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Risk Compensation in HIV Prevention: Implications for Vaccines, Microbicides, and Other Biomedical HIV Prevention Technologies

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Abstract

Studies investigating the effects of biological HIV prevention technologies have been reported with promising results for slowing the spread of HIV. Although prevention technologies can reduce the rate of HIV transmission at varying levels of efficaciousness, it is vital to anticipate the impact of HIV prevention technologies on subsequent sexual behaviors. Risk homeostasis theory posits that decreases in perceived risk, which will occur with access to HIV prevention technologies, will correspond with increases in risk taking behavior. Here we review the literature on risk compensation in response to HIV vaccines, topical microbicides, antiretroviral medications, and male circumcision. Behavioral risk compensation is evident in response to prevention technologies that are used in advance of HIV exposure and at minimal personal cost. We conclude that behavioral risk compensation be addressed by implementing adjunct behavioral risk reduction interventions to avoid negating the preventive benefits of biomedical HIV prevention technologies.

Introduction

An important step in reducing HIV transmission involves understanding how individuals contemplate their own risk, particularly in the context of increasingly available biomedical technologies for reducing HIV transmission. Reductions in HIV transmission risks that result from HIV prevention technologies, such as vaccines, topical microbicides, antiretroviral medications, and male circumcision, have the potential to simultaneously lower perceptions of risk which in turn may alter risk-related behaviors. An inadvertent increase in risk behaviors following the application of a risk reduction technology is termed behavioral disinhibition or risk compensation [1]. It is the evidence for potential increases in risk practices that can follow the introduction of risk reducing technologies that is the subject of this review.

Risk compensation threatens the potential benefits of newly developed and emerging HIV prevention technologies, no single one of which will likely exceed 60% protection. Because consistent use of condoms offers 90% protection against HIV, any significant reductions in condom use as well as increases in behaviors that risk co-occurring sexually transmitted infections (STI), can offset the protective value of a given prevention technology [2]. For example, mathematical modeling suggests that even modest increases in sexual risk behaviors resulting from increased use of antiretrovirals will offset the potential preventive benefits of HIV treatments [3]. Concerns that risk compensation threatens the protective benefits of HIV prevention technologies have been discussed [4], and there is now an emerging empirical literature on risk compensation in response to HIV prevention technologies.

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Here we review empirical and mathematical modeling studies that have investigated risk compensation for HIV transmission. Our literature search was completed in March 2007, using several automated search engines, including PsychINFO, PubMed, and Google Scholar with key terms risk compensation, risk homeostasis, behavioral disinhibition, risk perceptions, HIV technologies, and HIV prevention. Manual searches through selected journals (e.g., *AIDS, AIDS and Behavior, JAIDS*) for relevant articles were also completed. For the purpose of this review, we define HIV prevention technologies as biomedical and non-behavioral strategies aimed to reduce HIV transmission, namely HIV vaccines, topical microbicides, antiretroviral medications including their use in pre-exposure prophylaxis (PrEP) and post-exposure prophylaxis (PEP), and male circumcision. For the present paper, we define risk compensation as an increase in risk-related behaviors, such as numbers of sex partners, unprotected sex acts, and injection equipment sharing in response to biomedical prevention technologies.

Theoretical considerations

Knowing how individuals contemplate their perceived risk for HIV is a critical step in estimating the population impact of HIV prevention technologies. Wilde [5] developed *risk homeostatsis theory* to explain how individuals manage their personal risks. Risk homeostasis is defined as a system in which people accept a certain level of subjectively estimated risk to their health and safety in exchange for the benefits they expect to receive from that activity. Figure 1 shows Wilde's model adapted for HIV risk compensation. As circumstances in the environment change, such as the availability of risk reducing technologies, estimates of personal risk will change, which in turn will result in risk compensatory behavior change.

In Wilde's model, the first step in determining the level of risk an individual will accept for an adverse outcome, such as HIV infection, is to define the individual's target set point. Determining the target set point generally involves an analysis of the costs and benefits of protective and risk behaviors. Once the target set point is selected a comparative process occurs between perceived risks and the target level of risk that an individual is willing to take. A discrepancy between the target set point of the amount of risk that one is willing to take and one's perceived actual risk causes an adjustment in behavior that is aimed to reduce the discrepancy between the level risk willing to take and perceived actual risk. Maintaining constancy or homeostasis in perceived level of risk that is consistent with the target set point of risk requires self-monitoring and risk processing, resulting in a dynamic and closed-loop process [5]. The application of a risk reducing preventive technologies theoretically reduces constraints on risk behaviors without concomitant increases in perceived risks. Potential risk compensating behaviors, however, likely vary among different HIV prevention technologies.

Results of the review

We examined risk compensation resulting from HIV vaccines, topical microbicides, antiretroviral medications, and male circumcision. However, no studies were found that directly assessed risk compensating behaviors in relation to vaginal or anal microbicides. Table 1 summarizes the currently available evidence for behavioral risk compensation resulting from three sought after HIV prevention technologies: HIV vaccines, antiretroviral therapies, and male circumcision.

