Measures of sexual partnerships: lengths, gaps, overlaps and sexually transmitted infection

Betsy Foxman, PhD[1], Mark Newman, PhD[2], Bethany Percha, BS[2], King K. Holmes, MD,PhD[3], Sevgi O. Aral, PhD[4]

[1]Department of Epidemiology, University of Michigan School of Public Health

[2]Physics Department and Center for Study of Complex Systems, University of Michigan

[3]Center for AIDS and STD, and Department of Infectious Diseases, University of Washington School of Medicine

[4]Division of STD, Centers for Disease Control and Prevention, Atlanta, GA

Address correspondence to:

Betsy Foxman, PhD

Department of Epidemiology

109 Observatory Street, Ann Arbor, Michigan 48109-2029

Phone: 734-764-5487

Fax : 734-764-3192

Email: bfoxman@umich.edu

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Short summary: We describe the distributions of gaps, lengths and overlaps among participants in a random digit dialing survey conducted among 1194 Seattle residents during 2003-2004.

ABSTRACT

Goal: The length of time between partnerships ("gap") is an important determinant of the overall transmission system of sexually transmitted infections. We describe the distributions of gaps, lengths and overlaps among participants in a random digit dialing survey conducted among 1194 Seattle residents during 2003-2004.

Methods: Survey participants were restricted to those 18-39 years of age with fluency in the English language. We limited our analysis to the 1051 (88%) of participants who reported ever engaging in vaginal, oral or anal intercourse and reported information on gaps, lengths and overlaps.

Results: Most (59%) observed gaps between partnerships $\leq$ 6 months; therefore, the majority of 18 to 39 year olds seeking new partners find a new partner well within the infectious period of chlamydia, gonorrhea, and syphilis (if no treatment is received), and HSV, HPV, and HIV. This was generally true independent of gender, race, income, or education. Gap length was, however, correlated with age.

Conclusions: The observed shorter gap lengths among younger individuals re-enforce the need to focus interventions on adolescents and young adults, particularly those with the potential to mix with infected individuals.

Key Words: sex behavior, concurrency, social mixing

INTRODUCTION

The survival of a sexually transmitted infection (STI) (or any infectious disease) in a given population requires that each infected individual transmit, on average, to at least one additional individual. If, as is typically the case, transmission occurs only during a finite infectious period following acquisition, effective contact with a susceptible individual must occur during that infectious period if the disease is to persist. Thus, an important determinant of transmission for STIs is the length of time ("gap") between the end of an individual's partnership with one sexual partner and the start of their next partnership [1]. Gaps can be either positive, indicating that there is a nonzero interval between the two partnerships, or negative, indicating that the partnerships are concurrent, i.e., that they overlap. Concurrent partnerships are known to be a risk factor for STIs. As we emphasize here, however, even serially monogamous partnerships can be considered effectively concurrent if the gap length between them is shorter than the infectious period, since there is then a nonzero risk of transmission [1].

Several well-studied predictors of individual STI risk are closely tied to gap length. For example, greater numbers of sex partners and higher rates of partnership change imply shorter gap lengths. It is possible that gap length is the more fundamental predictor in this case and that the efficacy of these quantities as predictors of risk is at least in part due to their correlation with gap length. Variation in gap lengths among population subgroups has also been suggested as a possible explanation for differences in population transmission patterns by disease [1,2].

Infectious periods vary by disease, and are, on average, shorter for bacterial infections than for viral infections. Mean duration of infectiousness of gonorrhea is 6 months in the absence of a control program, falling to an estimated 1.8 months if a control program is present [3]. By contrast, an individual with HIV becomes infectious shortly after infection and continues shedding virus indefinitely thereafter, although not at a uniform rate. Infectiousness is highest shortly after infection; it also varies with treatment [4]. Thus we expect the impact of gap length on STI transmission patterns to be strongly disease-dependent.

Despite its theoretical importance, however, there have been few studies describing the statistics of gap lengths and their correlation with other known STI risk factors. In an analysis of data from the National Survey of Family Growth, Kraut-Becher and Aral [1] found that gap lengths among sexually active women aged 15 to 44 varied by age, race/ethnicity, education, income and history of the diagnosis of a sexually transmitted disease. The study was limited, however, in that information about sex partnerships other than spouses and cohabiting partners was restricted to the 5 years before the interview, and information on the continuity of relationships was limited. Moreover, the results were limited to women and the distributions of the gaps between relationships and lengths of relationships were not presented. To address these concerns, we here analyze the distributions of gaps and partnership lengths in a random digit dialing survey conducted among 1194 male and female residents of the city of Seattle, WA during 2003-2004 [5]. In the Seattle survey, all respondents reporting any sexual activity were asked about their last five sex partners. Age and same-sex partners were the only significant predictors of positive gap length among respondents aged 25-39; below age 25 the only significant predictor was income. The lengths of negative gaps – overlaps – increased with age in the 25 to 39 bracket, and were negatively correlated with age at first sex among those less than 25.

MATERIAL AND METHODS

Study population: We analyzed the results of a random digit dialing survey conducted in the Seattle area between 2003-2004 among residents age 18-39 years of age with fluency in the English language [5]. The RDD sample included listed and unlisted numbers and was obtained from Survey Sampling, Inc. of Westport, CT. Up to six attempts were made to contact each number at different times of day. The survey was conducted by the Social & Economic Sciences Research Center in Pullman, Washington.

