The Behavioral Response to Male Circumcision: Experimental Evidence from Kenya

by

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A thesis submitted in partial fulfillment
of the requirements for the
Degree of Bachelor of Arts with Honors
in Economics

Williams College
Williamstown, Massachusetts

May 11, 2011

Abstract

This paper investigates the behavioral response to male circumcision (MC) for HIV/AIDS prevention. Recent evidence from randomized controlled trials (RCTs) indicates that medically performed MC significantly reduces men's risk of acquiring HIV through sexual intercourse. However, HIV/AIDS incidence will not necessarily fall if the lowered risk of infection induces a higher propensity for risky sexual behavior. This paper emphasizes the role of an individual's belief about MC in affecting his sexual behavior: an individual will only exhibit a behavioral response to MC because of his concern about the risk of HIV infection if he believes the effect of MC on this risk. The paper first establishes a behavioral model to study an individual's tradeoff between pleasure from risky sex and risk of HIV infection, analyzing the effect of the safety-improving MC on this tradeoff. The paper then presents empirical evidence from a large-sample RCT of MC conducted in Kisumu, Kenya. In the RCT, MC increased sexual riskiness among the participants who were randomly assigned MC, whether they believed the protective effect of MC against HIV/AIDS. However, circumcised participants who believed the efficacy of MC (the circumcised believers) exhibited significantly less risky sexual behavior compared with those who did not believe this fact, so that the net effect of MC on the risky sexual behavior of circumcised believers was not significantly different from zero. Based on the empirical evidence, we discuss some policy implications for MC campaigns aiming for HIV/AIDS prevention.

JEL classification: D81, I18

Keywords: Beliefs, HIV/AIDS, male circumcision, risky sexual behavior.

Acknowledgements

First and foremost, I would like to thank Professor Nicholas L. Wilson for providing invaluable guidance and inspiration at every stage of this thesis. I would also like to thank Doctor Christine L. Mattson for sharing the data from the RCT of MC. In addition, I am deeply grateful for the very insightful comments from Prefessors Ralph M. Bradburd, Kenneth N. Kuttner, David A. Love, and Michael M. Rolleigh. Finally, I thank my fellow thesis students and the rest of the Williams economics department for creating and maintaining an enjoyable and intellectually stimulating environment for economic studies and research.

I welcome any comment on this thesis, and I am responsible for all errors.

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1 Introduction

Recent evidence from randomized controlled trials (RCTs) indicates that medically performed male circumcision (MC) significantly reduces men's risk of acquiring HIV through sexual intercourse (Gray et al. 2007). Seeing that sexual intercourse is the principal channel of interpersonal HIV transmission in Southern and Eastern Africa, the WHO and UNAIDS released recommendations of MC scale-up to countries in this region in March 2007 (WHO 2009a). As a result, many Sub-Saharan African countries have started mass MC campaigns. For example, an ambitious program of MC for HIV prevention has been recently embarked in Tanzania: the government aims to circumcise 2.8 million males aged 10-34 by 2016.[1]

Although MC decreases the risk of acquiring HIV per discordant coital act for men, HIV/AIDS incidence will not necessarily fall if the lowered risk of acquiring HIV is associated with a higher propensity for risky sexual behavior. Specifically, if circumcised men believe that circumcision reduces the risk of HIV infection, they may respond by demanding more risky behavior, commonly referred to as risk compensation or behavioral disinhibition (Gray et al. 2007b). In particular, if men overestimate the protective effect of circumcision, they may engage in so much more risky sex that their chance of acquiring HIV through sexual intercourse actually increases. In this case, MC campaigns may facilitate the spread of HIV. Thus, for successful HIV/AIDS prevention, it is important to study whether MC programs would induce changes in risky behavior.