HIV vaccines

A safe and effective HIV vaccine is arguably the single most sought after of all HIV prevention technologies. Since the earliest days of the HIV epidemic, dozens of candidate HIV vaccines have proceeded to phase I clinical trials [6], and many of these vaccines have resulted in varying rates of success in terms of their ability to produce HIV specific immune responses. Thus far, only two vaccines have progressed to phase III clinical trials, neither of which, unfortunately,

produced sufficiently positive results to justify moving forward. An effective HIV vaccine remains elusive because of HIV's rapid and adaptive mutation rate. New approaches to HIV vaccines are continually being developed and hope remains that a safe and effective HIV vaccine will one day be available.

Studies have assessed the potential behavioral effects of HIV vaccines. Mathematical models have taken into account the possibility for risk compensation in response to an HIV vaccine. With increases in risk compensating behavior, there is a negative cumulative effect of vaccinating individuals. However, the degree to which compensatory risk behaviors offset the effects of a vaccine is a function of not only vaccine efficacy and the degree of risk compensation, but also the virulence of HIV in the population. Co-occurring increases in risk behaviors with partial protection from a vaccine can potentially eliminate the spread of the most attenuated virus, whereas the most virulent strains of HIV will continue to spread [7].

Qualitative research has shown that individuals often express their own concerns about increases in vaccine induced sexual risk behaviors. Focus group research has reported that commercial sex workers, for example, would have few fears of HIV once they have been vaccinated, diminishing their motivation to have customers use condoms [8]. Individuals perceive HIV as less of a threat in the event that they were vaccinated and that they would likely increase their sexual risk behaviors following vaccination.

Risk compensation studies in the context of HIV vaccine trials are quite limited. In the few studies that have assessed risk compensation in relation to vaccine trial participation, increases in HIV risk behaviors have been observed, providing evidence that risk compensation occurs after receipt of an HIV vaccine (see Table 1). Increases in unprotected anal intercourse over the course of a placebo-control HIV vaccine trial has been reported [9], unprotected intercourse more than doubled over the course of the trial among participants who were vaccinated. Furthermore, hepatitis B vaccination, which can offer insight into HIV vaccination, among MSM has been associated with increases in unprotected anal intercourse [10].

Topical microbicides

Research is currently underway to develop chemical compounds to serve as topical *microbicides*, that when applied to the vaginal or rectal mucosa protects against HIV transmission [11]. Some microbicides have attempted to provide a barrier that keeps HIV from reaching target cells; whereas other products have attempted to maintain the natural protection of the vaginal environment, and still other agents have attempted to prevent HIV replication once the virus enters cells. To date, there are more than twenty different microbicides in various stages of clinical development.

Thus far, there is limited data on the effects of microbicides on compensatory risk behavior. Some evidence for potential risk compensation comes from studies of men who have sex with men (MSM). MSM who are HIV positive and engage in unprotected anal intercourse show greater acceptance towards using a microbicide than men who do not engage in unprotected anal intercourse [12]. Studies have also found that MSM who are unlikely to use condoms are more likely to use microbicides [13]. There is evidence for risk compensation in response to early use of nonoxynol-9, an effective spermicide that was once thought to offer protection against HIV. Use of nonoxynol-9 among MSM became common and, in some instances, MSM were replacing condoms with nonoxynol-9 [14]. Because microbicides will only be partially protective, along the order of 35% protective [15]; reductions in condom use in favor of microbicides could result in an increase in HIV transmission. However, use of microbicides by individuals who refuse to use condoms will surely have a protective benefit. The overall population protective benefits of microbicides is therefore unknown.

Antiretroviral medications for HIV prevention

There are three major avenues under study for using HIV treatments for HIV prevention: treatment to reduce HIV infectiousness, PrEP, and PEP.

Highly active antiretroviral therapy (HAART) for reducing HIV infectiousness

Because HAART decreases HIV viral load in blood, it is common to believe that individuals are less infectious when their viral load is undetectable. Evidence for risk reduction resulting from lower viral load comes from several sources, including the reduced risk of mother-to-child transmission when HIV positive pregnant women are treated with antiretrovirals. Also, HIV viral load has been identified as a critical predictor of HIV transmission among heterosexual couples in Uganda, where a 1-log increase in an HIV positive partner's viral load corresponds to a risk ratio of 2.45 for HIV transmission [16]. Having an undetectable viral load is often associated with increases in unprotected intercourse [17–19]. Moreover, taking protease inhibitors is associated with decreases in unprotected intercourse among MSM [20].

In a meta-analysis of the HIV treatment and risk behavior literature, Crepaz et al. [21] examined the relationship between HAART, viral load, and sexual risk behaviors. Individuals who believe that HAART reduces the likelihood of HIV transmission or that HIV transmission is less of a concern because of HAART are more likely to engage in unprotected sex. In addition, individuals are more likely to engage in unprotected sex if they endorse the belief that an undetectable viral load adds protection against transmitting HIV.