In the survey, we were able to contact 31,617 (84.1%) of the 37,000 telephone numbers in the initial sampling frame: 21,294 (55.4%) numbers were either non-residential or disconnected, 1527 (4.1%) were a data or fax lines, at 1939 (5.2%) there were only answering machines, 2448 (6.7%) never answered, 482 (1.3%) were always busy and 80 (0.2%) had telecommunication technical barriers. Of the 8683 households remaining, 6101 (70.2%) did not meet eligibility requirements, leaving 2582 eligible individuals. One thousand one hundred and ninety-four (1194) of the 2582 eligible individuals contacted (46.2%) agreed to participate and completed the interview. We limited our comparison to the 1051 (88%) of participants who reported ever engaging in vaginal, oral or anal intercourse and reported information on gaps, lengths and overlaps.

Survey Instrument: The survey instrument included questions on sexual history, partner and partnership characteristics of the respondent's five most recent partnerships, STI history, and demographics. The survey was pre-tested on a sample of the study population and revised prior to initiating data collection. The telephone survey required approximately 20 minutes to conduct and was administered using computer-assisted telephone interviewing software, which standardized the interview and minimized data entry errors. Respondents were given the option to select the gender of the available interviewers.

Data analysis: We used descriptive statistics and graphical techniques to describe the distributions of the gaps between partnerships, overlaps and lengths of partnerships. Distributions were stratified by sociodemographic characteristics. We fitted linear regression models to identify significant correlates of the observed distributions, adjusting for other variables.

RESULTS

Each of the 1114 sexually active participants was asked about their previous five sex partners; 1051 individuals described one or more partnerships. Figure 1 shows the cumulative distribution of the lifetime number of partners among those 1051 individuals. As the figure shows, many individuals had only a small number of partners -- 38% reported five partners or fewer during their lifetime. However, the distribution also has a "fat tail" representing a small fraction of the population who had a large number partners -- 15% of the population reported having 20 or more partners during their lifetime. Figure 1 is plotted on logarithmic scales and when viewed in this way the tail has an approximate straight-line form (dashed line), implying that the data follow a Pareto distribution or power law, at least approximately. A similar observation has been made in other studies as well [6,7]. (There are also some spikes in the distribution that are a result of digit preference – respondents had a tendency to round off larger numbers of partners to multiples of ten.)

Among individuals reporting two or more partnerships, several patterns were observed (Figure 2). Individuals often reported several sex partners of short duration at the beginning or end of a longer relationship (persons A, D, E, and F). Some individuals reported a sex partnership of short duration during a longer relationship (persons B and G), or an overlap between the end of one long partnership and beginning of another (persons C and G).

The distribution of the lengths of gaps between partnerships was almost identical regardless of whether the partnerships were the most recent or occurred in past. Figure 3 shows the distribution in cumulative form. Gaps of length less than zero correspond to overlapping relationships, and the cumulative distribution crosses zero around 75%, meaning that about 25% of relationships are succeeded by another overlapping relationship. (The fraction of *individuals* reporting any overlapping relationships is somewhat higher at around a third – see below.) If separated into positive gaps and negative gaps (overlaps) the distribution of each is almost perfectly exponential. The average overall gap length (including both positive and negative gaps) was 60.8 days (standard error=29.9 days; median=121.6); positive gaps averaged 354.1 days (standard error=19.1 days; median=187.4), and overlaps averaged 801.2 days (standard error=52.3 days; median=427.3).

The cumulative distribution of the lengths of completed partnerships is shown in Figure 4. As expected, the most recent partnership (denoted length 1 in the figure), which includes current partnerships, over-samples for longer partnerships (prevalence/incidence bias) so that the distribution has a broader tail than that for earlier partnerships. The distribution of the other four (denoted length 2-5 in the figure) appear similar. Each of the distributions appears to be roughly linear on the semi-logarithmic scales used in the figure, indicating an exponential distribution.

There were 317 individuals who reported overlaps (negative gaps) between any of their partnerships. The average length of overlaps increased with age (Figure 5a), while single, separated and divorced individuals reported overlaps somewhat shorter than those reported by married individuals. The average length of overlap was longer for individuals having same-sex only compared to opposite sex or same and opposite sex partners, but the differences were not statistically significant (Figure 5b). Neither positive gaps (Figure 5c) nor overlaps (not shown) varied by income. In addition, positive gaps were not associated with gender, marital status, race education or age at first sex (data not shown).

To explore sociodemographic correlates of the lengths of gaps and overlaps, we fitted a series of linear regression models predicting the length of the gap and of overlap (overlap is recorded as the absolute value of the time of overlap, i.e., a larger number corresponds to longer time of overlap). After adjustment for age, income, marital status, gender, age at first sex, and having same-sex partners were not significant predictors of gap length. Within individual age groups, however, other significant correlates appear, as shown in Table 1. Among individuals less than 25 years of age (17% of the total) but not those over 25, positive gaps between sex partners tended to be shorter for those with higher income; among those 25 and older, positive between partners was shorter for younger individuals and for individuals having same-sex partners. For overlaps, individuals reporting that they had their first sex at a lower age tended to have longer overlaps, but only among those of age less than 25; for individuals over 25 years, older individuals tended to have longer overlaps. No other variables were significant correlates.

