due restrictions related to the COVID-19 pandemic, the study was terminated early [20,21].

Recruitment and Enrolment Procedures

Before study commencement, a community worker sensitized the women to the study through a series of morning talks at the study site. Study staff provided women interested in the study with information regarding the study requirements and a referral to the study clinic. The inclusion criteria were: ≥18 years of age, pregnant or breastfeeding, documented HIV status (either positive or negative) in the antenatal record within 30 days of study participation, reported at least one current sexual partner within the past six months, ability to name five men in their social circle, and willingness to provide informed consent. At time of screening, women who expressed concerns about intimate partner violence (IPV) or social harms resulting from participation were considered ineligible for the study. All participants provided written informed consent as per local guidelines.

Ethics

Study participants were fully informed of the study procedures, the risks and benefits, privacy and confidentiality and their right to withdraw or not participate in the study. The study was approved by the University of Zambia Biomedical Research Ethics Committee, the Zambian National Health Research Authority, the Lusaka District Health Office, and the University of North Carolina at Chapel Hill Institutional Review Board.

Data Collection Tools

To inform our study questionnaire, we conducted a thorough literature review of HIV risk factors for women in sub-Saharan Africa, of which the following were prioritised for further investigation: multiple concurrent sexual partners, transactional sex, dry sex, anal sex, polygamy, sex with older partners, fear of rejection, alcohol use and violence [22-28]. The literature review further revealed that in Zambia, only 41% of women use a condom when engaging in high-risk sexual practices, compared to 55% of the prevalence of alcohol consumption in pregnancy is 18.5% and an estimated 30% of women are intimate partner violence victims [7,29]. Adding to women's HIV risk is the unknown serostatus of their male partners, as men in SSA are less likely than women to utilize HIV testing services [30]. Compounding these issues is the fact that, for economic reasons, both men and women in SSA mobilize for employment, which creates further opportunities for sexual networking and is known to encourage high-risk sexual behaviour [31]. Thus, we included sections in the data collection instrument to elicit information regarding these known HIV risks.

Data Collection Tools

The data collection procedure consisted of two sections. First, due to the sensitive nature of many of our questions—and to ensure confidentiality of our participants—we utilised audio computer-assisted self-interview (ACASI) to collect non-network data similar to other studies [32,33]. The ACASI software was programmed using Kobo Toolbox (Harvard Humanitarian Initiative, Cambridge, MA, USA) and installed onto tablet computers. The survey included questions about participants, their main partners' sexual health, HIV status, alcohol use, number of partners and demographics. It took 15-30 minutes to complete. After informed consent was

obtained, participants were shown how to use the ACASI by a local research assistant. The computer displayed one question at a time and read the questions and responses to the participant in the language of their choice (English, Bemba, Nyanja) using associated M4A audio files pre-recorded by a female native speaker. The participant entered responses using the keyboard, mouse or touch screen. As a direct interviewer is not required to conduct an ACASI, a single staff member supervised multiple interviews simultaneously [34].

After completing the ACASI, information regarding the participants' sexual and social networks was collected using Ego Net 2.0™ software (Medical Decision Logic, Inc., Baltimore, MD). The participants entered their responses directly using a keyboard, mouse or touch screen [34]. Each participant (ego) provided the first name only of five men in her social network (alters) with whom she had had a friendship, familiar relationship, romantic relationship or sexual relationship over the past twelve months. Egos indicated the type of relationship they had with each alter named. They could choose one of the following categories: friend, husband, relative, sex client, someone who gives me money, someone who pays for my shelter, or father of my child. The ego then answered the following questions about each alter: age; if they are a migrant worker; if they provide financial support; if they provide advice about preventing HIV; if they have disclosed their HIV status; if they use ART or PrEP; and if she has had sex with the alter. Lastly, the ego answered questions about the relationships between her alters. It took 10-20 minutes to complete the ego network section of the data collection procedure. Upon completion of study activities, including the ACASI and ego network portions of the interview, participants received transport reimbursement (equivalent of $5 USD) in local currency.

