Sexual risk behaviour and infection: epidemiological considerations

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MONITORING SEXUAL BEHAVIOUR

It is remarkable that, despite the great variation in both morbidities and risk behaviours, a systematic approach to the assessment and interpretation of the distribution of sexual behaviours in populations has not yet been developed. Measures of central tendency still seem to be the sexual behaviour indicators of choice. The accumulating data on HIV, other STDs, and sexual behaviour all point to their vast variability in populations. One recent analysis of HIV prevalence and incidence found wide variations in categories of exposure even across countries which have the same type of epidemic. Data on number of sex partners, from developed and developing countries, indicate that the majority of people in a population have few sex partners while a small minority report very large numbers. Similarly, data on frequency of sexual intercourse and sexual practices reveal great variation even, for example, within the population of a small US city.

Core groups

Monitoring the sexual behaviour of so-called “core groups” is important in the spread and prevention of STI. Core groups are defined as “small proportions of persons with an STD who are frequently infected with and transmit the disease, and who sustain the endemic and epidemic transmission of STD”.

Recent work on modelling of dynamic and network heterogeneities in the spread of STD sheds further light on the role of core groups in STD transmission dynamics. One feature of the spread of infection within a network is the rapid build up of correlations in the infection status of connected individuals—most infected individuals have infected sex partners, who have either transmitted the infection to them or acquired the infection from them. Such aggregation slows the spread of an epidemic by reducing the average number of susceptible partners per infected individual. Thus, within core groups the number of susceptibles will be depleted and STI spread will be curtailed if the size of the core group is not too large, the turnover rate (movement into and out of the core group) is small, the volume of sexual contacts between the core group and the periphery is limited, and, in the case of curable bacterial STI, the health system does not aggressively intervene to rapidly return infected individuals to susceptible status. During a recent outbreak of primary and secondary syphilis in Vancouver, British Columbia, the mass treatment intervention that was implemented resulted in increased incidence of primary and secondary syphilis, by returning infected people to susceptible status and thereby increasing the pool of susceptible individuals.

Standardised and repeated measurement of quantifiable parameters related to core groups, such as the absolute and relative size (relative to the size of the total population) of core groups, changes in core group size, movement into and out of core groups, and so forth is needed. A careful analysis of what needs to be measured, where, when, and for how long, is an important component of monitoring sexual behaviour. It must be recognised that within the context of STI transmission, the structure of the network changes over time as a result of births, deaths, and migrations into and out of the population, and as a result of the sexual contact structure changing due to treatment, removal of infected people from the susceptible pool, and differential contact patterns in core and non-core groups. A careful analysis of what needs to be measured is needed, with monitoring aimed at allowing a varied and dynamic population to be linked together and monitored, and at assessing the role of specific sexual behaviours in the transmission of specific STIs, with monitoring at the level of the individual and at the level of the population. It is remarkable that, despite the great variation in both morbidities and risk behaviours, a systematic approach to the assessment and interpretation of the distribution of sexual behaviours in populations has not yet been developed. Measures of central tendency still seem to be the sexual behaviour indicators of choice.
out of core groups, spatial movement of core groups, and the volume of sexual contact between core groups and the rest of the population may greatly enhance our understanding of the spread of STI in populations.

**Sexual mixing**

Earlier uses of the concept of core groups tended to be descriptive and theoretical, but in recent years STD researchers have focused increasingly on their quantifiable aspects. One analysis of sexual mixing between core and peripheral groups among African and white Americans suggested that the sizeable differential in STD rates between these two populations could be accounted for by their different rates of core to periphery sexual mixing. Ongoing work in Cotonou, Benin, explores qualitative and quantitative characteristics of behaviours and STI morbidity among female sex workers (SW) and their clients. These investigations described the extent of variability in sex work and SW-client connections across local areas and over time. Rapid assessments in the Russian towns Saratov, Balakovo, and Engels suggested that such methodologies may allow estimation of some parameters related to sex work and SW-client contacts. An individual based simulation model was developed, using estimates from Saratov Oblast (the region), to explore how the number of client contacts an SW makes, whether clients repeatedly visit the same SW or many different ones, and the relative size of the SW and client populations all influence the establishment and endemic prevalence of gonorrhoea (a short duration infection) and herpes simplex virus-2 (HSV-2) (a longer duration infection). For both pathogens, infection was more likely to persist if clients visited many different SWs, regardless of variation in the frequency of such contacts. This scenario also resulted in a higher endemic prevalence in SW and client populations. The size of the SW population (relative to the total population) was most important in determining the overall prevalence of infection, with larger populations of SWs resulting in a higher overall prevalence.

