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A quantitative risk assessment of multiple factors influencing HIV/AIDS transmission through unprotected sex among HIVseropositive men

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Abstract

The objective of this study is to conduct a quantitative risk assessment of multiple factors influencing HIV/AIDS transmission through unprotected sexual practices among HIVseropositive men. A knowledgebase was developed by reviewing different published sources. The data was collected from different sources including Centers for Disease Control and Prevention (CDC), selected journals, and reports. The risk pathway scenario tree was developed based on a comprehensive review of published literature. The variables are organized into nine major parameter categories. Monte Carlo simulations for the quantitative risk assessment of HIV/AIDS transmission was executed with the software @Risk 4.0 (Palisade Corporation) Results show that the value for the likelihood of unprotected sex due to having less knowledge about HIV/AIDS and negative attitude towards condom use and safer sex ranged from 1.24×10^{-5} to 8.47×10^{-4} with the mean and standard deviation of 1.83×10^{-4} and 8.63×10^{-5} respectively. The likelihood of unprotected sex due to having greater anger-hostility, anxiety, less satisfied with aspects of life and greater depressive symptoms ranged from 2.76×10^{-9} to 5.34×10^{-7} with the mean and standard deviation of 5.23×10^{-8} and 3.58×10^{-8} respectively. The findings suggest that HIV/AIDS research and intervention programs must be focused on behavior, and the broader setting within which individual risky behaviors occur.

Keywords

HIV/AIDS; pathways; quantitative risk assessment; Monte Carlo simulations; CDC

INTRODUCTION

The HIV/AIDS pandemic remains one of the most serious global health challenges. The number of HIV-seropositive people worldwide continued to grow in 2008, reaching an estimated 33.4 million and AIDS killed 2 million people worldwide 280,000 of them were children under 15 years old (UNAIDS and WHO, 2009). Daily over 7,400 people become infected and about 5,500 people die from AIDS, mostly because of inadequate access to HIV prevention care and treatment services (WHO, UNICEF and UNAIDS, 2009).

Globally HIV continues to spread mainly through sexual transmission (CDC, 2000). Many people infected with HIV engage in safer-sex practices; however, a considerable percentage of HIV-seropositive people continue to engage in unprotected sexual behaviors that place

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others at risk for infection and place themselves at risk for contracting secondary infections (e.g., syphilis, gonorrhea, herpesvirus-6) that may accelerate HIV/AIDS (Balquez, Madueno, Jurado, Fernandez and Munoz1995; Fleming and Wasserheit, 1999). As more and more HIV-seropositive people live longer and healthier lives because of the Highly Active Antiretroviral Therapy (Vittinghoff, Scheer, O'Malley, Colfax, Holmberg, and Buchibinder, 1999) an increasing number of sexual transmission of HIV may stem from those who know they are infected and engage in unprotected sex (Kalichman, 2000; Schiltz and Sandfort, 2000).

Research shows that misconceptions about HIV/AIDS and protective behaviors and low level of accurate knowledge about the transmission of HIV/AIDS and psychosocial factors such as depression and anxiety can contribute to HIV-seropositive people engaging in risky behaviors. Psychosocial problems, in turn, have been shown to influence sexual-risk taking and HIV/AIDS transmission (Benotsch et al. 1999). However, studies of the relationship between psychosocial problems and unsafe sexual practices have had inconsistent findings.

Four widely cited conceptual theories used in relation to HIV/AIDS are Health Belief Model (HBM); Theory of Reasoned Action (TRA) and its extension, the Theory of Planned Behavior (TPB); the Trans-theoretical Model (TTM) or Stages of Change Model (SOC); and the Precaution Adoption Process Model (PAPM). However, none of these models or theories was chosen for this study because this study was not intended to determine if the variables of any theories would predict a change in HIV/AIDS risky behaviors. The trans-theoretical model was not chosen for this study because it would have required a complex and cumbersome research design. The theories of reasoned action and planned behavior are the most cited in HIV/AIDS research, and have been found to be better predictors of HIV/AIDS health behavior than other models (Fishbein, 1993; Terry, Gallois & McCamish, 1993; Warwick et al., 1993).

