Testing the concurrency hypothesis: an analysis of partnership concurrency and HIV incidence among married couples in two population-based cohort studies in rural Uganda

Elizabeth Sully
Office of Population Research & Woodrow Wilson School of Public and International Affairs, Princeton University

Fred Nalugoda
Rakai Health Sciences Program

Kenneth Ekoru
Medical Research Council / Uganda Virus Research Institute

Tom Lutalo
Rakai Health Sciences Program

Georges Reniers
Department of Population Health, London School of Hygiene and Tropical Medicine

Janet Seeley
Medical Research Council / Uganda Virus Research Institute
Department of International Development, University of East Anglia
Abstract:
Concurrent partnerships are often considered a primary driver of the HIV epidemic in Sub-Saharan Africa. Due to data constraints, however, few studies have been able to demonstrate its effect using empirical data. In this paper, we test whether HIV transmission rates are higher for individuals with concurrent partners - an effect that is ascribed to the higher viral load shortly after seroconversion. Data spanning a 14-year time period are used from two rural community sero-surveillance sites in south-Western Uganda. Sero-concordant negative married couples are followed over time, examining the risk of seroconversion for couples exposed to concurrency. A discrete-time logit model is used to determine the risk of seroconversion among women whose husbands reported a concurrent partnership.

Acknowledgements:
We would like to extend our thanks to the survey, data and statistics teams of the MRC/UVRI General Population Cohort Study (GPC) and the Rakai Health Sciences Program Rural Community Cohort Study (RCCS). We would also like to thank all of the respondents of the GPC and RCCS for their time and participation in the survey. This study was made possible with financial support from an NICHD Center Grant to the Office of Population Research at Princeton University (R24HD047879).

Correspondence:
Elizabeth Sully, Office of Population Research, 284 Wallace Hall, Princeton University, Princeton, NJ, 08544. esully@princeton.edu
Extended Abstract

Previous research has suggested that concurrent partnerships are a primary driver of the HIV epidemic in Sub-Saharan Africa. Concurrency is defined as two overlapping sexual partnerships, where sex with one partner falls in between two acts of intercourse with another partner (UNAIDS Reference Group on Estimates Modelling and Projections: Working Group on Measuring Concurrent Sexual Partnerships 2010). The theory holds that the overlap in partnership timing drives higher HIV rates due to the increased risk of HIV transmission immediately following seroconversion. The viral load, which determines infectiousness, peaks in the first few months following seroconversion (Boily et al. 2009; Wawer et al. 2005). In concurrent partnerships, individuals are quite likely to have sex during the highly infectious early phase of the disease, and to transmit the virus to a sero-negative partner. Models suggest that the risk of transmission is reduced in serial monogamy, as the likelihood of coitus with new partners during the highly infectious window is lower.

An important, yet often misunderstood repercussion of partnership concurrency is that it only affects the probability of transmitting HIV, not the probability of acquiring HIV (Morris 2001). An individual who takes on a new partner may be at an increased risk of acquiring HIV, but this risk is not affected by the timing of the partnerships. The concurrency effect is about how the overlap in timing of partnerships makes the individual engaging in concurrency more likely to pass the virus on to their other partners. In other words, the concurrency hypothesis predicts a positive correlation between the index case’s concurrency and the HIV status of their partners (but not their own HIV status). This last point has important methodological implications because it means that individual-level ego-centered studies of HIV risk factors
cannot detect individual-level concurrency effects, and these are precisely the most commonly available type of data sources. Current attempts to empirically test the concurrency hypothesis have been unsuccessful due to the lack of data on linked partnerships and HIV incidence over time. In this paper we overcome both limitations by comparing HIV incidence among spouses of men who report extra-spousal partnerships and those that do not. This paper will be the first empirical test of the concurrency hypothesis at the individual level that meets these data requirements.

Determining the effect of concurrency has two important implications for HIV research and policy. First, previous research has shown that one’s partner’s infidelity, one form of concurrency in marriage, greatly contributes to one’s perceived risk of HIV (Anglewicz and Kohler 2009), and is associated with an increase risk of separation and divorce as a strategy to avoid the perceived risk from infidelity (G. Reniers 2008). There is a disconnect, however, between perceptions of risk and research that measures what this risk actually is. This paper fills this gap by measuring the effect of concurrency, and whether the perceptions of high risk are warranted. Second, measuring the effect of concurrency is important for HIV prevention policy in helping to determine whether emphasis should be placed on the number of partnerships, or whether timing of partnerships is important, as concurrency would suggest.