DISCUSSION

Among 18 to 39 year old Seattle residents participating in a random digit dialing survey, most (59%) of the gaps between partnerships were 6 months or less; thus, the majority of the population seeking new partners in this age group finds a new partner well within the infectious period of chlamydia, gonorrhea, and syphilis (if no treatment is received), and HSV, HPV, and

HIV. This was generally true independent of gender, race, income, or education. Among those 25 to 39, increasing age was associated with increasing time between partnerships.

Modeling studies suggest that overlapping partnerships are important drivers of the overall transmission of an STI through a population [2]. Over one-fifth of our population reported overlapping partnerships with overlaps of varying length: length of overlap increased with age among those 25 to 39, and decreased with age at first sex among those 18 to 25. We observed several different patterns of overlap, potentially correlated with life stage. Multiple short relationships, often overlapping, were not uncommon at the beginnings and ends of relationships. This is consistent with the qualitative work of Gorbach et al., who dubbed these as "transitional" concurrencies [8]. We also observed one or more short concurrencies during some long relationships, similar to Gorbach et al.'s "experimental" concurrencies. Some long overlapping relationships were also observed: the median length of overlap among those reporting an overlap was 427 days. The upper quartile ranged from 3 to 19 years. Patterns of multiple overlapping partnerships are particularly important for rapid transmission of STIs through a population.

Our findings have implications for future research in this area, for transmission system modeling and for the targeting of STI prevention efforts. Generalizations should, however, take into account the degree to which the Seattle population measured is representative of other populations. Further, our response rate, although consistent with other recent random digit dialing surveys, was not ideal [9].

We examined data on up to five relationships for each respondent. The cumulative distribution of the lengths of gaps between successive partnerships was essentially independent of whether we looked at the most recent partnership or at older partnerships (figure 3). This appears to be true even despite the known sampling bias for the most recent relationship in favor of longer duration. (In other words, there appears not to be a strong correlation between gap length and relationship length: for positive gaps the correlation is 0.47; for negative gaps (overlaps), 0.31.) Thus, it appears that future studies might effectively estimate gap length by measuring only the time between current and most recent relationship.

The availability of a relatively precise estimate of gap length and its distribution by STI correlates should enhance the ability of modelers to predict the impact of various gap lengths on the transmission system of particular STIs. However, with the exception of age and those engaging in same-sex relationships, we observed little variation in gap length among high risk STI subgroups. This is consistent with empirical studies that found few differences in concurrency rates among individuals in high and low HIV prevalent areas [10]. Thus, while gap length may be an important driver of disease spread, it may not vary sufficiently between population subgroups to explain observed differences in disease rates.

The data presented here will be useful in the estimation of parameters for quantitative modeling of the spread of STIs. For instance, Kretschmar and Dietz [11] have developed a detailed numerical model of the epidemiological effects of the formation and dissolution of partnerships in a sexually active population. Their model predicts, for example, the basic reproductive number R_0 of an infection as a function of a number of population-level parameters. Unfortunately, as Kretschmer and Dietz point out, a crucial pair of those parameters had undetermined values at the time of publication of the model, making the quantitative application of the model to real-world situations impossible. The parameters in question were the mean rate ρ per single member of the population of formation of new partnerships, and the mean rate σ per partnership of dissolution of partnerships. Using the results of the study described here, we can now give values for these two parameters.

The mean rate of new partnerships per year per member of the entire population studied was found to be 1.81 ± 0.17. The model, however, requires the rate per single individual. In the study population, 22.5% of individuals were single at the time of interview (defined as having no recent sexual partner with whom they expected to engage in intercourse again). Thus the rate of new partnerships per single individual is $\rho = 1.81/0.225 = 8.05 \pm 0.76$.

It is not possible completely to reconcile our findings with a model such as that of Kretschmar and Dietz: the model assumes that only single individuals instigate new partnerships, but our results indicate that in about 20% of new partnerships one or both partners is already involved with someone else. As discussed above, the mean gap between partnerships in the sampled population was 60.8 days, implying 6.00 new partnerships a year per single individual. This figure is of the same order of magnitude, but not exactly equal to, the estimate of ρ above precisely because of partnership concurrency. The most correct way to accommodate this discrepancy would be to extend the model to allow concurrent partnerships, but in the absence of such an extension the best we can say is that the appropriate value of ρ lies in the range of about 6 to 8 partnerships per year per single individual.

A similar calculation allows us to calculate σ, the rate of dissolution of partnerships. The fraction of individuals in partnerships at the time of our survey was 77.5% and, ignoring population growth, the average rate at which partnerships end is equal to the rate at which they form (since every partnership must end sometime), which is 1.81 ± 0.17, as above. Thus the rate of dissolution per member of a partnership is $1.81/0.775$. This is not precisely the rate of dissolution per partnership (which is the parameter called for by the model) since some individuals are in more than one partnership, although this turns out to be a small effect. Of the 842 people who reported being in a partnership at the time of interview, only 17, or 2.0%, were in two or more partnerships. Allowing for this small correction, we then arrive at a value of $\sigma = 2.29 \pm 0.21$. There is in this case no difficulty about reconciling our results with the formulation of the model: while it is not necessary that a person starting a new partnership be single (as the model assumes), it is clearly true that a person dissolving a partnership must be in a partnership, so this figure for σ corresponds to the parameter considered in [11]. Armed with these values for ρ and σ, it should now be possible to make quantitative predictions of R_0 and other parameters of epidemiological interest using models such as that of [11].