Unfortunately, peripheral blood viral load is not a reliable indicator of HIV infectiousness. In fact, the correlation between HIV viral load in blood plasma and semen ranges between .20 and .60 ($p<.05$ [22,23]), with some studies finding no association between blood and semen viral loads [24]. Beliefs regarding the protective benefits of having an undetectable viral load based on blood plasma are, therefore, potentially erroneous. In addition, viral load tests are based on detecting copies of free viral RNA in blood plasma and do not quantify cell-associated HIV, which is a major source of HIV in genital secretions [25]. Perhaps most important are non-HIV STIs that increase HIV viral shedding in the genital tract, again causing HIV in semen to spike well beyond what would be expected based on blood plasma viral loads [26]. Finally, different antiretroviral agents have varied degrees of genital compartment penetration, so drug levels are not necessarily the same in all compartments at any given time, especially when adherence to regimens is low. Nevertheless, there is strong evidence that beliefs that HAART offers protection against HIV transmission are prevalent and contribute to risk compensating behaviors.

Preexposure prophylaxis (PrEP)

PrEP is an HIV prevention method in which antiretrovirals are administered protectively to individuals who are known to be HIV negative. The rationale for PrEP is to prevent HIV from replicating following exposure to an HIV transmission event, therefore decreasing the likelihood of HIV establishing permanent infection [27]. The efficacy of PrEP, as an HIV prevention technology, is currently under study. To date, studies with reported results have been limited to non-human animals, which do demonstrate promise [28–29].

Because PrEP as a HIV prevention method is relatively novel, there is limited information on its effect on risk compensation. Nevertheless, there are risk compensation concerns about the use of PrEP, most noteworthy that PrEP could have a similar effect on behavior as HAART [18]. Considering that HAART is *not* generally prescribed for reducing the likelihood of HIV transmission and PrEP is, increased risk behavior seems particularly likely. At present, the

efficacy of PrEP for preventing HIV transmission is unknown and its effects on compensatory behaviors are also unknown.

Post Exposure Prophylaxis (PEP)

PEP is prescribed after potential exposure to HIV. Most PEP regimens consist of taking one to three different types of antiretroviral drugs for up to a period of two weeks. While the use of PEP is typically considered a last resort to avert an HIV infection, there is evidence that high risk individuals are more likely to rely on using PEP and that PEP could inadvertently increase an individual's sexual risk behavior [30].

However, in a cohort study that followed participants longitudinally and measured behavioral outcomes, there was no overall increase in sexual risk behaviors among participants who were provided an advance supply of PEP [31]. Additionally, as shown in Table 1, individuals who have used PEP have not shown evidence for increases in risk behavior [32].

The lack of evidence for risk compensation resulting from PEP suggests that, as suggested by Risk Homeostasis Theory, risk compensation is influenced by the perceived costs and benefits of a prevention technology. PEP offers individuals uncertain protection from HIV infection after a transmission event at the expense of considerable side effects and financial cost. These issues are well represented in qualitative research reported by Korner et al. [32]. Participant quotes reported by Korner et al. include the following "Well I would say that it's not going to make me less safe in the future…I don't want to have to put myself through that…having to take the pills regimented [sic] and the worry and the stress that it causes. I mean, I would rather not have to do that. [PEP] sort of gives you a taste of what it would be like to be HIV-positive and have to take those drugs continuously…when I went to the pharmacy and I had three big bottles of tablets that I had to get through and the way it makes you feel, it makes you think twice about doing anything risky (pages 881–882). Thus far, the availability of PEP has not been associated with risk compensation.

Male Circumcision

There has been substantial evidence for the biological plausibility and epidemiological likelihood that male circumcision reduces risks for HIV infection for some time [33,34]. Researchers have long recognized that circumcision has the potential to offer protective effects from STI including HIV infections. Most likely, the benefits of circumcision result from removal of highly susceptible cells for HIV transmission located in the foreskin as well as cornification of epithelial cells, allowing the skin to develop a protective keratin layer [34]. Initially, multiple studies found a correspondence between HIV prevalence and the number of circumcised men in a given population, particularly in sub-Saharan Africa [35].

There are now three large randomized clinical trials (RCTs) that were halted when interim analyses showed more than 50% reductions in HIV infection among men who were circumcised [36–38]. Williams et al. [39] suggested that increased coverage of male circumcision among men in southern Africa could avert as many as 2 million HIV infections and 300,000 deaths over a 10-year period. Kahn et al. [40] also suggested that the protective value of circumcision will be cost saving. The evidence for potential HIV protective benefits of male circumcision is therefore compelling.