These findings also point to the importance of turnover in and spatial movement of SWs in STI spread. Increases in turnover and spatial movement of SW populations may increase the numbers of specific SW-client links and perhaps influence STI spread in the same manner as larger SW populations. Monitoring sexual behaviour parameters among core groups must, therefore, include the measurement or estimation of spatial movement and turnover in SW populations. Spatial movement may cover different time periods, and may involve seasonal repeat migration or long term migration to another locale where the sex market may be more profitable. Movement of SWs may be closely related to their chronological and professional age and to the supply and demand conditions of the market. The average age of SWs, years in the profession, and average age at initiation into sex work may be helpful indicators of turnover. As with any other parameter, the distributions of these variables are even more informative than their measures of central tendency.

Clustering of STIs within populations means STI prevalence and incidence are high in some subpopulations and low in others. Mixing (and bridging) between members of high and low prevalence subpopulations may constitute risk factors for acquisition and transmission of STIs at the individual level and may facilitate spread at the population level. Sexual mixing between SWs and their clients is a classical example of such mixing. During the early 1980s, having sex with people from particular cities/countries was shown to be a risk factor for HIV infection, pointing to the importance of spatial measures of sexual mixing. Some studies of sexual mixing and bridge populations define these concepts in purely behavioural terms, with little reference to levels of STD prevalence and incidence. In the absence of STIs, risky sexual behaviours may not be associated with the acquisition of STDs. It is therefore important to include the biomedical indicators of STI in the definition of core groups, bridge populations, and sexual mixing. In a recent study of people infected with gonorrhoea and chlamydia in Seattle, Washington, 5.2% of respondents reported having had sex with people who lived outside their area of residence, over a period of three months. Based on data on sexual mixing/bridging patterns among a general population sample of Seattle residents, 47.5% of those who had had one or more sex partners during their lifetime reported that at least one of their last two partners was not a Seattle resident. Among respondents who reported one or more concurrent sex partnership over the previous 12 months, 43.7% reported at least one sex partner who lived outside Seattle. Thus, in Seattle spatial bridging occurs considerably more frequently among members of the general population than it does among the infected population. Although spatial bridging is not in itself a high risk activity, sexual mixing (bridging) with residents of geographical areas where incidence/prevalence of STI is higher may constitute a high risk activity.

**The role of sexual behaviour in STI transmission**

Untangling the role of behaviour in the transmission of HIV and other STIs has proved difficult. Observational studies that explore the relation between behavioural and biomedical outcomes often fail to show a strong relation between behaviours and acquisition of STI. Some behavioural intervention studies have also failed to show a strong relation between behaviours and STD acquisition. The association between behaviour and infection in observational studies is often either difficult to interpret or misleading.

**Misinterpretation due to context, study population, and partner’s infection status**

Misinterpretation of the relation between sexual behaviour and STI transmission can occur in a number of ways. Firstly, both the risk and preventive behaviours of the respondent may not be fully considered and interpreted in the context of each other. For example, it is often assumed that condom use is protective: someone who uses condoms 50% of the time is assumed to be at a lower risk than someone who does not use them. Yet the non-user may be at lower risk, because they have, say, unprotected sex 10 times per month, while the 50% user has sex 30 times per month, of which 15 encounters are unprotected.