Study Variables

The study dependent variable was ego HIV status, which was categorized according to the participant's antenatal card, where is it typically recorded. Independent variables were grouped into six categories: (1) ego sociodemographic characteristics; (2) main partner characteristics; (3) features of the relationship between ego and her main partner; (4) features of the relationships between alters and egos (i.e., alter-ego ties); (5) alter attributes; and (6) features of the relationships between alters (i.e., alter-alter ties).

Ego sociodemographic characteristics included age in years, ethnicity (Bemba, Nyanja, and Other), level of education (no schooling, some schooling, and completed secondary school), and whether ego was financially dependent on their main partner. Main partner characteristics included ego's main partner employment status (employed versus unemployed) and whether ego's main partner had been circumcised.

Four variables described the relationship between egos and their main partners. We considered whether ego's main partner had disclosed his HIV status to ego, whether ego's main partner used a condom for vaginal sex, and whether ego's main partner consumed alcohol before sex. We also included the degree to which ego trusted her main partner when he said he did not have sex with others, measured in a scale ranging from 0 (do not trust him at all) to 3 (trust him completely).

Alter-ego tie variables shed light on the relationships between egos and alters. These variables included nominating one or more relatives, the number of alters who were fathers of ego's children, the number of alters to whom egos had disclosed her HIV status, the number of alters with whom ego had daily interactions, and the number of occasional sexual partners (partners with whom ego had sexual relationships sometimes). In addition, we obtained the mean frequency of contact between ego and them alters using the item: "How frequently do you interact with [alter]? By that we mean talk to, spend time with" (once a year, every few months, monthly, weekly, or daily). We also considered the amount of support egos received from alters. Then, we averaged the responses obtained at the ego level. We also calculated a measure of support by combining responses to the items about financial support and advice: "Does [alter] provide you with advice about preventing HIV?" and "Do you rely on [alter] for financial support?" For each alter and item, responses were coded as not at all, sometimes, often, or all the time. Next, responses for each alter and item were summed per ego, resulting in a score at the ego level.

Four variables described alter attributes. First, we included the number of HIV-positive or HIV-unknown alters. A second variable described the ethnic similarity between ego and her alters: Krackhardt and Stern's external-internal (E-I) Index, which measures ego's propensity to have ties to alters with the same nominal characteristic, compared to the propensity to have alters with a different nominal characteristic [35]. The index ranges from −1 to +1 where −1 is completely homophilous (i.e., all alters are of the same ethnicity as ego) and +1 is completely heterophilous (i.e., all alters are ethnically different from ego). A third variable indicated whether ego had one or more sexual partners who were migrant workers. A fourth variable, the number of years between ego's and her sexual partners' age, captured age dissimilarity.

Finally, we included network density as a measure of the connectivity between alters. Network density is the number of ties among alters that are present in the network out of the possible number of ties if ego was connected to every other alter. In the present study, a tie between alters indicated they know each other. Appendix A presents a complete list of the variables included in the study, the interview items from which they were constructed, and the final coding utilized in the analyses. Variables were coded in order to maximize the differences between HIV-positive and HIV-negative egos while retaining variables with results greater than twenty per category.