Although research from observational studies has been mixed [41], there is evidence that risk compensation occurred among men receiving circumcision in two of the randomized trials that tested male circumcision for HIV prevention. For example, Auvert [36] asked men to report on a series of questions relating to sexual risk behaviors before and following circumcision. Participants who were circumcised reported more sexual contacts through the course of the

study with the exception of the healing time period immediately following the circumcision. Bailey [37] also reported that circumcised men demonstrated significantly greater sexual risk than non-circumcised men over the course of their follow-up. In this trial, consistent condom use did increase by 63% among circumcised men, but this was significantly less of an increase compared to the 95% increase observed in uncircumcised men. Similarly, unprotected sex decreased by 19% among circumcised men, which was significantly less than the 25% decrease observed in men who were not circumcised. Although these differences in risk behavior actually bolster the HIV protective effect observed among circumcised men - circumcised men were less likely to become HIV infected despite their higher risk behavior – the apparent risk compensation raises concerns over the long term should men contract other STIs over time. Of particular concern is how decreased condom use among circumcised men could increase incidence of ulcerative STI and therefore amplify HIV transmission. STIs are associated with a two to five-fold increase in HIV transmission [42]. Herpes simplex virus-2 (HSV-2) is particularly important in HIV transmission and male circumcision does not reduce the risk for HSV-2 [43]. In fact, in one of the circumcision RCTs, 28% of men were HSV-2 positive and HSV-2 was the only baseline predictor of HIV seroconversion [38]. Thus, male circumcision is a major HIV prevention breakthrough, the only biomedical HIV prevention technology with demonstrated effectiveness to date, and its overall impact on HIV prevention could be diminished by risk compensation [44].

Conclusions and implications for HIV prevention

The current paper reviews the extant literature regarding HIV prevention technologies and risk compensation. Based on our review, there is evidence for risk compensation occurring as a result of HIV prevention technologies. Clearly, HIV prevention technologies are greatly needed and offer promise for reducing HIV transmission rates. However, we suggest, based on the literature, that in order to maximize the benefits of these technologies risk compensation must be incorporated as a main focus in risk reduction interventions.

Moreover, the degree to which individuals will compensate their risk behaviors is currently unclear. Likewise, the degree to which different prevention technologies affect behavior is unclear, but would most likely vary as a function of the perceived lowered risk associated with that technology. Thus, considering changes in perceived risk may offer insight into subsequent behavioral changes and further improve upon strides being made in biomedical HIV prevention efforts. Most studies included in this review are representative of initial stages of emerging HIV prevention technologies. Because these technologies are still developing, and published clinical trials investigating microbicides and sexual risk behavior are not yet available, it is difficult to definitively state the impact of HIV prevention technologies on behaviors. Nevertheless, risk compensation needs to be a priority in studies researching the effectiveness of HIV prevention technologies.

To ensure optimal protection offered by HIV prevention technologies, brief risk reduction counseling should be concurrently implemented. Brief risk reduction counseling has been shown to be effective in reducing risk behaviors and subsequent STIs [54–55]. Existing risk reduction counseling models can be modified to address changes in perceived HIV transmission risks in response to prevention technologies, with the goal of curtailing increases in risk behavior post receipt of new HIV prevention technologies. Such counseling may focus on the calibration processes that reconcile risk perceptions and target set points for willingness to take risks. Adjusting behavioral risk reduction to offset risk compensation will therefore increase the preventive benefits of biomedical HIV prevention technologies.

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References

1 . Cassel MM, Halperin DT, Shelton JD, Stanton D. Risk compensation: the Achilled' heel of innovations in HIV prevention? British Medical Journal 2006;332:605–7. Highlights important considerations for implementing HIV prevention technologies. [PubMed: 16528088]

2. Wasserheit JN. Epidemiological synergy. Interrelationships between human immunodeficiency virus infection and other sexually transmitted diseases. Sexually Transmitted Diseases 1992;19:61–77. [PubMed: 1595015]

3. Blower SM, Gershengorn HB, Grant RM. A tale of two futures: HIV and antiretroviral therapy in San Francisco. Science 2000;287:650–4. [PubMed: 10649998]

4. Lui AY, Grant RM, Buchbinder SP. Preexposure prophyaxis for HIV: Unproven promise and potential pitfalls. Journal of the American Medical Association 2006;206:863–865.

5. Wilde, GJS. Target Risk: Dealing with the danger of death, disease, and damage in everyday decisions. PDE Publications; Ontario, Canada: 1994.

6. Centers for Disease Control and Prevention. HIV/AIDS Prevention Topics. 2006 [Accessed on November 4, 2006]. http://www.cdc.gov/hiv/resources/qa/ResearchRationale.htm#RRA1

7. Massad E, Coutinho FAB, Burattini MN, Lopez LF, Struchiner CJ. The impact of imperfect vaccines on the evolution of HIV virulence. Medical Hypotheses 2006;66:907–11. [PubMed: 16442745]

8. Nyamathi AM, Suhadev M, Swaminathan S, Fahey JL. Perceptions of a community sample about participation in future HIV vaccine trials in South India. AIDS and Behavior. 2006

9. Chesney MA, Chambers DB, Kahn JO. Risk behavior for HIV infection in participants in preventative HIV vaccine trials: A cautionary note. Journal of Acquired Immune Deficiency Syndrome and Human Retrovirology 1997;16:266–71.