In conclusion, we observed a median time between partnerships that makes most serially monogamous partnerships effectively concurrent for most STIs. Thus, should an STI be introduced into our general population sample of 18 to 39 year olds, no special circumstances would be required to maintain circulation (assuming little or no condom use). Finally, since gap length was correlated with age, our results reinforce the need to focus interventions on adolescents and young adults, particularly those with the potential to mix with infected individuals.

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FIGURE TITLES

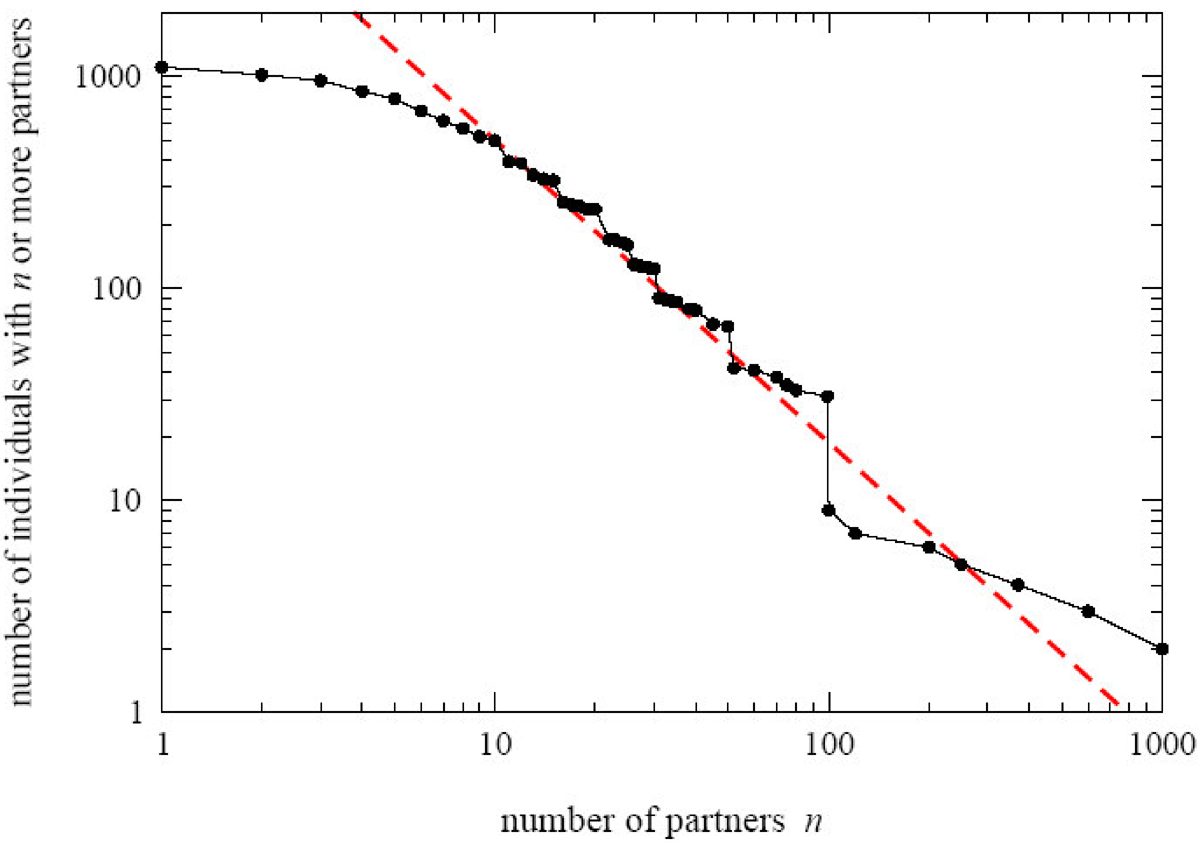
Figure 1: Cumulative distribution function of self-reported history of lifetime number of sex partners on logarithmic scales. The straight-line form in the tail of the distribution indicates a power law. The slope of the line is measured to be -1.4 ± 0.2 (dashed line), which corresponds to a value of -2.4 ± 0.2 for the exponent of the power law.