*Background*

Even though the concurrency hypothesis has intuitive appeal and the mathematical models are very persuasive indeed, a considerable debate has evolved around the empirical evidence—or lack thereof (Halperin and Epstein 2004; Mah and Halperin 2009; Mah and Halperin 2010; Maas and Zijdeman 2010; Morris 2009; Lurie and Rosenthal 2009a; Lurie and Rosenthal 2009b;
Lagarde et al. 2001; Larry Sawers and Stillwaggon 2010; Georges Reniers and Watkins 2010). Using mathematical modeling, Morris and Kretzschmar (1997) were able to illustrate the effect of concurrency on epidemic size, suggesting that “concurrent partnerships are an important independent risk factor for HIV transmission.” The empirical evidence, however, has provided mixed results: Sawers and Stillwaggon (2010) reviewed 28 country and city estimates and highlighted the high variability in concurrency prevalence estimates depending on the method of data collection. Recent research by Tanser et al. (2011) examined the geographic relationship between men’s reported concurrency and the HIV-incidence of women within the same area and found no association. While advancing the empirical evidence against concurrency, the assumption that sexual partnerships primarily occur within the same geographic space limits the reliability of these findings. Other studies have critiqued the concurrency models assumptions, such as unrealistically high level of coital frequency occurring with each (concurrent) partner, arguing instead a coital dilution effect may in large part compensate for the elevated transmission rates in concurrent partnerships (Sawers, Issac, and Stillwaggon 2011; Reniers and Tfaily 2012; Gaydosh, Reniers, and Helleringer 2013).

The debate around the concurrency hypothesis has been obfuscated due to discord on what constitutes a proper test of the concurrency hypothesis. There are two main areas that give rise to this confusion: (1) prevalence versus incidence, and (2) index versus alter respondents. In the first instance, most studies have relied on cross-sectional data at both the individual and country level to determine associations between concurrency and HIV prevalence. HIV prevalence captures cumulated exposure of a population prior to the survey, while concurrency is usually measured at the time of the interview, or 6 months prior. Moreover, the risk of concurrency operates via increased transmission of the virus, which is best captured by
measuring HIV incidence. To the second point, studies that do have HIV incidence data often focus on an index respondent’s reported concurrent partnerships. Index respondent incidence data only allow for the measurement of HIV acquisition, which will most likely be higher due to the increase in the number of sexual partners the index respondent now has. Linked partnership data is needed to evaluate HIV incidence in the alters of the index respondents who report concurrency.

One sexual network study was able to use linked partner data, and found an association between concurrency and sero-discordance, though the results were only cross-sectional and of a relatively small sample size (N=142) (Helleringer, Kohler, and Kalilani-Phiri 2009). Sero-discordance is also based on HIV prevalence, not incidence. Moreover, according to the concurrency hypothesis we could expect both partners to seroconvert within a short interval, making both partners sero-concordant positive, rather than sero-discordant.

In this paper we overcome the data limitations that have plagued previous studies by examining concurrency among married couples in a large population-based cohort in rural southwestern Uganda. Using extra-spousal partnerships as a measure of concurrency, as well as the UNAIDS suggested measure in one of the two samples, we examine men’s reports of concurrency and their wives’ HIV incidence over a 14-year period, starting in 1998. This is the first such study to overcome both data limitations, significantly advancing research on the concurrency hypothesis. The study will provide a test of the individual-level mechanisms the concurrency hypothesis proposes – that concurrent partnerships increase the likelihood of HIV transmission. We will not be able to test the population-level effect the concurrency hypothesis proposes, namely that concurrency creates a network structure that results in higher HIV risk.
Question and Hypotheses

To determine the effect of concurrency on HIV transmission this paper will answer the following two questions: (1) what is the risk of seroconversion for women in partnership episodes where husbands have concurrent partners? and (2) what percent of seroconversion in partnership episodes can be attributed to concurrency? The first question is focused on measuring the risk to an individual exposed to concurrency. However, even in the risk is low, concurrency may still account of a large portion of the seroconversions that are occurring within marriage.