10. Crosby R, DiClemente RJ, Mettey A. Correlates of recent unprotected anal sex among men having sex with men attending a large sex resort in the South. Sexually Transmitted Diseases 2003;30:909–13. [PubMed: 14646640]

11. Dhawan D, Mayer KH. Microbicides to prevent HIV transmission: overcoming obstacles to chemical barrier protection. Journal of Infectious Disease 2006;193:36–44.

12. Rader M, Marks G, Mansergh G, Crepaz N, Miller LC, Appleby PR, Murphy S. Preferences about the characteristics of future HIV prevention products among men who have sex with men. AIDS Education and Prevention 2001;13:149–59. [PubMed: 11398959]

13. Carballo-Dieguez A, O'sullivan LF, Lin P, Dolezal C, Pollack L, Catania J. Awareness and attitudes regarding microbicide and nonoxynol-9 use in a probability sample of gay men. AIDS and Behavior 2007;11:271–6. [PubMed: 16775772]

14. Mansergh G, Marks G, Rader M, Colfax GN, Buchbinder S. Rectal use of nonoxynol-9 among men who have sex with men. AIDS 2003;17:905–9. [PubMed: 12660538]

15. Weber J, Desai K, Darbyshire J. The development of vaginal microbicides for the prevention of HIV transmission. PLoS Medicine. 2005 2:e142.10.1371/journal.pmed.0020142 [PubMed: 15916473]

16. Quinn TC, Wawer MJ, Sewankambo N, Serwadda D, Li C, Wabwire-Mangen F, Meehan MO, Lutalo T, Gray RH. Viral load and heterosexual immunodeficiency virus type 1. Rakai Project Study Group. New England Journal of Medicine 2000;30:970–2.

17. Ostrow D, Fox KJ, Chmiel JS, Silvestre A, Visscher BR, Vanable PA, et al. Attitudes towards highly active antiretroviral therapy are associated with sexual risk taking among HIV-infected and uninfected homosexual men. AIDS 2002;16:775–780. [PubMed: 11964534]

18. Vanable PA, Ostrow DG, McKirnan DJ, Taywaditep KJ, Hope BA. Impact of combination therapies on HIV risk perceptions and sexual risk among HIV-positive and HIV-negative gay and bisexual men. Health Psychology 2000;19:134–45. [PubMed: 10762097]

19. Stolte IG, de Wit JBF, van Eeden A, Coutinho RA, Dukers NHTM. Perceived viral load, but not actual HIV-1-RNA load, is associated with sexual risk behavior among HIV-infected homosexual men. AIDS 2004;18:1943–49. [PubMed: 15353980]