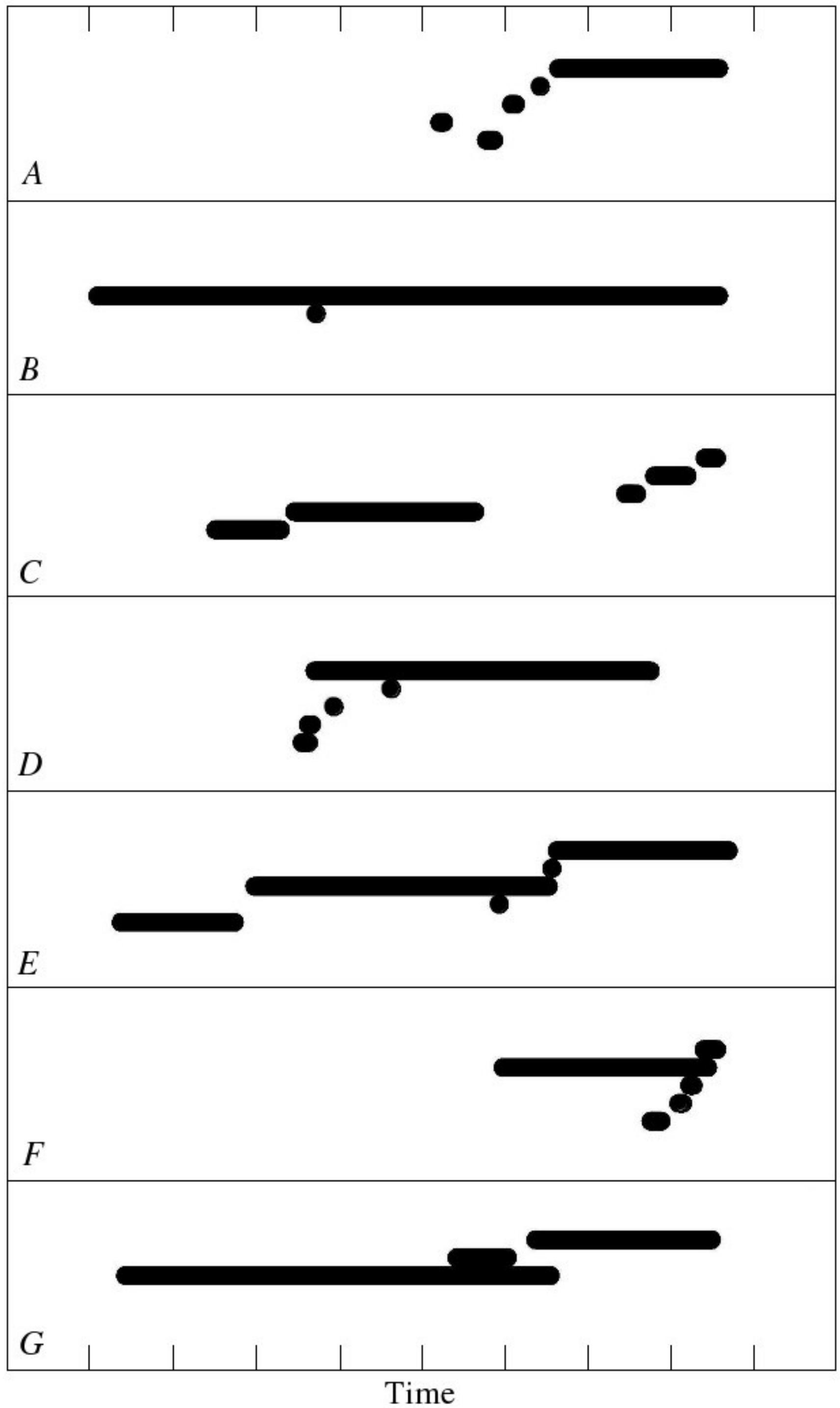
Figure 2: Examples of observed sexual histories, in weeks. Each row shows up to 5 sex partnerships reported by a respondent. For example, person A reported four partnerships of short duration, followed by a longer partnership.

Figure 3: Distribution of gap lengths. Gap 1 is the time between most recent and second most recent partner, gap 2 is the time between second most recent and third most recent partner, and so on. 59% of the gaps were less than 6 months (the dashed line). 1051 ever sexually active participants in random digit dialing survey of Seattle, 2003-2004.

Figure 4: Distribution of duration of sexual partnerships, by partnership. Length 1 is the duration of most recent sexual partners, length 2 second most recent, and so on. 1051 ever sexually active participants in random digit dialing survey of Seattle, 2003-2004.

Figure 5: Distribution of average duration of overlap between partnerships by a) age at time of interview; b) income at time of interview; and c) self reported history of engaging in sexual activity with opposite sex only, same sex only or both same and opposite sex partners. 1051 ever sexually active participants in random digit dialing survey of Seattle2003-2004; 317 individuals reported an overlap.


1000
100
10
1
1
10
100
1000
number of individuals with n or more partners
number of partners n