Secondly, associations between behaviour and infection differ by study population. Recent empirical evidence confirms that sexual risk behaviours vary by study population. A comparison of African-American women attending an STD clinic in North Carolina with African-American women in the surrounding community found statistically significant differences between the two populations with respect to marital status, employment status, income, number of sex partners, types of sex partners, whether or not the main partner had other sex partners, and whether or not the main partner had had an STD. Another study compared an STD clinic population to a general population sample obtained from a random digit dialling telephone survey and looked at factors associated with gonococcal infection. Three risk factors (age, black race, and whether or not the partner had spent a night in jail) emerged as important for gonorrhoeal infection in the STD clinic population. In the random digit dialling sample the above three risk factors were significant but five additional factors were also important. These included education at or above high school level, anal sex,
people are more likely to have safe sex with risky partners
the infection status of the partner, which is not known except
receptive anal intercourse without condoms is embedded in
sexual behaviours such as unprotected intercourse or
acquired from uninfected partners. Thus, the risk in risky
risk of acquiring an STI depends on whether the partner is
unknown, or not taken into account.43 44 The risk in risky
sexual behaviours such as unprotected intercourse or
receptive anal intercourse without condoms is embedded in
the infection status of the partner, which is not known except
in the context of discordant partner studies. Moreover,
behaviours are related to the infection status of the partner:
people are more likely to have safe sex with risky partners
and risky sex with safe partners.44 Statistical adjustment for
such confounding necessitates knowledge of the infection
status of each partner. More detailed information on sex
partners may enhance our ability to assess partners’ infection
status. The numerous behavioural indicators used to reflect
partners’ infection probability, such as number of partners,
duration and type of partnerships, concurrency, mixing (bridging)
(high prevalence subpopulations, sex with
drug users, sex with SWs, and so on, appear to be
insufficient. In the context of intervention trials where the
focus of sexual behaviour measurement is identification of
risk factors for STI acquisition, inclusion of people whose
partners are uninfected apparently creates a lack of precision
in measuring associations of behaviours and STD risk and
reduces the power of the study.49

Interdependency and conditionality of sexual
behaviours
As data on sexual behaviour accumulate, the interdependen-
cies among specific sexual behaviours and between epide-
miological parameters and behaviours become increasingly
clear. The examples are many: among gay men frequency of
risk behaviour increases as their viral load decreases;
similarly, men who have sex with men on highly active
retroviral therapy may increase their high risk sexual activity
and know they are uninfected; they can have many sex partners if they get frequently tested
and know they are uninfected; they have receptive anal
intercourse without a condom if they are infected or if they
know their partner is uninfected. It is, therefore, important to
interpret behavioural findings in the appropriate behavioural
context, and identify and measure all relevant interrelated
behaviours.

Timing
The timing of the measurement of sexual behaviour may
affect the association between behaviour and infection. Many
studies which measure sexual behaviour include, as respon-
dents, people visiting STD clinics. People present at STD
clinics are usually there because they have an STD or because
they are concerned about a recent exposure to an STI; in
other words their behaviour has been particularly risky in the
recent past. If study participants are selected at a time when
their behaviour has been recently particularly risky, sexual
risk behaviours will tend to be overestimated. Moreover their
behaviour in the following few months will be more like their
usual behaviour and will be less risky—a phenomenon
known as “regression to the mean.”44 A regression to the
mean would also be expected when measuring sexual
behaviours of people accessing HIV counselling and testing
services. At the population level, similar changes in behaviour
are observed in response to HIV epidemics. As a result partly
of the selective higher mortality of core group members,45
and partly of reductions in sexual risk behaviours of the survivors,
mixed populations and subpopulations present less risky
sexual behaviours following HIV epidemics. Behaviours of
men who have sex with men in the United States,46 of
the general population in Uganda46 47 are well known examples of such changes.

The effects of timing may also complicate the measure-
ment of relations between sexual behaviour and a number of
other variables including infection status, other behavioural
and biomedical risk factors, and societal and contextual
determinants. Cross sectional studies often look for associa-
tions between infection rates and sexual behaviour by
focusing on current sexual behaviour.44 Yet the behaviours
responsible for current infection rates may have been
generated in 10–15 years earlier and may have changed
following the emergence and spread of infection. Results of
behavioural intervention trials conducted with STD clinic
attendees as participants may be particularly vulnerable to
the effects of timing on the measurement of sexual
behaviour.40 Temporal changes in sexual behaviour have a
differential effect on the measured associations between
behaviours and specific STIs. Infections such as gonorrhoeal
and chlamydial infection (short duration infections) are in
general acquired as a result of recent sexual behaviours,
whereas infections with HIV and HSV-2 (long duration
infections) may be acquired through behaviours that took
place decades earlier.