20. DiClemente RJ, Funkhouser E, Wingood G, Fawal H, Holmberg SD, Vermund SH. Protease inhibitor combination therapy and decreased condom use among gay men. Southern Medical Journal 2002;95:421–5. [PubMed: 11958240]
21. Crepaz N, Hart TA, Marks G. Highly active antiretroviral therapy and sexual risk behavior: A meta-analytic review. Journal of the American Medical Association 2004;292:224–236. [PubMed: 15249572]
22. Pinto-Neto LF, Vieira N, Soprani M, Cunha C, Cabral V, Ribeiro-Rodrigues R. Longitudinal comparison between plasma and seminal HIV-1 viral loads during antiretroviral treatment. Revista da Sociedade Brasileira de Medicina Tropical 2003;36:689–694. [PubMed: 15049108]
23. Kalichman SC, Di Berto G, Eaton LE. Associations among HIV Concentration in Blood Plasma and Semen: Review and Implications of Empirical Findings. Sexually Transmitted Diseases. in press.
24. Kalichman SC, Cage M, Rompa D, Austin J, Luke W, Barnett T, Tharnish P, O'Mowrey T, Schinazi R. Human immunodeficiency virus in semen and plasma: Investigation of sexual transmission risk and behavioral correlates. AIDS Res Hum Retroviruses 2001;17:1695–1703. [PubMed: 11788021]
25. Cohen MS. Thomas Parran Award Lecture: Transmission and Prevention of Transmission of HIV-1. Sexually Transmitted Diseases 2006;33:338–341. [PubMed: 16721328]
26. Jackson JB, Barnett S, Piwowar-Manning E, Apuzzo L, Raines C, Hendrix C, Hamzeh F, Gallant J. A phase I/II study of nevirapine for pre-exposure prophylaxis of HIV-1 transmission in uninfected subjects at high risk. AIDS 2003;17:547–53. [PubMed: 12598775]
27. Veazey RS, Springer MS, Marx PA, Dufour J, Klasse PJ, Moore JP. Protection of macaques from vaginal SHIV challenges by an orally delivered CCR5 inhibitor. Nature Medicine 2005;11:1293–4.
28. Cohen J. Prevention cocktails: Combining tools to stop HIV's spread. Science 2005;309:1002–5. [PubMed: 16099959]
29. Kalichman SC, Nachimson D, Cherry C, Williams E. AIDS treatment advances and behavioral prevention set-backs: Preliminary assessment of reduced threat perceptions. Health Psychology 1998;17:546–50. [PubMed: 9848805]
30. Schechter M, do Lago R, Mendelsohn AB, Moreira R, Moulton LH, Harrison LH. the Praca Onze Study Team. Behavioral impact, acceptability, and HIV incidence among men with access to postexposure chemoprophylaxis for HIV. Journal of Acquired Immune Deficiency Syndrome 2004;35:519–25.
31. Martin JN, Roland ME, Neilands TB, Krone MR, Bamberger JD, Kohn RP, Chesney MA, Franses K, Kahn JO, Coates TJ, Katz MH. Use of the postexposure prophylaxis against HIV infection following sexual exposure does not lead to increases in high-risk behavior. AIDS 2004;18:787–92. [PubMed: 15075514]
32. Korner H, Hendry O, Kippax S. Safe sex after post-exposure prophylaxis for HIV: Interventions, challenges and ambivalences of gay men. AIDS Care 2006;18:879–87. [PubMed: 17012076]
33. Johnson K, Way A. Risk factors for HIV infection in a national adult population: evidence from 2003 Kenya Demographic and Health Survey. JAIDS 2006;42:627–36. [PubMed: 16868500]
34. Fink A. A possible explanation for the heterosexual male infection with AIDS. New England Journal of Medicine 1986;314:1167. [PubMed: 3762636]
35. de Vincenzi I, Mertens T. Male circumcision: a role of HIV prevention? AIDS 1994;8:153–60. [PubMed: 8043224]
36. Auvert B, Taljaard D, Lagarde E, Sobngwi-Tambekou J, Sitta R, Puren A. Randomized, controlled intervention trial of male circumscision for reduction of HIV infection risk: The ANRS 1265 trial. PLoS Medicine 2005;2:1112–22.
37. Bailey RC, Moses S, Parker CB, Agot K, Maclean I, Krieger JN, Williams CFM, Campbell RT, Ndinya-Achola JO. Male circumcision for HIV prevention in young men in Kisumu, Kenya: a randomized controlled trial. Lancet 2007;369:643–56. [PubMed: 17321310]
38. Gray RH, Kigozi G, Serwadda D, Makumbi F, Watya S, Nalugoda F, et al. Male circumcision for HIV prevention in men in Rakai, Uganda: a randomized trial. Lancet 2007;369:657–66. [PubMed: 17321311]
39. Williams BG, Lloyd-Smith JO, Gouws E, Hankins C, Getz WM, et al. The potential impact of male circumcision on HIV in Sub-Saharan Africa. PLoS Med 2006;3:e262.10.1371/journal.pmed.0030262 [PubMed: 16822094]