To date, although the possibility of risk compensation associated with MC has raised much concern in public health policy debate, formal studies investigating the behavioral response to MC have been scarce. A few RCTs of MC did not show strong evidence of

[1] Plusnews. February 07 2011. "TANZANIA: Male circumcision campaign targets 2.8 million". `http://www.plusnews.org/Report.aspx?ReportId=91849`

risk compensation. Gray et al. (2007a) find little evidence of behavioral disinhibition in their RCT in Rakai, Uganda. In another RCT in Kisumu, Kenya, Bailey et al. (2007) find that both circumcised and uncircumcised men decreased their risky sexual practices after receiving risk reduction counseling, but there was little difference between the two groups of men in terms of changes in sexual behavior. Seeing that the measures of sexual risk may be insufficient in previous studies, Mattson et al. (2008) develop an 18-item measure of risky behavior for their RCT in Kisumu, Kenya, and find no significant differences in the 18-item sexual risk propensity scores between circumcised and uncircumcised men.

While none of these RCTs shows evident risk compensation in the context of MC, we note that an individual's belief about the efficacy of MC, which is an essential factor that determines his behavioral response, has not been carefully investigated in these RCTs. It is worth emphasizing that, in these studies, experiment participants were at best informed of inconclusive evidence of the reduced risk of contracting HIV after MC, and it is reasonable that not all men believed that MC would protect them from HIV/AIDS. Individuals will demonstrate risk compensation in response to MC only if they believe its effect on HIV transmission. In an experimental setting, even if some circumcised men who believe the health benenfit of MC become sexually riskier, other circumcised men may not because they do not realize that unprotected sex has become less risky for them. Thus, overall, the circumcised group may not exhibit significantly different behavioral responses in comparison with the uncircumcised group, since neither uncircumcised men nor circumcised men who do not recognize the protective effect of MC will adjust their sexual behavior. A relevant study that stresses individuals' beliefs about MC is Godlonton et al. (2010), in which the authors present results from a Malawi-based RCT that, after learning that MC lowers the risk of HIV infection, circumcised men did not become sexually riskier, but uncircumcised men became less willing to engage in risky sex.

In this paper, we use data from a large-sample RCT of MC conducted in Kisumu, Kenya to examine the behavioral response to MC, with a particular emphasis on the role of an individual's belief about the MC-associated safety improvement. Our empirical analysis indicates that the participants who were randomly assigned MC significantly increased their risky sexual behavior, whether they believed the protective effect of MC. For instance, in the 6-month period after MC was randomly assigned at baseline, being circumcised made an average participant have 0.23 more sexual partners, while in the period concerned the participants had 1.52 partners on average. However, the circumcised participants who believed that MC would protect them from HIV infection (the circumcised believers) were significantly less sexually risky as compared to the circumcised participants who did not believe the efficacy of MC (the circumcised non-believers), contradicting the theory of risk compensation. For example, in the 6-month period after baseline, being a circumcised believer was associated with a reduction of 12 percentage points in the likelihood of having multiple sexual partners, while around 40% of all participants in the experiment reported multi-partnership. Moreover, the net effect of MC on the sexual riskiness of circumcised believers was not significantly different from zero. Since the risk of each sexual act was reduced by MC, and the circumcised believers did not become riskier in response to MC, the HIV incidence among these participants would decrease unambiguously. Such results provide empirical support for the scale-up of MC in order to reduce HIV incidence in populations with HIV prevalence, as the organisers of MC campaigns typically persuade men to accept MC by highlighting the associated health benefits so that men who undergo the procedure are likely to believe its protective effect.

The finding that MC increased sexual riskiness regardless of individuals' beliefs about its efficacy suggests that men may adjust their sexual behavior in response to MC for reasons other than the risk of HIV infection. A possible explanation is the fact that MC protects men from a few non-HIV sexually transmitted infections (STIs).[2] Aside from the concern about the risk of HIV infection, an individual who acquires STIs less often is likely to have better sexual performance and develop a higher demand for risky sex. Additionally, the lowered incidence of STIs can lead to increased marketability to find sexual partners who want to avoid STIs, a possibility that points to increased sexual riskiness of the circumcised man as well.

