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Short Communication

Population sexual behavior and HIV prevalence in Sub-Saharan Africa: missing links?

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SUMMARY

Objectives: Patterns of sexual partnering should shape HIV transmission in human populations. The objective of this study was to assess empirical associations between population casual sex behavior and HIV prevalence, and between different measures of casual sex behavior.
Methods: An ecological study design was applied to nationally representative data, those of the Demographic and Health Surveys, in 25 countries of Sub-Saharan Africa. Spearman rank correlation was used to assess different correlations for males and females and their statistical significance.
Results: Correlations between HIV prevalence and means and variances of the number of casual sex partners were positive, but small and statistically insignificant. The majority of correlations across means and variances of the number of casual sex partners were positive, large, and statistically significant. However, all correlations between the means, as well as variances, and the variance of unmarried females were weak and statistically insignificant.
Conclusions: Population sexual behavior was not predictive of HIV prevalence across these countries. Nevertheless, the strong correlations across means and variances of sexual behavior suggest that self-reported sexual data are self-consistent and convey valid information content. Unmarried female behavior seemed puzzling, but could be playing an influential role in HIV transmission patterns.

1. Introduction

Sexually transmitted infections (STIs), including HIV, propagate through sexual contact. The patterns of sexual partnering and structure of sexual networks should shape STI transmission.[1] Mathematical modeling studies have affirmed and clarified this assertion.[2–5] It has been shown that measures of HIV infection, such as the basic reproduction number (R_0), epidemic size, and HIV prevalence, as well as network statistics such as concurrency, are associated with the mean and variance of the number of sexual partners.[2–5] For example,

$$R_0 \propto \mu + \sigma^2/\mu, \quad (1)$$

where μ is the mean and σ^2 is the variance.[2] Given the close link between R_0 and HIV prevalence, similar equations can be derived, using mathematical models, for the relationship between HIV prevalence and the mean and variance of the number of partners.

Although the theoretical links between population behavior and STI epidemiology are well established, there is a question as to whether such predicted associations can be observed empirically. Concerns about the validity of self-reported sexual data pose a predicament in the use of population behavior data to interpret or predict STI transmission patterns.[6–8]

Against this background, the behavior–epidemic link was examined through an ecological study design, by analyzing empirical data on HIV infection and casual sex behavior, defined here as any reported sex between a man and a woman outside the context of marriage or cohabitation. This was done for 25 countries in Sub-Saharan Africa (SSA), the region most affected by HIV, and using nationally representative data, those of the Demographic and Health Surveys (DHS).[9] Two questions were addressed: (1) Are mean and variance of the number of casual sex partners associated with HIV prevalence across SSA? (2) Are self-reported casual sex data internally consistent to convey credible information content?

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2. Methods

Countries were included based on the availability of DHS HIV serological survey data.[9] Informed by an analysis of casual sex partners over the last 12 months,[10] the mean and variance of casual sex partners stratified by marital status (married/unmarried) and sex (male/female), in addition to HIV population prevalence, were investigated. Spearman rank correlation was used to assess different correlations. p-Values were calculated using the permutation exact test, and significance was set at $p < 0.05$. 95% Confidence intervals (CI) were calculated using bootstrapping. All analyses were carried out using Stata SE 13.0 and R version 3.1.1 software.

3. Results

Table 1 shows the calculated correlations. Correlations between HIV prevalence and means and variances of the number of casual sex partners were positive, but small (<0.5) and statistically insignificant. The correlations with the mean for unmarried females ($p < 0.05$, but with bootstrap CI overlapping with zero), and the mean and variance for unmarried males ($p = 0.05$), were of borderline significance. All correlations between HIV prevalence and mean + variance/mean of partners (note Equation 1) were also small (<0.5) and statistically insignificant.

In contrast, the majority of correlations across means and variances of casual sex partners were positive, large (≥0.5), and statistically significant. Correlations between the different means were positive, very large (>>0.5), and statistically significant. Correlations between the different variances were positive, large, and statistically significant apart from those with the variance of unmarried females. Correlations between means and variances were also positive, large, and statistically significant, again with the exception of those with the variance of unmarried females. All correlations between the means, as well as variances, and the variance of unmarried females were weak (~0) and statistically insignificant.

4. Discussion

Population casual sex behavior, defined as sex outside marriage or cohabitation, was not predictive of HIV prevalence. Contrary to theoretical predictions (such as Equation 1), and what is expected for an STI, HIV prevalence was not correlated with casual sex means or variances. This finding casts doubt on the validity of self-reported sexual data, or their utility to understand STI patterns. It affirms a volume of evidence indicating limitations to self-reported sexual data.[8]

Nevertheless, the strong correlations observed across casual sex means and variances suggest the opposite conclusion – that self-reported sexual data are inherently self-consistent and convey credible information content. As expected in a sexual network, the means and variances in a given population stratum (say females) were found to be correlated with those in other strata (say those of males).