APPENDIX A

Study variables			
Variable	**Item**	**Original response options**	**Final coding of responses**
Ego sociodemographics			
Ego age	How old are you?	Age in years	Age in years
Ego ethnicity	Which ethnic groups do you belong to?	Bemba (N = 77 - 35.16%) Nyanja (N = 121 - 55.25%) Tonga (N = 7 - 3.20%) Senga (N = 5 - 2.28%) Mambwe (N = 4 - 1.83%) Lozi (N = 1 - 0.46%) Ngoni (N = 3 - 1.37%) Ndebele (N = 1 - 0.46%)	Bemba Nyanja Other (includes Tonga, Senga, Mambwe, Lozi, Ngoni, and Ndebele) All respondents identified as part of only one ethnic group
Ego level of education	What is your current education level?	No school (N = 42 - 19.18%) Some primary school (N = 60 - 27.40%) Completed primary school (N = 22 - 10.05%) Some secondary school (N = 42 - 19.18%) Completed secondary school (N = 51 - 23.29 %)	No school Some schooling (includes some primary school, completed primary school, and some secondary school) Completed secondary school
Ego depends financially on partner	During the past 12 months, where did you get most of your money?	Employment (N = 57 - 26.03%) Family (N = 72 - 32.88%) Friends (N = 9 - 4.11%) Partner (N = 79 - 36.07%)	1 indicates ego obtains most of her money from partner, 0 otherwise
Main partner characteristics			
Main partner is employed	Please answer the following questions about your MAIN PARTNER… Is he employed?	Yes (N = 137 - 62.56%) No (N = 72 - 32.88%) I don't know (N = 7 - 3.20%)	Yes, No, NA (includes I don't know and NA)
Main partner has been circumcised	Please answer the following questions about your MAIN PARTNER… To the best of your knowledge, has this partner been circumcised?	Yes (N = 101 - 46.12%) No (N = 100 - 45.66%) I don't know (N = 11 - 5.02%)	Yes, No, NA (includes I don't know and NA)
Relationship between ego and main partner			
Main partner disclosure of HIV status to ego	Please answer the following questions about your MAIN PARTNER… Has he told you his HIV status?	Yes (N = 163 - 74.43%) No (N = 43 - 19.63%) I don't know (N = 0 - 0%)	Yes, No, NA (includes I don't know and NA)
Main partner uses condom during vaginal sex	Please answer the following questions about your MAIN PARTNER… Do you use a condom when you have vaginal sex with him?	Always (N = 22 - 10.05%) Sometimes (N = 81 - 36.99%) Never (N = 99 - 45.21%)	1 = sometimes or always 0 = never
Main partner consumes alcohol before sex	Please answer the following questions about your MAIN PARTNER… How often does he have a drink containing alcohol just before or during sex?	Always (N = 15 - 6.85%) Sometimes (N = 47 - 21.46%) Never (N = 154 - 70.32%)	1 = sometimes or always 0 = never

Ego trusts main partner	Please answer the following questions about your MAIN PARTNER… Do you trust him when he tells you he does not have sex with other people?	I do not trust him at all (N = 47 - 21.46%) I trust him some of the time (N = 47 - 21.46%) I trust him most of the time (N = 45 - 20.55%) I trust him completely (N = 55 - 25.11%)	Coded as a numeric scale: 0 = I do not trust him at all, 1 = I trust him some of the time, 2 = I trust him most of the time, 3 = I trust him completely.
Alter-ego tie variables			
One or more relatives	How would you describe your relationship with [alter]?	Friend (N = 525 - 47.95%) Husband (N = 175 - 15.98%) Relative (N = 308 - 28.13%) Sex client (N = 11 - 1.00%) Someone who gives me money (N = 5 - 0.46%) Someone who pays for my shelter (N = 1 - 0.09%) Father of my child (N = 75 - 6.85%)	1 = one or more alters are relatives 0 = none of ego's alters are relatives
Number of alters fathers of ego's children	How would you describe your relationship with [alter]?	Friend (N = 525 - 47.95%) Husband (N = 175 - 15.98%) Relative (N = 308 - 28.13%) Sex client (N = 11 - 1.00%) Someone who gives me money (N = 5 - 0.46%) Someone who pays for my shelter (N = 1 - 0.09%) Father of my child (N = 75 - 6.85%)	Number of alters who are fathers of ego's children.
Mean frequency of contact	How frequently do you interact with [alter]? By that we mean talk to, spend time with.	Daily (N = 329 - 30.05%) Weekly (N = 252 - 23.01%) Monthly (N = 228 - 20.82%) Every few months (N = 118 - 10.78%) Once a year (N = 173 - 15.80%)	For each alter, responses were coded as: 1 = once a year, 2 = every few months, 3 = monthly, 4 = weekly, 5 = daily. Then, an average was calculated at the ego level
Number of alters with whom ego has daily interactions	How frequently do you interact with [alter]? By that we mean talk to, spend time with.	Daily (N = 329 - 30.05%) Weekly (N = 252 - 23.01%) Monthly (N = 228 - 20.82%) Every few months (N = 118 - 10.78%) Once a year (N = 173 - 15.80%)	Number of alters with whom interactions occur daily.
Support (sum of advice and financial support scores)	Does [alter] provide you with advice about preventing HIV? Do you rely on [alter] for financial support?	Not at all (N = 584 - 53.33%) Sometimes (N = 297 - 27.12%) Often (N = 123 - 11.23%) All the time (N = 96 - 8.77%) Not at all (N = 672 - 61.37%) Sometimes (N = 249 - 22.74%) Often (N = 59 - 5.39%) All the time (N = 120 - 10.96%)	For each alter and item, responses were coded as: 1 = not at all, 2 = sometimes, 3 = often, 4 = all the time. Then, responses for each alter and item were summed per ego, resulting in a score at the ego level.

