The Dynamics of Substance Use and Sex Networks in HIV Transmission

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ABSTRACT *This article (1) reviews the research to identify mechanisms that may underlie HIV heterosexual transmission in developed and developing countries, (2) examines linkages between sex and substance use HIV transmission risks, and (3) describes sex network measurement issues relevant to developing HIV preventive interventions. The research contributions of developed countries to understanding sexually transmitted HIV have long recognized the influence of substance use and sex networks. Research in developing countries has contributed significantly to the environmental and biological understanding of HIV sexual transmission dynamics. Although much of the research in developing countries has recruited participants from venues where alcohol or other substance use is pervasive (e.g., truck stops), few studies have explicitly examined the relationship between HIV sex risk and substance use in these contexts. Finally, sex network characteristics and structural features, which have been found to play identifiable roles in the spread of HIV, are measurable at the individual level and can contribute substantively to the development and the evaluation of HIV-preventive interventions implemented at the network or community level.*

KEYWORDS *HIV sexual transmission, Substance use, HIV prevention and control, Developing countries, Sex networks, Surveillance.*

INTRODUCTION

Efforts to understand the dynamics of HIV transmission and to develop large-scale preventive interventions should involve experts from a diverse group of disciplines, including, for example, epidemiologists, economists, social scientists, demographers, and health care providers. Not until now, however, more than 20 years into the epidemic, are multidisciplinary research efforts in response to the HIV pandemic becoming the norm. This article attempts to develop a holistic HIV-preventive research and intervention agenda that focuses on environmental and social issues crucial to the dynamics of HIV transmission and prevention. It uses information gleaned from both research and practice and takes into account that the vast majority of HIV cases are heterosexually transmitted.¹ Specifically, the article aims to (1) review the literature to identify mechanisms that may underlie HIV sexual transmission; (2) examine linkages between sex and substance use transmission risks; and (3) describe network measurement issues relevant to developing and evaluating preventive interventions aimed at the group, the network, or the community. The literature is reviewed separately for developed and developing countries, since the focus of HIV research in each of these contexts historically has differed fairly dramatically.

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UNDERSTANDING HIV SEXUAL TRANSMISSION IN THE CONTEXT OF DEVELOPED COUNTRIES

The research contributions of industrialized or developed countries in understanding the dynamics of sexually transmitted HIV have long recognized the influence of substance use. Early identification of the increased risk of acquiring HIV infection by the female sex partners of injecting drug users (IDUs) was an integral step to recognizing the substance use–sexual transmission connection.^{2–4} Throughout the 1990s, researchers documented the importance of substance use in HIV sexual transmission. Findings were especially compelling for crack cocaine.^{5–8} Recent research suggests that some injectors may be acquiring HIV through sexual transmission rather than through drug-mediated practices.^{9–11} Implicit in these findings is the importance of sex network influences on the probability and actuality of becoming HIV infected.

Social network methodology has been used extensively in efforts to understand the influence of sex networks in the transmission of sexually transmitted infections (STIs), including HIV.^{12–16} Both network member characteristics and network structural features have been implicated in transmission. For example, Service, Blower, and Osmond^{17,18} were among the first to recognize age mixing in sex networks as a risk factor for HIV transmission among young gay men in San Francisco, since older age in the gay community was associated with an increased probability of being HIV infected. Race/ethnicity, drug use discordance, known serodiscordance, and education have also been implicated in heterosexual transmission risk.^{12,19–21} In terms of structural features, core groups (i.e., groups within which infections are found to concentrate, such as sex workers), concurrent (simultaneous) sex partnerships, and bridging (i.e., individuals who connect higher and lower risk populations through sex behaviors) have been found to influence disease prevalence, incidence, or transmission risk,^{22–28} with much of the empirical research examining sex partner concurrency.^{29–31} Finally, some studies have examined the interrelationships among substance use, sex practices, and network influence on the risk of HIV transmission. In a recent analysis of HIV-infected noninjecting heroin users (NIUs) and their sex partners, HIV-infected NIUs were significantly more likely to report unprotected sex with “lower” risk sex partners (i.e., sex partners who were not infected with HIV, not IDUs, or not men who had sex with men) than would be expected if unprotected sex and lower risk sex partners were independent.³² These data suggest that HIV-infected NIUs serve as a potential bridge for the heterosexual transmission of HIV to the more general population.

Research in developed countries has consistently shown the influence of substance use on HIV heterosexual transmission. Moreover, it has demonstrated that the characteristics of members of sex networks, as well as of the networks themselves, are related to the prevalence, incidence, and transmission potential of STIs, including HIV.