The central purpose of this study was to tease out and quantify the contributions of each psychosocial factor, of HIV/AIDS related knowledge and belief on the likelihood of unprotected sex. Thus, no single model was applied in this study. Despite the strong relationship between psychosocial determinants and risky sexual behavior in HIV-seropositive people, to date, relatively few studies have attempted to assess the role of psychosocial determinants in HIV/AIDS risky behaviors. The objective of this study is to conduct a quantitative risk assessment of multiple factors influencing HIV/AIDS transmission through unprotected sexual practices among HIVseropositive men. This study addresses two key research questions: What places people at risk of acquiring HIV infection through unprotected sex? and What are the determinants of risky behaviors? Epidemiologic approaches, which provide the framework for addressing HIV/AIDS transmission in a multidisciplinary and integrative manner, are implemented to address the above research questions.

The hypothesis we are testing is that a quantitative risk assessment of risky sexual behaviors for HIV/AIDS transmission through unprotected sex that interrelate multiple factors can be done to tease out the risky sexual behavior's contributions quantitatively for each of these factors upon the HIV/AIDS transmission.

MATERIALS AND METHODS

This Quantitative risk assessment is based on a comprehensive review of published literature that have examined psychological, social and interpersonal variables as correlates of sexual risk behavior in people who are HIV-positive, The Epidemiologic Problem Oriented Approach (EPOA) methodology was used to gather the fundamental information and data,

which are used in the variable and parameter estimations and analysis (biological, mathematical, statistical and computer simulations) used for risk assessments and modeling (Habtemariam 1989, Yu et al, 1997). EPOA consists of two generic steps; problem identification and problem solving.

The risk pathway presented in figure 1 consists of a sequence of specific events and for each node or event a specific question related to the risk of unprotected sex is asked. The product of the probabilities of the answers to these questions determined the final risk related to unprotected sex. However, other relevant social factors such as social capital, cultural context, and neighborhood effects (social environments, socioeconomic factors, and physical environment) which affect people's decisions to engage in unprotected sex were not included in this study. The review included 17 published articles contributing tests of association for 23 variables associated with sexual risk behaviors. Monte Carlo Simulations with the software @Risk 4.0 (Palisade Corporation) was used for analysis. Sensitivity analysis was used to show the aggregate effect of each input variable on the likelihood of unprotected sex. A total of 10,000 iterations were done for the simulations. The variables are organized into 9 major categories (Figure 1). @ Risk Beta distributions were used to calculate the likelihood of HIV transmission through unprotected sex due to having less knowledge about HIV/AIDS and beliefs about condoms and safer sex and due to emotional states and personality affecting safer sex.

Quantitative Risk Assessment requires that each parameter should be described and scientific evidence presented to justify the parameter estimates. The quantified parameter values of the model were presented in terms of beta distributions. The Beta distribution is a family of continuous probability distributions defined on the interval (0, 1) parameterized by two positive shape parameters, typically denoted by α and β . It has two main uses: 1) As the description of uncertainty or random variation of a probability, fraction or prevalence; 2) It can be rescaled and shifted to create distributions with a wide range of shapes and over a finite range. It is sometimes used to model expert opinion. In this research, we used it to capture the uncertainty of the effect size, as this value is coming from a sample population.

To see the effect of various inputs on the output, sensitivity analysis was performed using a regression tornado graphs, and tables of regression and correlations.

PARAMETER ESTIMATES

P1 The probability that having less knowledge about HIV/AIDS is associated with the likelihood of HIV transmission through unprotected sex

The two specific variables examined are having less knowledge about HIV/AIDS and not knowing condom use can prevent HIV infection. The effect sizes are 0.3 (n=109) (McCown, 1993) and 0.51 (n=181) (Hushti, Parsons, and Cotton, 1998) respectively. Since the effect size is interpreted as a proportion in some literature ((Hushti, Parsons, and Cotton, 1998; National Center for Education Statistics, 2002; Mason Academic Research System, 2009), the effect size was translated into proportions (p) throughout parameter estimation (Table 1). The probability distributions of individual variables were determined by using the @Risk beta distributions @RiskBeta(α_1 , α_2), where $\alpha_1 = p \cdot n + 1$ and $\alpha_2 = q \cdot n + 1$ where $q = 1 - p$.