Number of alters to whom ego has disclosed HIV status	Have you disclosed your current HIV status to [alter]?	Yes (N = 465 - 42.47%) No (N = 620 - 56.62%) I don't know (N = 15 - 1.37%)	Yes, No, NA (includes I don't know and NA)
Number of "sometimes" sexual partners	Do you have sex with [alter]?	Always (N = 169 - 15.43%) Sometimes (N = 162 - 14.79%) Never (N = 769 - 70.23%)	Number of "sometimes" sexual partners
Alter attributes			
Number of HIV-positive or HIV-unknown alters	Is [alter] HIV-positive? Is [alter] HIV-negative?	Yes (N = 86 - 7.85%) No (N = 503 - 45.94%) I don't know (N = 511 - 46.67%) Yes (N = 458 - 41.83%) No (N = 37 - 3.38%) I don't know (N = 605 - 55.25%)	Number of alters identified by the respondent as HIV-positive or HIV-unknown. Alters about whom ego provided inconsistent responses (e.g., "yes" to both items or "no" to both items) are coded as "unknown."
E-I based on ethnicity	Which ethnic groups does [alter] belong to?	Bemba (N = 353 - 32.24%) Nyanja (N = 368 - 33.61%) Tonga (N = 113 - 10.32%) Senga (N = 100 - 9.13%) Mambwe (N = 71 - 6.48%) Lozi (N = 47 - 4.29%) Ngoni (N = 31 - 2.83%) Ndebele (N = 17 - 1.55%)	Number of alters of ethnicity different from ego (external ties) minus the number of alters of the same ethnicity as ego (internal ties), divided by the total number of alters. All respondents mentioned only one ethnic group per alter.
One or more sexual partners are migrant workers	Is [alter] a migrant worker?	Yes (N = 209 - 19.09%) No (N = 843 - 76.99%) I don't know (N = 48 - 4.38%)	One or more sexual partners (i.e., alters with whom ego has sexual relationships sometimes or always) identified as migrant workers
Euclidean distance between ego's and sexual partners' age	How old is [alter]?	Age in years	For each alter identified as a sexual partner (i.e., an alter with whom ego has sexual relationships sometimes or always), we obtain the mean of squared differences between ego's age and each alters' age.
Alter-alter ties			
Network density	Think about the relationship between [alter] and [alter]. Which of the following would describe how they know one another?	Friends Relatives Know each other ONLY because they know me Work together Know each other by name Know each other by sight Do not know each other	Number of ties out of possible ties. We do not distinguish between types of ties because exploratory analyses revealed the number of ties per type of tie are very similar for HIV-positive and HIV-negative egos.

Analytical Strategy

In this exploratory study, we started by identifying associations between the dependent variable (ego HIV status) and six sets of independent variables, grouped according to the six categories previously described. To identify associations, we conducted bivariate tests between ego HIV status and each independent variable individually. Test statistics included the Wilcoxon-Mann-Whitney test for interval or ordinal variables and chi-square test for categorical variables.

We conducted logistic regression analyses to assess the relationship between predictors and ego HIV status when multiple variables were included in the same model. Because bivariate analyses of the relationships between predictors suggested the presence of collinearity, we did not include all predictors in the logistic regression models [35]. To reduce multicollinearity and promote a par-

simonious specification, we narrowed the set of predictors based on: (1) the magnitude of the observed differences in the variable by ego HIV status (using the bivariate tests mentioned above); and (2) the variable's substantive relevance as suggested from previous empirical work.

We fitted logistic regression models using a sequential approach, wherein we examined the association between five sets of variables (e.g., ego sociodemographic characteristics, main partner characteristics) and ego HIV status separately to assess relationships when other types of variables were excluded from the model. Final models included independent variables from all five sets to assess the unique contribution of each variable with all other sets of predictors present in the model. Two variables strongly associated with ego HIV status were collinear (number of alters to whom ego has disclosed her HIV status and number of HIV-positive or HIV-unknown alters). Therefore, we fitted two final regression models reported here, each including one of the two collinear variables and all other independent variables. We displayed all logistic regression analysis results using odds ratios (ORs) and 95% confidence intervals. We also calculated variance inflation factors for every model to identify any remaining issues of multicollinearity.