UNDERSTANDING HIV SEXUAL TRANSMISSION IN THE CONTEXT OF DEVELOPING COUNTRIES

Research in developing countries has contributed significantly to the conceptual, environmental, and biological understanding of HIV sexual transmission dynamics. In Africa, the early identification and utilization of core groups of the population, particularly sex workers, to monitor the epidemic led to a consideration of popula-

tion mixing patterns.^{33–36} In efforts to more fully understand the dynamics underlying observed population mixing patterns, researchers have begun to focus on environmental factors, such as migratory labor practices, which facilitate transmission through the geographic diffusion and mixing of populations with varying HIV prevalences.^{37–41} For example, investigators in Thailand found that 25% of truckers in their study had had sex with commercial sex workers, as well as with other female partners, such as their wives.⁴² The truckers acted as a conduit or bridge between different populations of women at higher and lower risk of being HIV infected. Thus, the occupational requirement of extended periods away from wives likely fueled, at least in part, truckers' structural role in HIV transmission.

A great deal of what is known about the biology of transmission has been learned from research in developing countries. Research conducted with core group populations has helped document the fact that STIs are potent biological cofactors in the sexual transmission of HIV.^{34,36,43} However, HIV-preventive interventions targeted at STI control in generalized epidemics^{34,44,45} have had dramatically different results, suggesting the need for further specification of the phase of the epidemic to improve understanding of transmission dynamics and the timing of specific interventions.⁴⁶ These data suggest that STI control may be only one component of multimethod and multilevel approaches to preventing HIV infection. More recently, research has described relationships between increased HIV viral load and heterosexual transmission,⁴⁷ as well as gender differences in the way HIV is acquired and transmitted.⁴⁸

The cumulative research has informed understanding of the biological and environmental components of HIV sexual transmission dynamics. However, further research is needed to characterize the epidemiology and co-occurrence of substance use and HIV sex transmission risk in developing countries. In many developing countries, the possible role of substance use in HIV transmission has been virtually ignored, with the notable exception of the narcotics-driven HIV epidemics occurring in Eastern Europe and Central Asia.

LINKAGES BETWEEN SUBSTANCE USE AND HIV SEX TRANSMISSION IN DEVELOPING COUNTRIES

One of the most rapid responses to HIV epidemics occurred in Eastern Europe and Central Asia in recognition of the narcotics-driven epidemics that dominate the region. Nongovernmental organizations, including the United Nations, were quick to establish syringe exchange programs in targeted areas as the epidemic spread.^{49,50} Unfortunately, the HIV epidemic has become more generalized in the region since the mid-1990s. For example, 1% of the adult population in Ukraine is known to be HIV infected, with an increasing proportion of individuals infected through sexual transmission.⁵¹ These data suggest that HIV prevention approaches among drug-using populations in developing countries may underemphasize the importance of sexual transmission risks. Conversely, HIV preventive interventions that focus on sex risk reduction may overlook the role of drugs, including alcohol, in facilitating unsafe sex. Given fairly ubiquitous alcohol use in developing countries with endemic or expanding sex-mediated HIV epidemics, future research is needed to better understand the role of alcohol and other substance use in shaping the scope and magnitude of the epidemic in these settings.

Although much research in developing countries has recruited study participants from venues where alcohol or other substance use is pervasive (e.g., bars,

truck stops, brothels, and other sex work environments), few studies have explicitly examined the relationship between HIV sex risk and substance use in these contexts.^{34,39,40,52–55} Exceptions include a study in Zimbabwe, where researchers found 3.4% HIV incidence among male beer hall patrons, and the only significant risk factor associated with both HIV prevalence and incidence was having had sex while intoxicated.⁵² Another study in Manipur, India, found that sex workers had high HIV prevalence in general, but the prevalence was nine times higher among sex workers who also injected drugs.⁵⁵ Among adolescents frequenting truck stops in Kenya, alcohol and khat use were both significantly associated with having, selling, and purchasing sex at the truck stop.³⁹ Finally, recent qualitative research reports that drinking establishments in southern Africa, where turnover among sex partners is common and condom use is minimal, are of primary importance in meeting future sex partners.^{40,53} Research in developing countries on associations between substance use and sex practices has consistently identified increased HIV transmission or transmission potential as an outcome. Although few in number, these studies support the thesis that a substance use–sex risk relationship in HIV transmission may be understudied or even overlooked in developing countries.

Changing drug trafficking patterns and international policing efforts have been linked to increases in the availability of illicit drugs in developing countries where they have not previously been available.⁵⁶ Moreover, although drug trafficking may be acknowledged by individual countries, the issue of drug use by citizens is often politically sensitive and does not receive attention until an HIV threat has already manifested itself,⁵⁷ as is the case in the former Soviet Republics. In countries where HIV is already endemic, however, little is known about the potentially increased risk of HIV transmission posed by the introduction of injecting drug use. A recent ethnographic study among women IDUs in a coastal resort city in Kenya found that, although heroin has been used since the mid-1990s when it was first introduced, injecting was not observed until 1999 when the smokable form of heroin was replaced with powdered—and readily injected—heroin.⁵⁸ Although no community-wide HIV prevalence studies have been conducted since that time, this is a completely new phenomenon in which injecting drug use has been introduced into an environment in which 20% of adults are already HIV infected. There is the possibility of exponential HIV transmission in the population due to the combination of increasing numbers of heroin injectors and existing levels of sexual risk and HIV that has yet to be explored.