P2 The probability of negative beliefs about condoms and safer sex is associated with the likelihood of HIV transmission through unprotected sex.

Two specific variables examined in relation to sexual risk behavior are having belief that safer sex decreases sexual pleasure and having negative attitudes towards condoms. Effect sizes are 0.39 (n=43) (Graham and Ian, 1996) and 0.25 (n=94) (Hays, Paul, Ekstrand,

Kegeles, Stall, and Coates, 1997) respectively. The probability value for individual variables was determined by @RiskBeta as described previously.

P3 The probability of lack of sexual communication is associated with the likelihood of HIV transmission through unprotected sex.

Three variables examined in relation to sexual risk behavior are not disclosing one's HIV positive status to sex partner, less frequently tried to talk to sex partners into practicing safer sex, and problems communicating about safer sex. The respective effect sizes 0.16 (n=182) (Godin, Savard, Kok, Fortin, and Boyer, 1996), 0.19 (n=256) (Rosa and Marks, 1998) and 0.5 (n=43) (Semple, Patterson, and Grant, 2000). The respective @RiskBeta probability distributions were (30.12, 153.88), (49.64, 208.36) and (22.5, 22.5).

P4 The probability of negative HIV related attribution is associated with the likelihood of HIV transmission through unprotected sex.

Three specific variables were used: attributing responsibility/blame for one's HIV infection to other, people, attributing one's HIV infection to something that another person intentionally did it to you, and attributing cause of one's HIV infection to self. The respective effect sizes were 0.35 (n=71) (Hays, Paul, Ekstrand, Kegeles, Stall, and Coates, 1997), 0.49 (n=71) (Hays, Paul, Ekstrand, Kegeles, Stall, and Coates, 1997), and 0.3 (n=49) (Bingman, Marks, and Crepaz, 2001). The respective @RiskBeta probability distributions were (25.85, 47.15), (35.79, 37.21) and (15.7, 35.3).

P5 The probability of less intention/commitment to use condoms and safer sex is associated with the likelihood of HIV transmission through unprotected sex.

Five specific variables examined were: less intention to use condoms, less intention to avoid unsafe sex, less self commitment to practice safer sex, less commitment to others to practice safer sex and less confidence in one's ability to enact safer sex practices. Their respective effect sizes were 0.37 (n=40) (Clement, 1992), 0.22 (n=85) (Vroome, Wit, Stroebe, Sandfort, and Griensven, 1998), 0.37 (n=51) (Kalichman, Kelly, and Rompa, 1997), 0.32 (n=51) (Kalichman, Kelly, and Rompa, 1997) and 0.37 (n=181) (Darrow, Webster, Kurtz, Buckley, Patel, and Stempel, 1998). Their respective @RiskBeta probability distributions were (15.8, 26.2), (19.7, 67.3), (19.87, 33.13), (17.32, 35.68) and (67.97, 115.3).

P6 The probability of emotional states and personality affecting safer sex is associated with the likelihood of HIV transmission through unprotected sex.

Five specific variables examined in relation to sexual risk behavior were: greater anger-hostility, greater anxiety, greater depressive symptoms, less satisfied with aspects of life, and greater tolerance of HIV positive persons who withhold disclosure from partners. Their respective effect size sizes were 0.29 (n=111) (Hushti, Parsons, and Cotton, 1998), 0.24 (n=111) (Hushti, Parsons, and Cotton, 1998), 0.5 (n=49) (Marks and Bingman, 1998), 0.39 (n=32) (Clement, 1992) and 0.18 (n=202) (Kalichman, Greenberg, and Abel, 1997). Their respective @RiskBeta probability distributions were (33.19, 79.81), (27.64, 85.36), (25.5, 25.5), (13.48, 20.52) and (37.56, 166.64).