We hypothesize that while concurrency will be common in marital partnerships, the HIV risk faced by women exposed to their husband’s concurrency will actually be quite small. Intuitively it seems that if the husband seroconverts, it would be likely that his wife would eventually seroconvert after repeated exposure to the virus. There are two reasons why this may not be the case, justifying the hypothesis the risk from concurrency is smaller than modeling studies have suggested.

First, the concurrency hypothesis’ proposed high risk is suggested to in part be the result of the high viral load following seroconversion. There is only a short three-month window in which transmission rates would be high. Depending on the frequency of coitus, exposure within this three-month widow may vary across partnerships. Following this three-month interval the viral load drops substantially. Continued exposure to an HIV positive partner may not result in the seroconversion of the negative partner in this longer interval with a lower viral load. Current research has found that sero-discordant partnerships account for only a small portion of sero-incident cases in a generalized HIV epidemic (Chemaitelly et al. 2012).

Second, it is possible that individuals in concurrent partnerships take precautionary measures that minimize the risk associated with concurrency or having multiple partners. Using
detailed partnership data in the RCCS we will also explore how coital frequency, circumcision, and condom use may mitigate exposure.

**Data**

The data come from a two rural community sero-surveillance surveys in South-Western Uganda: the General Population Cohort (GPC) study conducted by the Medical Research Council and the Uganda Virus Research Institute (MRC/UVRI), and the Rakai Community Cohort Study (RCCS) conducted by the Rakai Health Sciences Program (RHSP). The GPC and the RCCS are both open-cohort studies with longitudinal data on marital histories, linked partnerships, sexual behavior and HIV incidence. The GPC was established in 1989 and now covers 25 villages. We will be using a sub-sample of the GPC for which marital partnerships can be linked, providing a sample of 4,511 marriages from 2000-2009. The RCCS was established in 1994 and covers 50 villages with approximately 16,000 adults 15-49 years old. There are 12,349 linked partnerships in the RCCS sample.

To determine the effect of concurrency on HIV infection, we limit our data to a sample of married adults 15 years and older with linked partnership data. To isolate the effect of concurrency, sero-concordant positive and sero-discordant couples are removed from the sample. It is not possible to rule out non-concurrency related transmission among sero-discordant couples, and seroconversion has already occurred in sero-concordant positive couples. We therefore limit our sample to couples who are sero-concordant negative at first observation (the red box in Tables 1 and 2), providing a sample of 10,615 sero-concordant negative couples.
### Table 1: Couples sero-status at first observation in GPC (N=4511)

<table>
<thead>
<tr>
<th>Wife's Sero-Status</th>
<th>Husband’s Sero-Status</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>Negative</td>
<td>2408</td>
<td>114</td>
</tr>
<tr>
<td>Positive</td>
<td>94</td>
<td>106</td>
</tr>
<tr>
<td>Unknown</td>
<td>563</td>
<td>77</td>
</tr>
</tbody>
</table>

### Table 2: Sero-Status and sero-concordance at first observation in RCCS data (N=12,349)

<table>
<thead>
<tr>
<th>Wife’s Sero-Status</th>
<th>Husband’s Sero-Status</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>Negative</td>
<td>8207</td>
<td>435</td>
</tr>
<tr>
<td>Positive</td>
<td>468</td>
<td>561</td>
</tr>
<tr>
<td>Unknown</td>
<td>973</td>
<td>152</td>
</tr>
</tbody>
</table>

**Measuring Concurrency**

We use two measures of concurrency in this paper. First, concurrency is measured as any report of an extra-spousal partnership in the preceding 12 months. The main assumption of this measure is that all individuals who are married are engaging in coitus with their spousal partner. Lacking exact relationship duration and coital frequency information, this is the best measure available for this analysis. While this does not adhere to the recommended UNAIDS measure (see below) for concurrency, it serves as a close proximate measure among married individuals. This measure is used first as it can be constructed for both the GPC and the RCCS data.

The second measure of concurrency is the UNAIDS recommended definition, where sex with one partner falls between two acts of sex with another partner (UNAIDS Reference Group on Estimates Modelling and Projections. 2009). The RCCS has data on dates of first and last sex for up to four sexual partners in the last 12 months. This is used to calculate the cumulative prevalence of concurrency in the previous 1 year. This measure will be compared to the first measure that is common across both datasets, providing an important sensitivity test.