Results

Of the 219 women enrolled, 69 (31.5%) were HIV-positive and 150 (68.5%) were HIV-negative. All participants nominated five men as alters, for a total of 1095 alters. Table 1 presents sample characteristics by ego HIV status and in the whole sample. The mean age of the participants was 26, over 90% of women identified as either Nyanja or Bemba, 56% had some schooling, and 36% were financially dependent on their main partner.

Bivariate Results

Table 1 presents bivariate associations between predictors and ego HIV status. Results indicate HIV-positive egos were, on average, older than HIV-negative egos. In addition, the main partners of HIV-positive egos were more likely to consume alcohol before sex. HIV-positive egos tended to disclose their HIV status to fewer alters compared with HIV-negative egos. HIV-positive egos had fewer alters with whom they had daily interactions and tended to have more alters who were HIV-positive or whose HIV status was unknown. The networks of HIV-positive egos tended be more heterophilous in terms of ethnicity. Finally, HIV-positive egos tended to be more dissimilar to their sexual partners in terms of age when compared to HIV-negative egos.

Table 1: Bivariate Differences between HIV-positive and HIV-negative egos

	Overall		HIV Positive		HIV Negative		p-value*	
	N/Mean	Proportion	N	Proportion/ Mean	N	Proportion/ Mean		
Total	219	100%	69	31.51%	150	68.49%		
Sociodemographic characteristics								
Ego age	26.45			28.1		25.7	0	**
Ego ethnicity								
Bemba	77	35.16%	22	31.88%	55	36.67%	0.48	
Nyanja	121	55.25%	42	60.87%	79	52.67%		
Other	21	9.59%	5	7.25%	16	10.67%		
Ego level of education								
No schooling	42	19.18%	18	26.09%	24	16.00%	0.19	
Some schooling	124	56.62%	38	55.07%	86	57.33%		
Completed secondary school	51	23.29%	13	18.84%	38	25.33%		
Ego depends financially on partner	79	36.07%	29	42.03%	50	33.33%	0.310	
Main partner characteristics								
Main partner is employed	137	62.56%	42	60.87%	95	63.33%	0.66	
Main partner has been circumcised	153	69.86%	28	40.58%	73	48.67%	0.510	
Relationship between ego and main partner								

Main partner disclosure of HIV status to ego	163	74.43%	47	68.12%	116	77.33%	0.25	
Main partner uses condom during vaginal sex	103	47.03%	37	53.62%	66	44.00%	0.24	
Main partner consumes alcohol before sex	62	28.31%	27	39.13%	35	23.33%	0.02	*
Ego trusts main partner	1.56			1.32		1.66	0.11	
Alter-ego tie variables								
One or more relatives	130	59.36%	35	50.72%	95	63.33%	0.11	
Number of alters fathers of ego's children	0.34			0.38		0.33	0.95	
Mean frequency of contact	3.40			3.28		3.46	0.08	
Number of alters with whom ego has daily interactions	1.50			1.28		1.60	0.01	*
Support (sum of advice and financial support scores)	1.42			1.45		1.41	0.63	
Number of alters to whom ego has disclosed HIV status	2.15			1.66		2.37	0	**
Number of "sometimes" sexual partners	0.42			0.46		0.40	0.180	
Alter attributes								
Number of HIV-positive or HIV-unknown alters	2.93			3.99		2.45	<0.001	***
E-I based on ethnicity	0.23			0.40		0.16	0.01	**
One or more sexual partners are migrant workers	60	27.40%	16	23.19%	44	29.33%	0.43	
Euclidean distance between ego's and sexual partners' age	5.82			6.53		5.48	0.04	*
Alter-alter ties								
Network density	0.47			0.44		0.48	0.28	

* Wilcoxon-Mann-Whitney test statistic was calculated for interval or ordinal variables; Chi-square test was calculated for categorical variables. *$p < 0.05$; ** $p < 0.01$; ***$p < 0.001$

Logistic Regression Models

Table 2 presents results from logistic regression models on ego HIV status. Models 1-5 show results from separate regression models for each of five sets of variables in the study. Models 6a and 6b are final models. Model 6a includes number of HIV-positive or HIV-unknown alters and excludes number of alters to whom ego had disclosed her HIV status. Model 6b includes number of alters to whom ego had disclosed her HIV status and excludes number of HIV-positive or HIV-unknown alters.