A
B
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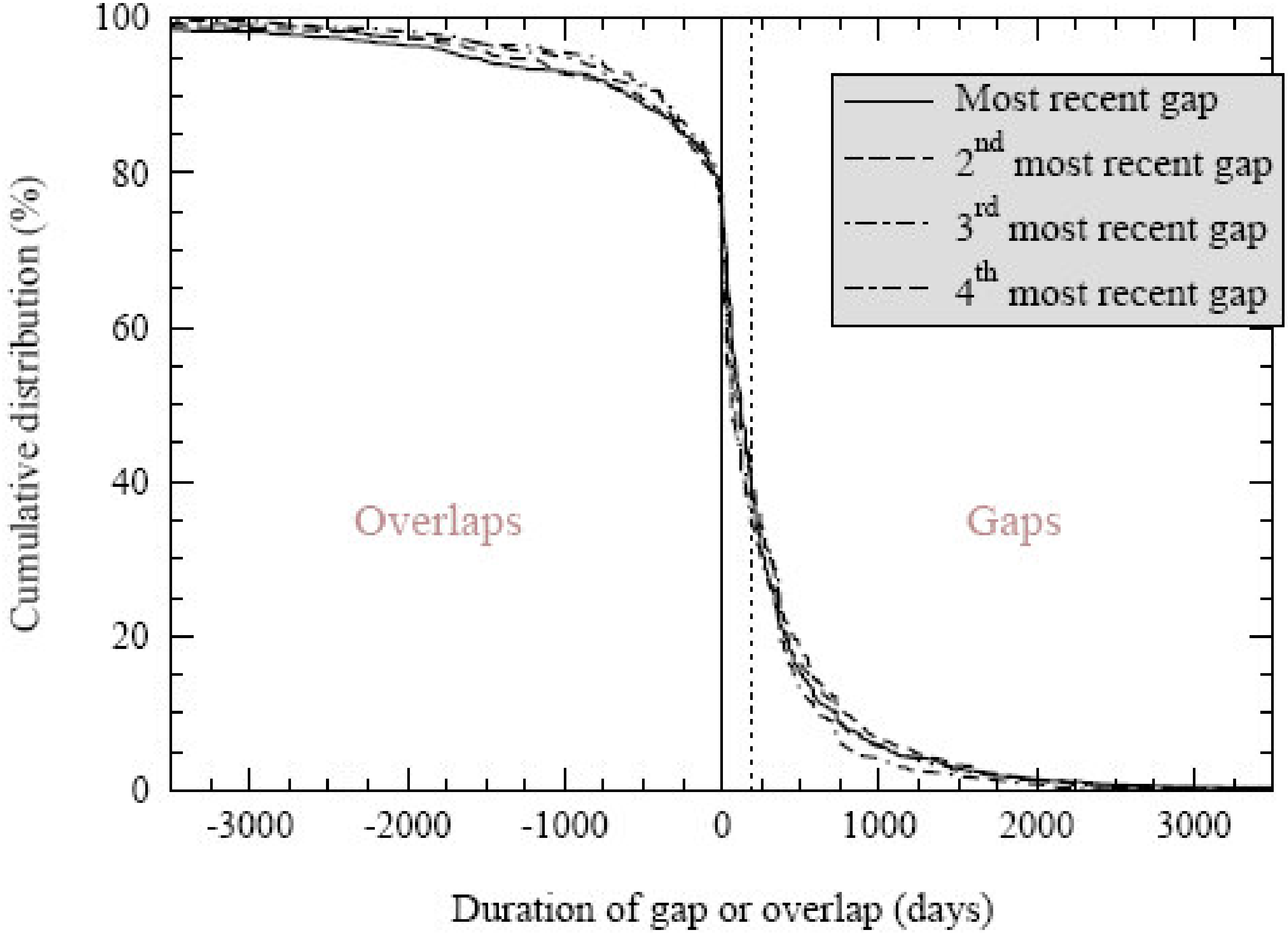
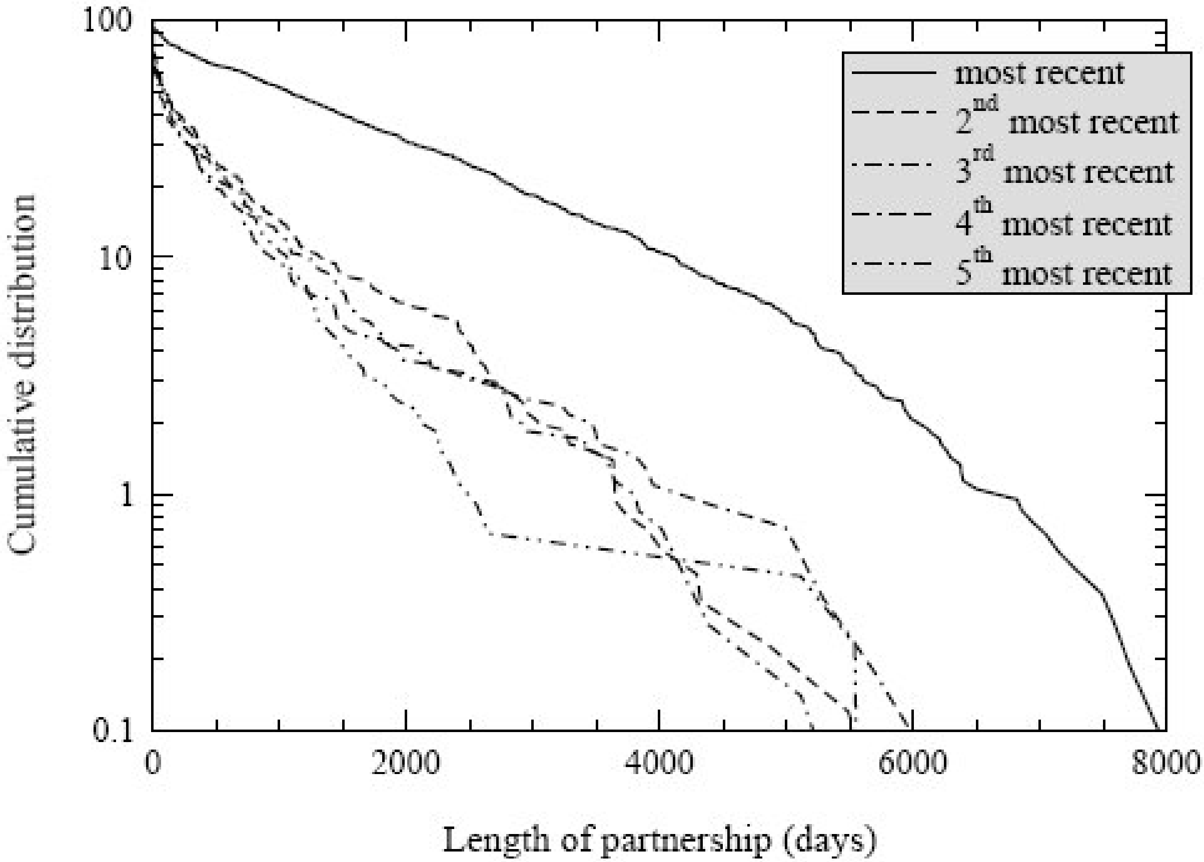
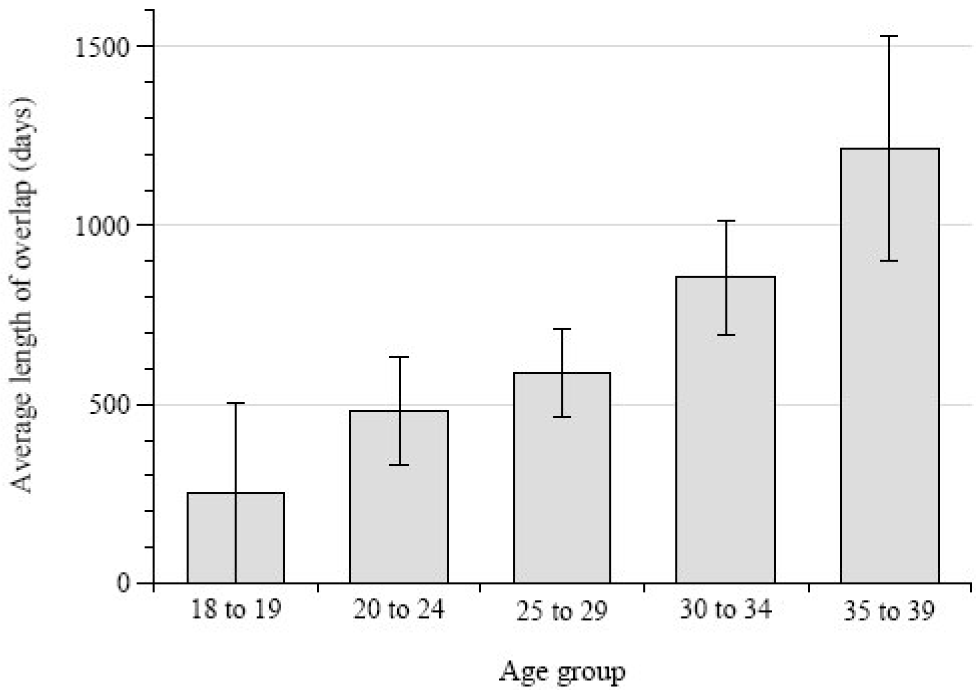
E
F
G
Time