40. Kahn JG, Marseille E, Auvert B. Cost-effectiveness of male circumcision for HIV prevention in a South African setting. PLoS Med 2006;3(12):e517.10.1371/journal. pmed.0030517 [PubMed: 17194197]
41. Agot KE, Kiarie JN, Nguyen HQ, Odhiambo JO, Onyango TM, Weiss NS. Male circumcision in Siaya and Bondo districts, Kenya: prospective cohort study to assess behavioral disinhibition following circumcision. JAIDS 2007;1:66–70. [PubMed: 17019365]
42. Fleming DT, Wasserheit JN. From epidemiological synergy to public health policy and practice: The contribution of other sexually transmitted diseases to sexual transmission of HIV infection. Sex Trans Infect 1999;75:3–17.
43. Weiss HA, Thomas SL, Munabi SK, Hayes RJ. Male circumcision and risk of syphilis, chancroid, and genital herpes: A systematic review and meta-analysis. Sexually Transmitted Infections 2006;82:101–9. [PubMed: 16581731]
44. Kalichman SC, Eaton L, Pinkerton S. Male circumcision in HIV prevention. Lancet 2007;369:1597. [PubMed: 17499590]
45. Crosby RA, Holtgrave DR. Will sexual risk behavior increase after being vaccinated for AIDS? International Journal of STD & AIDS 2006;17:180–4. [PubMed: 16510006]
46. Chesney MA, Chambers DB, Kahn JO. Risk behavior for HIV infection in participants in preventative HIV vaccine trials: A cautionary note. Journal of Acquired Immune Deficiency Syndrome and Human Retrovirology 1997;16:266–71.
47. Hart GJ, Williamson LM. Increase in HIV sexual risk behavior in homosexual men in Scotland, 1996–2002: prevention failure? Sexually Transmitted Infections 2005;81:367–372. [PubMed: 16199733]
48. Kalichman SC. Post-Exposure Prophylaxis for HIV infection in gay and bisexual men: Implications for the future of HIV prevention. American Journal of Preventive Medicine 1998;15:120–7. [PubMed: 9713667]
49. Stolte IG, de Wit JBF, van Eeden A, Coutinho RA, Dukers NHTM. Perceived viral load, but not actual HIV-1-RNA load, is associated with sexual risk behavior among HIV-infected homosexual men. AIDS 2004;18:1943–49. [PubMed: 15353980]
50. Dukers NHTM, Goudsmit J, de Wit JBF, Prins M, Weverling GJ, Coutinho RA. Sexual risk behavior relates to the virological and immunological improvements during highly active antiretroviral therapy in HIV-1 infection. AIDS 2001;15:369–78. [PubMed: 11273217]
51. Ostrow DE, Fox KJ, Chmiel JS, Silvestre A, Visscher BR, Vanable PA, et al. Attitudes towards highly active antiretroviral therapy are associated with sexual risk taking among HIV-infected and uninfected homosexual men. AIDS 2002;16:775–780. [PubMed: 11964534]
52. Martin JN, Roland ME, Neilands TB, Krone MR, Bamberger JD, Kohn RP, Chesney MA, Franses K, Kahn JO, Coates TJ, Katz MH. Use of the postexposure prophylaxis against HIV infection following sexual exposure does not lead to increases in high-risk behavior. AIDS 2004;18:787–92. [PubMed: 15075514]
53. Schechter M, do Lago R, Mendelsohn AB, Moreira R, Moulton LH, Harrison LH. the Praca Onze Study Team. Behavioral impact, acceptability, and HIV incidence among men with access to postexposure chemoprophylaxis for HIV. Journal of Acquired Immune Deficiency Syndrome 2004;35:519–25.
54. Kalichman SC, DiFonzo K, Kyomugsha F, Simpson D, Presser K, Bjordstrom B. When Briefer Can Be Better: Single Session Approaches to HIV Risk Reduction Interventions. Interamerican Journal of Psychology 2001;35:41–58.
55. Kalichman SC, Simbayi LC, Vermaak R, Cain D, Jooste S, Peltzer K. HIV/AIDS Risk Reduction Counseling for Alcohol Using Sexually Transmitted Infections Clinic Patients in Cape Town South Africa. Journal of Acquired Immune Deficiency Syndromes 2007;44:594–600. [PubMed: 17325606]

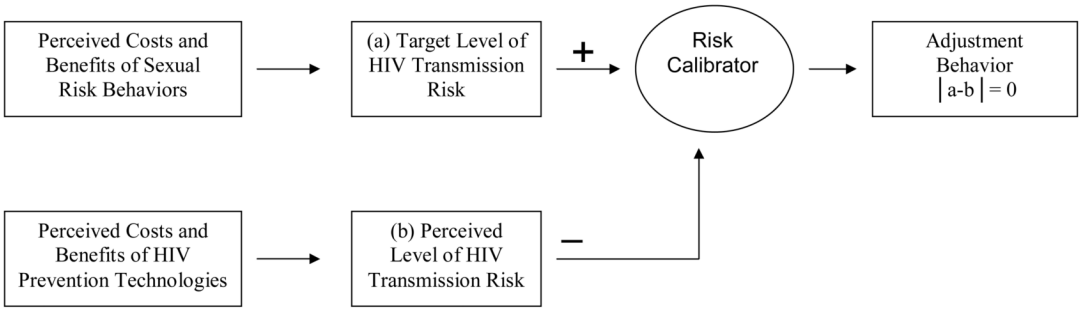

Figure 1. A model of risk compensation and sexual risk behaviors
Note: Adapted from Wilde's [7] *risk homeostasis model*.

Table 1

Behavioral risk compensation and HIV prevention technologies.