Results shown in Table 2 indicate consistency in the magnitude, direction, and confidence intervals for most estimates across models. We centred our description of results on the associations with the lowest observed p-values. Results indicated that as ego age increased, so too did the estimated odds of being HIV-positive (OR = 1.09, $p < 0.01$; Model 1). Nonetheless, the relationship between ego age and being HIV-positive did not attain statistical significance in the full models. That the ego ages did not attain statistical

significance in the full models was not surprising: ego ages' ORs were close to 1.00 across models and the increase of parameters in the full model resulted in a loss of precision.

Findings shown in Table 2 also suggest women whose main partners consumed alcohol before sex were more than twice as likely to be HIV-positive compared to women whose main partners did not consume alcohol before sex (OR = 2.20, $p < 0.05$, Model 3; and OR = 2.25, $p < 0.05$, Model 6b). Main partner's alcohol consumption did not remain statistically significant in the full model that included number of HIV-positive or HIV-unknown (Model 6a). However, the magnitude, direction and confidence intervals for main partner's alcohol consumption were approximate across models. Figure 1, Panel A presents the predicted probability (estimated using Model 6b) of being HIV-positive when ego's main partner consumed and did not consume alcohol before sex. Women whose main partners consumed alcohol before sex had a predicted probability of being HIV-positive of 56.3%, holding other variables at their means or reference categories. Meanwhile, women whose main partners did not consume alcohol before sex had a predicted probability of being HIV-positive of 36.3%, holding other variables at their means or reference categories.

Our findings also provide evidence of a negative association between the number of alters to whom ego disclosed her HIV status and being HIV-positive: the more alters cognizant of ego HIV status, the smaller the odds of ego being HIV-positive (OR = 0.72, $p < 0.01$, Model 4; and OR = 0.66, $p < 0.01$, Model 6b). Figure 1, Panel B plots the predicted probability, estimated using Model 6b, of being HIV-positive as the number of alters to whom ego disclosed her HIV status increased. Women who had not disclosed their HIV status to any of them alters had a predicted probability of being HIV-positive equal to 57.5%, holding all other variables at their means or reference categories. By contrast, the probability of being HIV-positive was 15.4% for women who had disclosed their HIV status to all five of their nominated alters, holding all other variables at their means or reference categories.

Finally, we observed increases in the odds of being HIV-positive for egos with a greater number of HIV-positive or HIV-unknown alters (OR = 2.22, $p < 0.001$, Table 2, Model 1; and OR = 2.30, $p < 0.001$, Model 6a). Figure 1, Panel C shows predicted probabilities (using Model 6a) of being HIV-positive at different numbers of alters who are HIV-positive or HIV-unknown, while holding all other variables at their means or reference categories. The predicted probability of being HIV-positive was 3.8% for women with five HIV-negative alters compared to 71.7% for women with five HIV-positive or HIV-unknown alters, holding all other variables at their means or reference categories.

Table 2: Logistic regression of HIV Status On Ego and Network Characteristics

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6a	Model 6b
	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)
Ego Sociodemographics							
Ego age	1.09 (1.03 - 1.16)**					1.05 (0.98 - 1.14)	1.07 (1.00 - 1.15)
Ego level of education (reference: No school)							
Some schooling	0.54 (0.25 - 1.16)					0.75 (0.29 - 1.98)	0.57 (0.23 - 1.41)
Completed secondary school	0.43 (0.17 - 1.06)					0.49 (0.16 - 1.49)	0.52 (0.18 - 1.47)
Ego depends financially on partner	1.24 (0.66 - 2.29)					1.00 (0.46 - 2.12)	0.85 (0.41 - 1.74)
Main partner characteristics							
Main partner has been circumcised		0.78 (0.42 - 1.42)				0.80 (0.38 - 1.68)	0.88 (0.44 - 1.77)
Relationship between ego and main partner							
Main partner consumes alcohol before sex			2.20 (1.18 - 4.09)*			2.18 (1.00 - 4.82)	2.25 (1.07 - 4.76)*
Alter-ego tie variables							
Number of alters to whom ego has disclosed HIV status				0.72 (0.58 - 0.89)**			0.66(0.51 - 0.85)**
Alter attributes							