Specific behaviours and specific STIs
The interaction between the epidemiological properties of the
sexually transmitted pathogen and the behaviours relevant to
its spread often receives inadequate attention in the
measurement of sexual behaviour. “The initial spread and
long-term behaviour of any infectious disease are determined
by both its epidemiological characteristics and the graph
theoretical properties of the network—such as the average
number of neighbours, degree of clustering and the path
length between nodes.”46 An additional determinant of the
initial spread and long term behaviour of curable bacterial
STI, alongside those mentioned above, is the ability of
healthcare systems to diagnose and treat the infected,
sometimes with unexpected results. For example, mass
treatment of core groups in Vancouver, British Columbia, in response to a primary and secondary syphilis epidemic, eventually led to increases in syphilis.32 More central to the task of measuring sexual behaviour, however, is the implicit assumption that the same sexual behaviours are equally important to the spread of all STIs. Recent mathematical modelling work suggests that the behaviours responsible for the ongoing transmission of HSV-2 and gonorrhoea may be different.33 For short lived, high transmission probability infections like gonorrhoea, the number of sex partners may be more important than the number of sex acts with each partner. For long duration, low transmission probability infections such as HSV-2, a moderate number of sex partners, with many acts with each partner, may maximise the number of infections generated by an infected individual.34 The importance of other variables describing sex partner networks may also differ according to the biology of infection. For example, concurrency of partnerships and short gaps between partnerships35 may be more important in the spread of high transmission probability, short duration infections,36 and relatively less important in the spread of low transmission probability, long duration infections.

These observations may help guide sexual behaviour measurement efforts in the future, and may help expand behavioural intervention repertoires. Such considerations may also in part account for some counterintuitive findings in STD epidemiology.

Study design and STD transmission dynamics
Epidemiological models suggest that in order to make valid estimates of the effect of behaviour on infection, it is important to differentiate between at least three distinct components of STD transmission dynamics: transmissibility of infection upon exposure between an infected and an uninfected person, likelihood of sexual exposure between infected and uninfected individuals, and duration of infection among infected people. Despite clear recognition of these three distinct components of STD transmission dynamics, studies of the relation between sexual behaviour and STD transmission do not, in general, adequately differentiate between them. Different study designs may be appropriate for the measurement of sexual behaviours relevant to each of the three components. For example, behaviours related to transmissibility, such as condom use, can be evaluated effectively only in discordant partners.31–33 Behaviours related to sexual exposure between infected and uninfected individuals may be effectively studied among partnered and non-partnered people. Populations with very high and very low levels of prevalence/incidence may not be appropriate for the study of behaviours related to sexual exposure between infected and uninfected.34 Finally, behaviours related to duration of infectiousness including healthcare seeking, testing, and therapy compliance behaviours, would best be studied in infected or very high risk populations.

The particular STI under consideration may also have important implications for the choice of study population. Levels of prevalence and incidence (as mentioned above), transmission probability and duration of infectiousness vary with specific STIs.

CONCLUSION
The measurement of sexual behaviour serves a number of distinct purposes including assessment and temporal monitoring of risk behaviours in populations and the assessment of the role of sexual behaviour in the acquisition and transmission of specific STI. Evidence to date makes it clear that the purpose for which the measurement is undertaken is vitally important in defining the sexual behaviours to be measured, the populations to be studied, the time periods to be covered, and the contextual parameters to be considered. The specific purpose of the measurement may, for example, determine whether sexual behaviour is conceptualised at the individual or the population level. Sexual behaviour measurement is a complex and complicated business and needs to be undertaken with a precise grasp of the purposes of the endeavour.

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REFERENCES


29 Aral SO. St Lawrence JS. The ecology of sex work and drug use in Saratov Oblast, Russia. Sex Transm Dis 2002; 29: 798–805.


45 Chesson HW, Dee TS, Aral SO. AIDS mortality may have contributed to the decline in syphilis rates in the United States in the 1990’s. Sex Transm Dis 2003; 30: 419–24.