P7 The probability that reduced concern about unsafe sex because of new treatments for HIV/AIDS is associated with the likelihood of HIV transmission through unprotected sex

The effect size between reduced concern about unsafe sex because of new treatments for HIV/AIDS and unprotected sex is 0.4 (n=96) (Vanable, Ostrow, McKirnan, Taywaditep, and Hope, 2000). The @RiskBeta probability distribution was (39.4, 58.6)

P8 The probability of greater number of previous sex partner is associated with the likelihood of unprotected sex is associated with the likelihood of HIV transmission through unprotected sex

The effect size between greater number of previous sex partner and unprotected sex is 0.39 (n=43) (Johnson, 1993). The @RiskBeta probability distribution was @RiskBeta(17.77, 27.33)

P9 The probability of using more avoidance coping strategies (e.g., distraction from thinking about one's infection) is associated with the likelihood of HIV transmission through unprotected sex

The effect size between using more avoidance coping strategies and unprotected sex is 0.44 (n=49) (Weinhardt, Carey, Johnson, and Bickham, 1999). The @RiskBeta probability distribution was (17.77, 27.33)

RESULTS

Results of the analysis show that having less knowledge about HIV/AIDS, believing that safer sex decreases sexual pleasure, having less intention to engage in safer sex, and having little commitment to self or others to practice safer sex are associated with likelihood of unprotected sex. The value for the likelihood of unprotected sex due to having less knowledge about HIV/AIDS and negative attitude towards condom and safer sex ranged from 1.24×10^{-5} to 8.47×10^{-4} with the mean and standard deviation of 1.83×10^{-4} and 8.63×10^{-5} respectively (Table 2).

The result in Table 2 also shows that emotional states and personality affecting safer sex (P6) such as depression, anxiety, or emotional distress were associated with the likelihood of unprotected sex. The likelihood of unprotected sex due to these variables ranged from 2.76×10^{-9} to 5.34×10^{-7} with the mean and standard deviation of 5.23×10^{-8} and 3.58×10^{-8} respectively.

Sensitivity Analysis

Sensitivity analysis results of selected variables that were examined together with their sensitivity ranking with respect to the likelihood of unprotected sex due to having less knowledge about HIV/AIDS and negative beliefs about condom use and safer sex are given in Table 3 (a). The results of sensitivity analysis of 8 variables that were examined for the sensitivity ranking for likelihood of unprotected sex due to emotional states and personality are presented in Table 3 (b). Table 3 (a) shows that attributing cause of one's HIV infection to self (0.312), less commitment to others to practice safer sex (0.288), and less intention to avoid unsafe sex (0.286) were strong predictors of unprotected sex. The results in Table 3 (b) indicate that emotional states such as less satisfied with aspects of life (0.441), greater number of sexual partners (0.376), and anxiety (0.334) were strong predictors of the likelihood of unprotected sex.

Tornado charts

The two tornado charts (Figure 2) provide pictorial representation of a sensitivity analysis of the simulation results intended to demonstrate the importance of each input to an output. They illustrate the degree to which the uncertainties of output variables are affected by the

uncertainty of the individual variables within the node. The higher the degree of correlation between the input and output variables (calculated using rank-order correlation), the more the input variable is affecting the output. For example, the uncertainties of the variables “attributing cause of one’s HIV infection to self” 0.298 and “less commitment to others to practice safer sex ” 0.291 are higher when compared with the uncertainties of the variables “less confidence in one’s ability to enact safer sex practices ” 0.14 and “not knowing condoms can prevent HIV infection ” 0.112 (Figure 2).

DISCUSSION

In this study, an exhaustive review of literature on the epidemiology and determinants of HIV/AIDS transmission has been organized into two major categories from which relevant data for building the epidemiologic model for factors influencing unprotected sexual practices was derived. These are psychosocial variables and negative belief about condom use. The findings suggest that psychosocial problems and negative belief about condom use influence unprotected sexual intercourse and may contribute to the high probability of HIV infection within high-risk populations. Epidemiologic modelling is an essential research tool that scientists can employ to quantify the contribution of each HIV/AIDS risky behaviors to examine alternative strategies for effective interventions that lead to better planning and policy-making for all disease control and prevention efforts.