Number of HIV-positive or HIV-unknown alters					2.22 (1.73 - 2.94)***	2.30 (1.75 - 3.14)***	
One or more sexual partners who migrant workers					0.57 (0.27 - 1.18)	0.68 (0.29 - 1.55)	0.79 (0.34 - 1.75)
Constant	0.07 (0.01 - 0.36)**	0.49 (0.32 - 0.74)***	0.35 (0.24 - 0.50)***	0.85 (0.52 - 1.39)	0.04 (0.01 - 0.10)***	0.01 (0.00 - 0.10)***	0.23 (0.03 - 1.76)
N	215	201	216	208	219	194	184
Null deviance	269.85	246.74	267.52	256.77	272.92	238.36	222.73
Residual deviance	256.03	246.08	261.33	246.92	221.22	181.45	200.77

Notes: Results presented in odds ratios. Variance inflation factors (VIF) were calculated to determine the presence of moderate multicollinearity. All VIFs were below 1.5. *p < 0.05; ** p < 0.01; ***p < 0.001

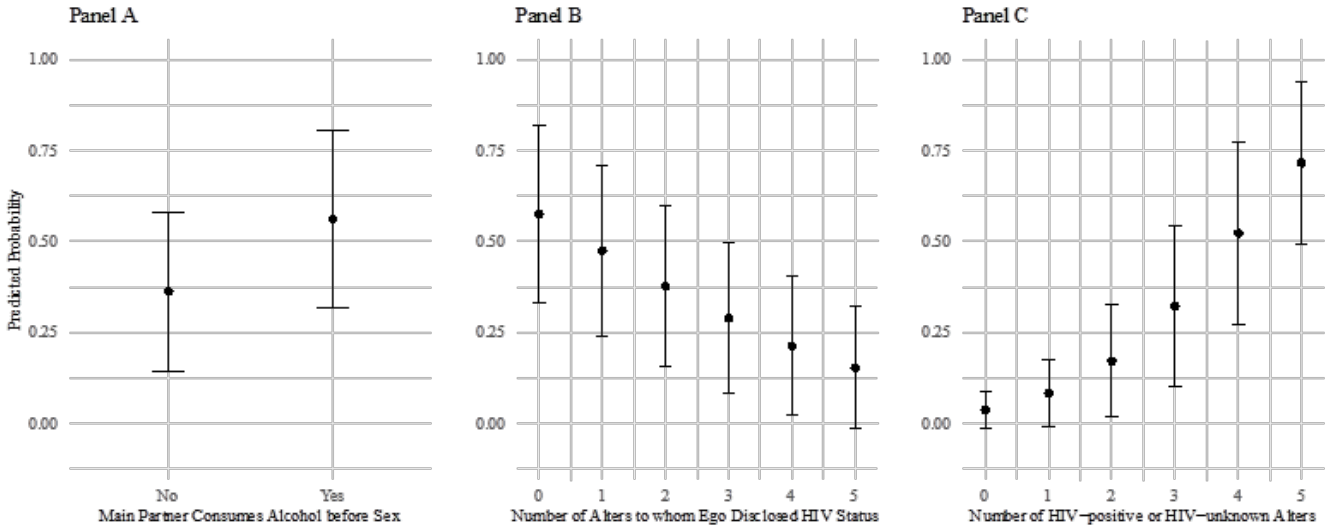

Figure 1: Predicted probabilities and 95% prediction intervals of being HIV-positive as a function of three variables: main partner alcohol consumption (Panel A), number of alters to whom ego has disclosed her HIV status (Panel B), and number of alters that are HIV-positive or HIV-unknown (Panel C). For each panel, all other variables are set at either their means (for continuous variables) or reference categories (for categorical variables). All predicted probabilities are estimated from full models. We use Model 6b in Table 2 for panels A and B and Model 6a in Table 2 for panel C.