SEX NETWORK VARIABLE MEASUREMENT AND IMPLICATIONS FOR INTERVENTION DEVELOPMENT AND EVALUATION

A distinction may be made between dyadic relationships, consisting of two people, and larger sex networks that are composed of multiple dyadic relationships. Dyads should be singled out from other sex network structures because they have a clear and identifiable role in HIV heterosexual transmission and may provide a point of intervention to disrupt disease transmission. In fact, there have already been two small-scale interventions to prevent heterosexual transmission between HIV-serodiscordant couples,^{59,60} and additional network-level interventions have been proposed.⁶¹ To scale up these interventions and to develop potentially more cost-effective alternative interventions, it is necessary to understand the characteristics and interactions of sex partner dyads and networks both at the population level and

among targeted communities at increased risk of acquiring or transmitting HIV. Therefore, sex network variables need to be included in both surveillance and research efforts.

For surveillance purposes, sex network variables may be measured at the aggregate level. In addition to the number of sex partners during a given period of time, data collected at this level include sex partner characteristics linked to an increased risk of disease transmission (e.g., number of sex partners known to be HIV infected, number of sex partners met at a drinking establishment). Additional data should be collected on the number of sex partners with given characteristics (e.g., both higher and lower risk characteristics), as well as on the frequency of condom use with sex partners. Questions to ascertain this information are straightforward (e.g., how many of your partners did you know well? How often was a condom used when you had sex with people you know well?). These data may be grouped to further understand transmission dynamics at the population level. Data can be constructed to capture disassortative (i.e., like with unlike) mixing patterns between sex partners; the proportion of sex partners possessing specific HIV risk attributes; the respondent's bridging role due to having sex with both higher and lower risk sex partners; and concurrent sex partnerships over short and longer term time frames.

Individuals may provide egocentric-level (i.e., partner-specific) data that capture structural network features and describe linkages between and among sex partners, although such data are more difficult and time-consuming to collect. Structural-level influences that are measurable through egocentric data collection include multiplexity (i.e., overlap between behavioral risk and social influence networks);⁶² density (i.e., the proportion of people in an individual's network who know each other and/or share behaviors); and sex partner change or turnover, particularly if the study is longitudinal. These data are partner specific and link information concerning an individual's behaviors and relationships with each partner, as well as documenting the relationships among network members; these data may not be measured at the aggregate level.

Despite a high level of analytical complexity involved with sex network variables, the constructs that can be developed from these data may more accurately reflect and quantify transmission dynamics than the more familiar, traditional approaches that have been utilized thus far. However, the development of meaningful constructs predicates the consistent measurement of *both* respondent and sex partner characteristics. The ability to recognize HIV transmission dynamics associated with specific sex network characteristics or structures is key for developing interventions at either the network or the community level. In addition, since interventions implemented at the network or community level will benefit individuals who have direct contact with intervention staff, as well as those who never have contact with intervention staff, only data that describe the network or community (e.g., targeted or sentinel surveillance data) may be used to evaluate interventions that affect an unknown proportion of the population. As a result, it is essential to develop and improve network- and community-level measures of the prevalence, incidence, and changes in network characteristics and structures.

Researchers have been working to conceptualize and design interventions for the network or community level. Such interventions have the potential to break or interrupt the connection between components or groups (e.g., by isolating or removing individuals who bridge higher and lower risk populations). Researchers have examined the potential of place- or site-based interventions that are developed

by identifying sites where new sex partnerships are known to form.^{40,63} Developing and evaluating such interventions requires estimates of the proportion of the population that participates in place-based networks⁴⁰ as well as accurate population- and community-level surveillance data. Follow-up evaluation methods will also require accurate surveillance data, at least as one component in the overall evaluation.

CONCLUSION

There is a need to synthesize experience and practice from developed countries, in which substance use has been shown to be an important mechanism of HIV sexual transmission, and from developing countries, where HIV has been linked to environmental factors that facilitate sexual transmission. Moreover, given that HIV sexual transmission dynamics are linked to interactions between substance use and sex network factors, it is critical to examine substance use as a framework within which HIV sexual transmission occurs, particularly in developing countries that focus on either substance use or sex-mediated HIV transmission though not on both. The characteristics of network members and structural relationships within and across sex networks have identifiable roles in the spread of HIV. These characteristics and relationships are measurable at the individual level and can contribute substantively to improving network and community surveillance. They are also essential for the development and evaluation of network- and community-based interventions.

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