Study, results confirmed that psychosocial variables, lack of knowledge and misconceptions about HIV/AIDS and negative attitudes and beliefs about condoms are linked to the tendency to have sexual intercourse without condoms. The findings also indicate that HIV-seropositive people continue to engage in HIV/AIDS risky behaviors after the knowledge of their HIV status. There are several possible explanations for this finding. First, with the advent of HAART in 1996 mortality among HIV-seropositive people decreased dramatically (Bouhnik et al., 2007). Most of the HIV-seropositive people who get therapeutic benefits from HAART may attain an improved quality of life and functional status with the alleviation of the physiological, social, and psychological consequences of HIV/AIDS. These gains may be accompanied by increases in HIV/AIDS-risky behaviors that include unprotected sexual intercourse. Secondly, HIV seropositive people may have unrealistic beliefs about the impact of HAART on disease transmission rates and therefore may perceive the consequences of transmitting HIV/AIDS as being less serious than in the past. In this era of HAART, addressing the psychosocial health burdens and negative belief about condom use among HIV-seropositive people will be an essential component to the development of effective strategies to combat HIV/AIDS. Understanding the multiple variables that impact on HIV/AIDS-risky behaviors in HIV-seropositive people will be critical in the search for alternatives to the way in which these problems are addressed at the present time. Cross-disciplinary research – to include advanced knowledge of basic and applied psychological and social research and the manners in which they interact together – is needed to develop effective HIV/AIDS prevention and control strategies.

CONCLUSION

To date, only a limited number of studies have examined the impact of psychosocial factors on unprotected sex. Incorporating the psychosocial variables in assessing sexual risk behavior in HIV-seropositive people could be helpful in formulating public policies and prevention strategies for HIV/AIDS prevention. Factors that predicted unprotected sex are lack of basic knowledge about HIV/AIDS transmission and prevention, lack of awareness of their partner's HIV status, problems communicating about safer sex, attributing their HIV infection to something that another person intentionally did it to them, anxiety, depression and less intention/commitment to use condoms and safer sex. The findings illustrate the

types of strategies that need to be addressed in behavioral interventions for HIV-seropositive people.

RISK MITIGATIONS, RECOMMENDATIONS AND FUTURE RESEARCH PLANS

Based on the findings of this study, our recommendations are:

1. Further research is needed to replicate and expand upon these findings. This study has focused on individual-level risk factors. Future research and interventions related to HIV/AIDS must focus more keenly on socioeconomic factors, contextual dimensions, social networks or ecological variables, such as the community-level, relationship-level, and biological-level variables.
2. Additional research is needed to examine the resistance to behavior change as well as the motivation for behavior change as these factors are central to the design of effective HIV/AIDS prevention and intervention strategies
3. Develop cross-disciplinary research that includes advanced knowledge of basic and applied psychological and social research and the ways in which they interact together.
4. Encourage strong collaborations among researchers, policy-makers, and communities to identify and address biomedical, behavioral, and psychosocial factors that are responsible for the risky sexual behaviors that ultimately result in further transmission of HIV/AIDS.
5. A holistic and integrated approach that focuses on psychological processes, behavioral skills, and the dynamics of sexual interactions and relationships should be developed at multiple intervention levels

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Figure 1.
Risk scenario pathway for the likelihood of unprotected sex

Figure 2.

Tornado chart showing the likelihood of unprotected sex due to : 1) less knowledge about HIV/AIDS and beliefs, 2) emotional states and personality