Discussion

Our findings reveal differences in known HIV risk and protective factors between HIV-negative and HIV-positive pregnant and breastfeeding women. Protective factors including higher education, partner circumcision and disclosure of HIV status to partners were higher in HIV-negative women. However, risk factors including sex partners who are migrant workers, condom less and dry sex, a belief that partners have sex with men and lack of trust in partner were high in HIV-negative women. Condom use was low among all the women in this study and there was no significant association between education or sexual partners outside marriage and condom use (see Table S2 of supplemental data). In Zambia a number of factors resulting from gender inequity make it difficult for women to insist on condom use and may contribute to the low condom use found in our study [36]. Additionally, the social norm that condom use is considered unnecessary within marriage or when a woman is pregnant may also have influenced this result.

The risk of HIV acquisition among the sexual partners of HIV-positive study participants was potentially exacerbated due to the lack of HIV status disclosure and the use of alcohol during sex observed in this cohort. Previous studies in SSA have shown a low rate of disclosure of HIV serostatus to sexual partners and decreased condom use among users of alcohol [37]. HIV-positive participants in our study reported stigma associated with their serostatus as evidenced by lower rates of disclosure of HIV status, fewer men who were relatives within their networks and more diversity in partners' ethnicity (meaning they chose sexual partners outside of their own tribe). Other studies in the region have also shown that HIV-positive women are more likely to choose to have sexual partners outside of their community in order to preserve their social capital and to reduce HIV-related stigma [38-40].

In Zambia, high levels of gossip within a community have been

found to decrease male testing rates for fear of community rejection [36]. Our study site was located at a level 1 hospital within a compound, where the community interact daily and rely upon one another for work, water and food, and our findings of non-disclosure of HIV status may reflect fear of being ostracised from the community.

Within the egocentric networks of both HIV-positive and HIV-negative participants, non-disclosure of HIV status was predominant. Similar to other studies in the region, concern regarding negative consequences linked to HIV disclosure (violence, abandonment, loss of social capital or income) may have been barriers to disclosure. Women who had disclosed their HIV status had reduced odds of being HIV-positive suggesting that finding ways to encourage women to disclose their HIV status will lead to positive health outcomes. Disclosure may be particularly crucial for pregnant women. During pregnancy, women are at considerably increased risk for HIV acquisition (male-to-female) and transmission (female-to-male). Without partner support, it is often difficult for women to adhere to recommended HIV treatment and breastfeeding regimens, behaviours that are necessary to reduce transmission of HIV to their infants, protect their own health, and ensure the health of their partner [41,42].

Limitations

These findings must be interpreted within the context of the study's limitations. First, participants were recruited solely from one clinic and may not represent pregnant and breastfeeding women residing in other regions. Residential instability is common among women in Zambia, making residential sampling challenging, and often convenience sampling at ANC clinics serving pregnant women is the only viable way to collect data from this population. Second, although we conducted a thorough literature review there may be domains that effect HIV risk and prevention that were missing. Third, due to the early closure of the study due to COVID-19 pandemic, the recruitment of HIV-positive women was lower than the HIV-negative group. It is possible there are greater differences between the groups than found in this study, a larger sample size may have revealed previously unobserved differences. Fourth, while the original study design included qualitative interviews to explore further the findings from the surveys, it was not possible to complete this portion of the study due to early closure. The qualitative study may have provided depth to understanding reasons why this cohort did not disclose their HIV status. Finally, data on alter behaviours and HIV status relied on the ego's perspective, a method used when, as in this case, the alters are difficult to access.

Conclusions

In an era of the Undetectable = Untransmissable (U=U) campaign and pre-exposure prophylaxis (PrEP), ways to assist women with safe disclosure of HIV status may improve not only their own health, but also the health of their partners and infants. Given the many obstacles to obtaining information to influence behaviour change, there is value in understanding both the prevention and risk potential within egocentric networks to inform efforts to design and implement behaviour change interventions. This study provides some evidence that non-disclosure of HIV status occurs among the networks of both HIV-negative and HIV-positive pregnant and breastfeeding women. Further research is needed to inform strategies to improve HIV disclosure within complex social networks.

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