Cumulative distribution (%)
100
80
60
40
20
0
-3000
-2000
-1000
0
1000
2000
3000
Duration of gap or overlap (days)
Overlaps
Gaps
Most recent gap
2nd most recent gap
3rd most recent gap
4th most recent gap

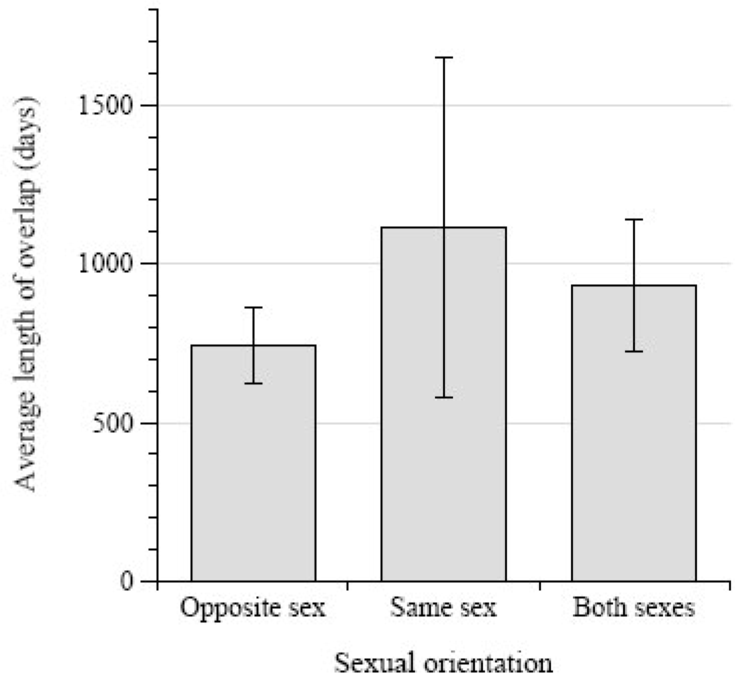

100
10
1
0.1
0
2000
4000
6000
8000
Cumulative distribution
Length of partnership (days)
most recent
2nd most recent
3rd most recent
4th most recent
5th most recent

A.