Table 1

Parameter estimates for the @RiskBeta probability distributions

Parameter Description	P	n	$\alpha 1$	$\alpha 2$
P1: The probability that having less knowledge about HIV/AIDS is associated with the likelihood of HIV transmission through unprotected sex				
Less HIV/AIDS knowledge	0.31	109	34.79	76.21
Not knowing condoms can prevent HIV infection	0.51	181	93.31	89.69
P2: The probability of negative beliefs about condoms and safer sex is associated with the likelihood of HIV transmission through unprotected sex				
Belief that safer sex decreases sexual pleasure	0.39	43	17.77	27.23
Negative attitude towards condoms	0.25	94	24.5	71.5
P3: The probability of lack of sexual communication is associated with the likelihood of HIV through unprotected sex				
Not disclosing one's HIV positive status to sex partner	0.16	182	30.12	153.88
Less frequently tried to talk to sex partners into practicing safer sex	0.19	256	49.64	208.36
Problems communicating about safer sex	0.5	43	22.5	22.5
P4: The probability of negative HIV related attribution is associated with the likelihood of HIV through unprotected sex				
Attributing responsibility/blame for one's HIV infection to other person	0.35	71	25.85	47.15
Attributing one's HIV infection to something that another person intentionally did it to you	0.49	71	35.79	37.21
Attributing cause of one's HIV infection to self	0.3	49	15.7	35.3
P5: The probability of less intention/commitment to use condoms and safer sex is associated with the likelihood of HIV transmission through unprotected sex				
Less intention to use condoms	0.37	40	15.8	26.2
Less intention to avoid unsafe sex	0.22	85	19.7	67.3
Less self commitment to practice safer sex	0.37	51	19.87	33.13
Less commitment to others to practice safer sex	0.32	51	17.32	35.68
Less confidence in one's ability to enact safer sex practices	0.37	181	67.97	115.03
P6: The probability of emotional states and personality affecting safer sex is associated with the likelihood of HIV transmission through unprotected sex				
Greater anger-hostility	0.29	111	33.19	79.81
Greater anxiety	0.24	111	27.64	85.36
Greater depressive symptoms	0.5	49	25.5	25.5
Less satisfied with aspects of life	0.39	32	13.48	20.52
Greater tolerance of HIV positive persons who withhold disclosure from partners	0.18	202	37.36	166.64
P7: Reduced concern about unsafe sex because of new treatments for HIV/AIDS	0.4	96	39.4	58.6
P8: Greater number of previous sex partners	0.39	43	17.77	27.23
P9: Using more avoidance coping strategies (distraction from thinking about one's infection)	0.44	49	22.56	28.44

Table 2

Output summary statistics for the likelihood of unprotected sex due to having less knowledge about HIV/AIDS and negative attitude towards condom and safer sex and emotional states and personality affecting safer sex

@RISK Output statistics	Emotional states and personality affecting safer sex	Having less knowledge about HIV/AIDS and beliefs
Mean	5.23E-08	1.83E-04
Maximum	5.34E-07	8.47E-04
Standard Deviation	3.58E-08	8.63E-05
Variance	1.28E-15	7.45E-09
Mode	6.98E-08	6.93E-05
5%	1.50E-08	7.43E-05
95%	1.20E-07	3.45E-04

Table 3

Sensitivity ranking for the likelihood of unprotected sex due to: (a) having less knowledge about mode of HIV/AIDS transmission and negative beliefs about condoms and safer sex, and (b) emotional states and personality

Sensitivity Ranking by Step-Wise Regression	Variables	Regression
(a) The likelihood of unprotected sex due to having less knowledge about mode of HIV/AIDS transmission and negative beliefs about condoms and safer sex		
1	Attributing cause of one's HIV infection to self	0.312
2	Less commitment to others to practice safer sex	0.288
3	Less intention to avoid unsafe sex	0.286
4	Less intention to use condoms	0.284
5	Belief that safer sex decreases sexual pleasure	0.273
6	Less self commitment to practice safer sex	0.252
7	Negative attitude towards condoms	0.248
8	Not disclosing one's HIV positive status to sex partner	0.237
9	Attributing responsibility/blame for one's HIV infection to other persons	0.226
10	Problems communicating about safer sex	0.215
11	Less HIV/AIDS knowledge	0.197
12	Less frequently tried to talk to sex partners into practicing safer sex	0.187
13	Attributing one's HIV infection to something that another person intentionally did it to you	0.180
14	Less confidence in one's ability to enact safer sex practices	0.133
15	Not knowing condoms can prevent HIV infection	0.103
(b) The likelihood of unprotected sex due to emotional states and personality		
	1 Less satisfied with aspects of life	0.441
	2 Greater number of previous sex partners	0.376
	3 Greater anxiety	0.344
	4 Using more avoidance coping strategies	0.327
	5 Greater tolerance of HIV positive persons who withhold disclosure from partners	0.304
	6 Greater anger-hostility	0.301
	7 Greater depressive symptoms	0.291
	8 Reduced concern about unsafe sex because of new treatments for HIV/AIDS	0.261