Author/Sample	Design	Risk Compensation Related Results
HIV Vaccines		
Crosby & Holtgrave [45]/278 adults from three populations: gay men, African American women, and IDUsers, located in southeastern US.	Cross sectional survey. Participants were recruited from drug abuse services venues, gay-identified venues, grocery stores, homeless shelters, and university campus.	Increase in risk behavior following hypothetical vaccine receipt was positively associated with increased intent to get vaccinated, r = .23, p < .01. Increased HIV risk behavior after being vaccinated was associated with: frequent worry about having HIV, AOR=3.4, 95% CI=1.46–7.91, p < .001 - >32 years of age, AOR=2.95, 95% CI=1.58–5.5, p < .001. Almost 25% of sample indicated that their HIV risk behavior would increase after receiving vaccine.
Chesney et al., 1997 [46]/48 HIV-negative men and women. Study was conducted at San Francisco General Hospital.	Participants were enrolled in one of two placebo-controlled HIV vaccine trials. Baseline, 6-month, 12-month, 24-month follow-ups were included in study.	Insertive UAI increased over the course of the trial, X^2 = 5.32, p < .05: • 9% reported insertive UAI in the 6 months prior to enrollment. • 13% reported insertive UAI at 6 month follow up. • 20% reported insertive UAI at 12 month follow up. Higher risk behavior was seen in participants who hoped the vaccine protected them from HIV, z = 3.32, p < .01.
Antiretroviral medication as prevention		
Hart & Williamson [47]/6508 men, recruited from “gay” bars in Scotland.	Cross sectional surveys conducted in 1996, 1999, and 2002.	• Unprotected anal intercourse, with casual partners, increased after introduction of HAART, 1996-10.7%, 1999-11.2%, and 2002-18.6%, $X^2(2) = 18.1, p<.001$. • Unprotected anal intercourse was associated with HIV treatment optimism, OR 1.38, 95% CI 1.05–1.83, p<.05.
Kalichman et al. [48]/298 HIV negative, gay or bisexual men, recruited from a gay pride festival in Atlanta, GA	Cross sectional survey conducted in 1997.	• Men reporting UAR were more likely to report:-AIDS treatments reduce the threat of HIV transmission, F(1, 288)=4.51, p<.05. • HIV treatments reduce worry about unsafe sex, $X^2(1)=24.73$, p<.01. • it is safe to have anal intercourse with a man who has an undetectable viral load, $X^2(1)=17.43$, p<.01.
Stolte et al., [49]/57 HIV positive homosexual men attending a HIV treatment clinic in Amsterdam.	Interviews were conducted in three serial waves.	• Men with a favorable perception of their viral load, regardless of their actual viral load, were more likely to engage in risky sex with a negative or unknown status partner, AOR=5.58, 95% CI = 1.94–16.05, p<.01.

Author/Sample	Design	Risk Compensation Related Results
Dukers et al., [50]/Study 1) 1,062 HIV neg and pos participants, and study, 2) 365 HIV pos participants, located in Amsterdam.	Cohort study. Men were followed for at least five years during 1984–2000. All participants were ≤ 30 years of age at entry of study.	• HIV negative men were more likely to report unprotected anal intercourse in the time period after HAART (78%), than before HAART, (62%), p<.05. • HIV positive men reported more unprotected anal intercourse, with casual partners, after their viral load became undetectable, OR=2.4, 95%CI=1.0–5.7, p<.05. • HIV positive men reported more unprotected anal intercourse, with casual partners, after their CD4 cell count increased while on HAART, OR=3.1, 95%CI=1.2–8.1, p<.05.
Ostrow et al., 2002 [51]/547 HIV negative and HIV positive men reporting anal sex. Multicenter AIDS Cohort Study in USA.	Cross sectional study, nested within an ongoing prospective cohort study.	• HIV negative men who most agreed that HAART reduced concern about becoming HIV infected, were more likely to report UAR intercourse than other HIV negative men (AOR, 3.31, CI=1.27–8.62). • HIV positive men, who had reduced concern for HIV transmission because of HAART, were more likely to report UAI intercourse (AOR, 6.05, CI=1.7–12.4).
Martin [52]/397 adults with high risk exposure to HIV.	Non-randomized trial including receipt of PEP and antiretroviral medication and risk behavior counseling.	• Twelve months post receipt of PEP: • 73% of participants reported decrease in high- risk sexual behavior, while 13% reported no change, and 14% increased. • 85% of participants had no change in STD incidence, while 8.5% reported a decrease, and 6.8% reported an increase.
Schechter et al. [53]/200 HIV-negative homosexual men in Rio de Janeiro, Brazil	Cohort study where men were given an advance four day supply of PEP.	• High risk behaviors decreased over time • Among PEP users, 47% reported unprotected anal sex in previous six months at baseline visit vs. 39.7% at last visit. • Among non-PEP users, 36% reported unprotected anal sex in previous six months vs. 24.2% at last visit, p<.01.
Male circumcision		
Auvert et al. [36]/1,582 HIV neg men in control, 1,546 HIV neg men in an intervention, located in South Africa	RCT, men in intervention group received circumcision during study. 3, 12, and 21 month follow up. Study stopped at interim analysis.	• Sexual behavior measures were higher in intervention group than in control group for the month 4 through month 12 period. • Mean number of sexual contacts was higher in the intervention group than in the control group: -month 4 through month 12 period, 5.9 vs. 5.0, p < .001. • month 13 through month 21 period, 7.5 vs. 6.4, p < .01.
Bailey et al. [37]/2,784 men aged 18–24 in Kisumu, Kenya	RCT, men in intervention group received circumcision during study. 1, 3, 6, 12, 18 and 24 month follow up. Study stopped at interim analysis.	• Unprotected sexual intercourse among circumcised/uncircumcised men at baseline was 63%/63% and 24 month follow up was 51%/46%, p<.05. • Consistent condom use among circumcised/uncircumcised men at baseline was 22%/21% and at 24 month follow up was 36%/41%, p<.05.

Author/Sample	Design	Risk Compensation Related Results
Gray et al. [38]/4,996 men aged 15–49 in Rakai district, Uganda	RCT, men in intervention group received circumcision. 6, 12 and 24 month follow ups. Study stopped at interim analysis.	• No differences were identified between groups in terms of sexual risk behaviors.