These paradoxical findings may be reconciled considering that the link between sexual behavior and STI risk of exposure is subtle and complex. Data, such as number of partners, may have valid information, but cannot capture the complexity of sexual behavior or STI dynamics. Research is needed to identify the type of data that can best summarize sexual networking and predict STI risk of

Table 1
Associations between HIV prevalence and self-reported population casual sex behavior, and between different measures of casual sex behavior. Calculated correlations between country-specific HIV prevalence and country-specific means and variances of the number of casual sex partners over the last 12 months stratified by marital status and sex. The table also includes correlations between the different country-specific means of number of casual sex partners, between the different country-specific variances of casual sex partners, and between the country-specific means and variances of casual sex partners. Spearman rank correlation was used and statistical significance was set at $p < 0.05$[a]

	Married males		Unmarried males		Married females		Unmarried females		HIV prevalence
	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean
Married males									
Mean		0.76* (0.48, 0.91)	0.87* (0.68, 0.95)	0.73* (0.36, 0.95)	0.79* (0.55, 0.91)	0.58* (0.16, 0.88)	0.80* (0.59, 0.90)	0.09 (−0.38, 0.60)	0.32 (−0.06, 0.61)
Variance			0.52* (0.13, 0.80)	0.67* (0.25, 0.93)	0.54* (0.18, 0.76)	0.48* (0.01, 0.82)	0.32 (−0.10, 0.67)	−0.07 (−0.51, 0.44)	0.05 (−0.36, 0.46)
Mean + variance/mean									−0.26 (−0.62, 0.18)
Unmarried males									
Mean				0.69* (0.34, 0.90)	0.62* (0.28, 0.84)	0.44* (0.01, 0.78)	0.89* (0.74, 0.95)	0.05 (−0.39, 0.56)	0.38 (−0.04, 0.65)
Variance					0.60* (0.24, 0.86)	0.46* (0.00, 0.83)	0.56* (0.18, 0.81)	0.10 (−0.37, 0.59)	0.38 (0.00, 0.67)
Mean + variance/mean									0.16 (−0.22, 0.51)
Married females									
Mean						0.86* (0.61, 0.98)	0.70* (0.37, 0.89)	0.09 (−0.34, 0.54)	0.20 (−0.24, 0.57)
Variance							0.52* (0.14, 0.80)	0.24 (−0.22, 0.66)	0.15 (−0.30, 0.54)
Mean + variance/mean									0.11 (−0.30, 0.52)
Unmarried females									
Mean								0.13 (−0.33, 0.60)	0.40* (−0.04, 0.69)
Variance									0.081 (−0.40, 0.52)
Mean + variance/mean									−0.10 (−0.53, 0.36)

[a] Note: The numbers in brackets denote the bootstrapped 95% confidence intervals for the correlation coefficients.
* Denotes a statistically significant correlation ($p < 0.05$).

exposure. Further data analyses may also suggest novel methodologies to extract better information content from the data.

Unmarried female behavior is puzzling. The mean for unmarried females was the only behavioral measure associated with HIV prevalence ($p < 0.05$). Ironically, variance for unmarried females was also the only behavioral measure that correlated poorly with the rest of the behavioral measures. It is speculated that these results may imply an influential role for unmarried females in STI dynamics and global patterns. Unmarried female behavior can amplify heterogeneity in male behavior; males seem globally to behave more similarly than females,[10] leading to higher sexual network connectivity. These results also suggest that variance for unmarried females is a poorly captured measure in surveys, possibly reflecting under-reporting.[11,12]

Three sensitivity analyses were conducted to assess the robustness of findings (not shown). The correlations were calculated (1) including both spousal and casual partners, (2) using model-estimated means and variances (based on a recent methodology[10]), and (3) using a less stringent cut-off for significance ($p < 0.1$). These analyses confirmed our findings.

Other factors may contribute to the lack of observed association between sexual behavior measures and HIV prevalence. The existence of the association is predicted based on mathematical models of HIV transmission, and different models may have different predictions for the nature of this association. The association could also be affected by temporal factors; HIV prevalence may correlate with earlier sexual behavior rather than recent behavior. However, the association was investigated at the same time point. Investigating the association at different time points may contribute to explaining the lack of observed association between current sexual behavior and current HIV prevalence.

In conclusion, self-reported population sexual behavior was not found to be predictive of HIV prevalence, but appeared inherently self-consistent and with valid information content. Unmarried female behavior appears to play an influential role in STI transmission patterns.

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Authors' contributions: RO conceived the study and performed the analyses. LJA led the conception and performance of the study. Both authors contributed to the interpretation of results and writing of the manuscript.

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