The concurrency hypothesis is about the timing of partnerships, rather than the quantity of partners. However, our measure of concurrency does not differentiate between individuals
with one or more extra-spousal partnerships. To take into account the effect of the number of partners, we do control in our models for lifetime number of sexual partnerships and number of partners in the previous 12 months. We also test the sensitivity of our measure of concurrency to the inclusion and exclusion of formal concurrency in polygynous unions.

We only look at seroconversions that occur in the year of the reported concurrency and in the subsequent year as we do not know when in the interval concurrency occurred. Between these measures, we should be capturing the three-month period of elevated viral loads. Figure 1 highlights in red the seroconversion trajectories that would indicate concurrency-related seroconversion in couples.

Figure 1: Seroconversion trajectories that would indicate concurrency-related seroconversion among couples exposed to concurrency (red).
The Comparison Group

This analysis measures the risk of concurrency by comparing HIV acquisition in wives whose husbands do and do not have concurrent partnerships. The ideal test of the concurrency hypothesis would compare concurrent to sequential partners to measure the effect of partnership timing. However, we only have linked partnership data for married couples. We do not have a sample of sequential partnerships with which to compare the concurrent partnerships. Assuming continued coitus during marriage, any new partner among married individuals is considered concurrent.

Comparing sero-concordant negative couples that are and are not exposed to concurrency is also problematic. Assuming sexual intercourse is the only pathway for exposure among married couples, couples not reporting concurrency would have a risk of 0. To address this issue, the unit of analysis will not be couples, but partnership episodes. Of the sample initially sero-concordant negative, it is possible that the husband seroconverts after taking on concurrent partners, but the wife does not seroconvert in time t or t+1. If the husband is no longer engaging in concurrency in future years, the wife may still seroconvert in subsequent years. A partnership episode is therefore define as a husband's reported concurrency, or lack thereof, at time t and the seroconversion of wives at time t and time t+1. Using partnership episodes for analysis, one couple could contribute multiple episodes, only some of which report concurrency. With this method, the incidence in the non-exposed group is no longer 0.

Seroconversions within marriage will also occur among couples that start off sero-discordant. Therefore, we also compare HIV risk to sero-discordant partnerships where concurrency is not being reported. For example, we can compare the incidence among sero-
discordant couples with the incidence among wives in partnership episodes where they are exposed to concurrency.

**Methods**

Descriptive analysis will be used to trace the seroconversions for all marital partnerships that are sero-concordant negative in the first round of observation. This analysis will show seroconversion differences among couples reporting and not reporting concurrent partnerships, as well as trace which of the couples in the partnership seroconverts first. Seroconversions among wives whose husbands remain sero-negative indicate potential underreporting of concurrent partnerships among women. The trajectory data will also be used to measure the risk of seroconversion among all couples experiencing concurrency, as well as to determine what percent of all seroconversions among married couples are correlated with concurrency.

We then estimate the risk of seroconversion among wives using a discrete-time logit model. Our main predictor is husbands’ reports of concurrency in each partnership episode, which is a time-varying covariate. Controls will be added for both the husband and wives age. Whether the wife reported a concurrent partner is also controlled for as her seroconversion may result from her own increased number of partners, rather than from the risk of her husband. In a second model we add a control for the husband’s number of partners in the previous year to see how controlling for quantum of partners effects the risk of seroconversion.

In a third model, we will examine how the risk of concurrency changes once condom use and coital frequency are accounted for. If these factors are minimizing the rates of seroconversion among couples with concurrent partnerships, we could expect controlling for
these variables would lead to an increase in the coefficients for concurrency. Condom use with concurrent partners can be tested in both the RCCS and GPC, while coital frequency is only available in the RCCS. First correlations between concurrency and mitigating behaviors will be examined, and then controls will be added to the hazard model to see how $\beta_1$ changes.

As a sensitivity analysis, we run two additional models that take into account the competing risks of migration and marital dissolution. First, we treat competing risks as cases of censoring, such that all wives whose husbands migrated or whose marriages dissolved are censored in that year. Second, rather than censor cases of migration and marital dissolution, we keep those women in the analysis. We are then interested in the risk of seroconversion among women whose husbands are absent, women whose husbands are present and don’t report a concurrent partner, and women whose husbands are present and do report a concurrent partner. We compare these results to the case where competing risks were treated as censored to test the sensitivity of our results.

**Preliminary Results**

*(Forthcoming, please contact authors).*
References