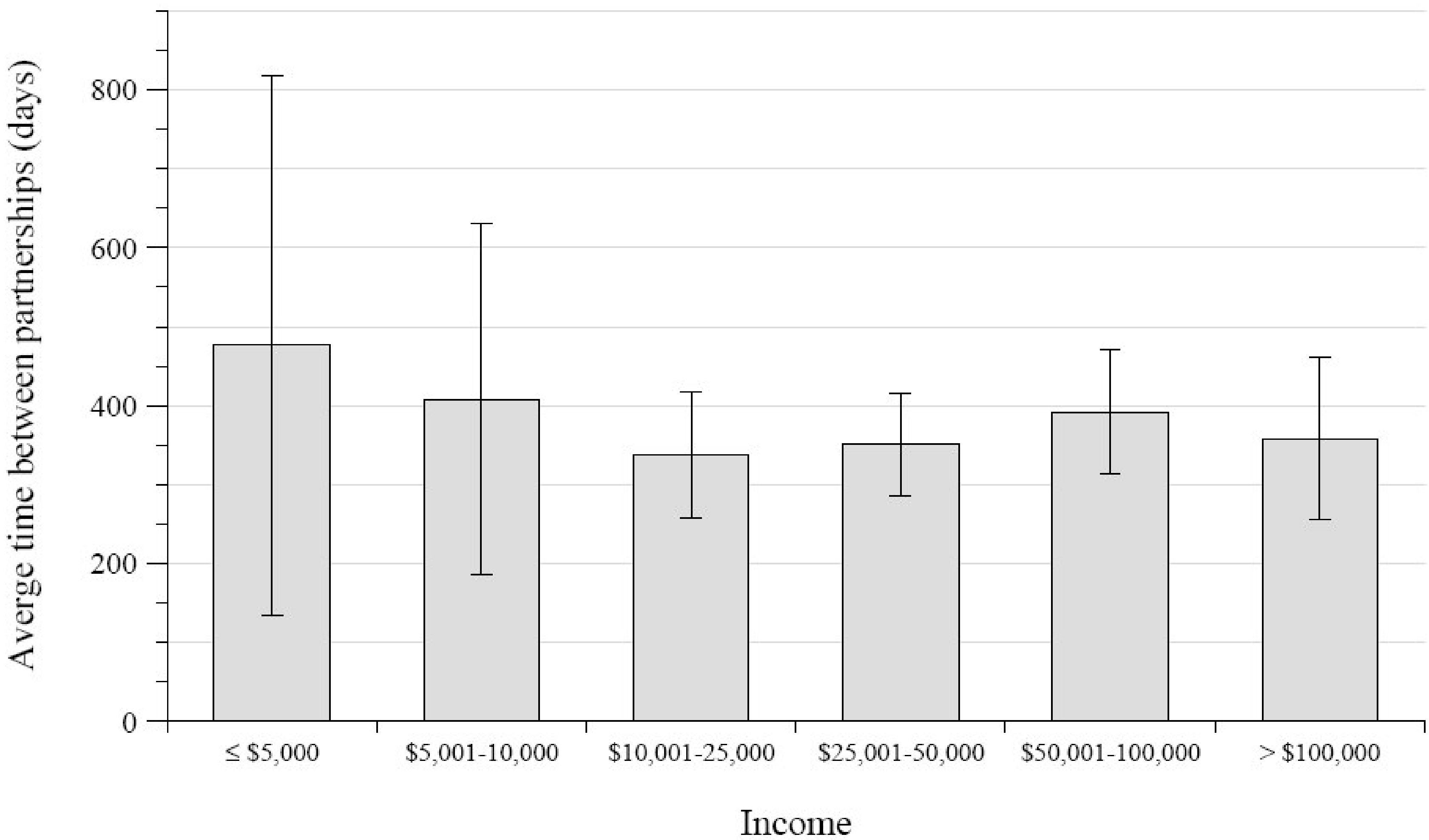


1500
1000
500
0
Average length of overlap (days)
18 to 19
20 to 24
25 to 29
30 to 34
35 to 39
Age group

B.


Average length of overlap (days)
1500
1000
500
0
Opposite sex
Same sex
Both sexes
Sexual orientation

C.



Averge time between partnerships (days)
800
600
400
200
0
≤ $5,000
$5,001-10,000
$10,001-25,000
$25,001-50,000
$50,001-100,000
> $100,000
Income

Table 1: Linear regression models predicting length of overlap, length of gaps between partners and overall gap length (positive and negative)

	Age < 25				Age > 24			
Dependent Variable (n for age<25/ n for age>24)	Variable	Parameter Estimate	Standard Error	P Value	Variable	Parameter Estimate	Standard Error	P Value
Positive gap*	Intercept	414.3	71.5	<.0001	Intercept	-118.3	186.2	0.53
(n=112/536)	Income	-51.1	19.9	0.01	Age	16.4	5.8	0.005
Average overlap**	Intercept	1590.1	494.0	0.00	Intercept	-1055.2	452.5	0.0205
(n=46/271)	Age at first sex	-69.6	30.2	0.03	Age	60.5	14.2	<.0001

* Gap between most recent and second most recent partner

**Averaged across all partners