Although MC may affect individuals' sexual behavior through channels other than those related to the risk of acquiring HIV, this paper is concerned with, in particular, how an individual optimizes his choice of risky sexual behavior taking into account this risk. We establish a simple behavioral model for the analysis of this optimazation problem. Since an individual will re-optimize against the lowered risk of HIV infection only if he believes that MC actually reduces the risk, this model will shed light on why, among all circumcised men in the RCT, believers and non-believers responded differently to MC. It is intuitive that, if an individual derives utility from risky sex with the understanding that risky sex carries some risk of acquiring HIV, and he believes that MC reduces the risk of each sexual act, then he will increase his consumption of risky sex in response to MC. In this case, the change in the overall probability of HIV infection is ambiguous: although each sexual act becomes less risky, he will engage in a greater amount of risky sex.

[2]Though there used to be mixed evidence on this point, in recent years many relevant studies support that MC protects men from a few non-HIV STIs. For example, MC reduces trichomonas vaginalis infection among men, http://www.ncbi.nlm.nih.gov/pubmed/19074928; MC lowers the risk of human papillomavirus (HPV) infection in men, http://www.ncbi.nlm.nih.gov/pubmed/18284369, and helps prevent HPV transmission from men to women, http://globalhealth.kff.org/Daily-Reports/2011/January/07/GH-010711-Circumcision-HPV.aspx; MC protects men from syphilis and chancroid, http://sti.bmj.com/content/82/2/101.short; MC is not associated with women's risk of incident chlamydial, gonococcal, and trichomonal infections, http://www.ncbi.nlm.nih.gov/pubmed/18418300

Starting from this simple case, we extend our analysis by considering possible cases where MC will not necessarily induce an increase in risky behavior. In the absence of MC, if an individual believes that risky sex carries a high probability of HIV infection, he may believe that he will contract HIV almost surely even if he only engages in a moderate amount of risky sex. Then after he reaches this moderate amount, the marginal cost from the risk of HIV infection will be very low, while he continues to derive relatively high utility from risky sex. In this case, he will face little tradeoff between the sexual pleasure and the risk of acquiring HIV, and he may simply consume risky sex as much as possible. If he accepts MC and believes that MC will protect him from HIV, however, he will face significant tradeoff between sexual pleasure and infection risk when he reaches some level of risky sex consumption at which, prior to MC, he would believe that he has probably acquired HIV. Thus he may choose to consume some moderate amount of risky sex that best balances the pleasure-risk tradeoff, rather than consume his maximum possible amount of risky sex. In this case, his optimal consumption of risky sex decreases in response to MC. We will formalize the intuition behind these different cases in Section 3.

The analysis of risky sexual behavior can be generalized to understanding consumers' demand for a risky good that generates utility but simultaneously carries some risk of utility loss. For instance, there is a large volume of literature about how driving safety regulations affect drivers' risky driving. The driving setting reminds us of risky sexual behavior in many ways. Risky driving can not only produce pleasure for some drivers, but also facilitate the realization of other types of utility, e.g. when the driver is driving to work in a great hurry. Nevertheless, the driver puts his life at stake by driving in an unsafe manner. Driving safety regulations, such as mandatory seatbelts, are aimed at lowering the risk of unsafe driving, but if drivers become much riskier in response to safer driving conditions, then such regulations may be counterproductive. Peltzman (1975) provides a pioneering model of offsetting effects of drivers' response to devices to improve driving safety. In this model, individuals react to a safety regulation by increasing their risky behavior, abating the benefit of the regulation. Peltzman's paper inspired much empirical work on traffic-related risk compensation, and many researchers have found evidence supporting Peltzman's offsetting effect. For example, Winston et al (2006) use disaggregate data to analyze the effects of airbags and antilock brakes on automobile safety, and find that these safety devices do not significantly affect collisions or injuries, suggesting that drivers trade off enhanced safety for speedier trips.

It is interesting that we observe risk compensation in response to an improvement in safety in the case of driving, but not in the context of MC. This is probably because when individuals drive with moderate attention to safety without devices for safe driving, they still face significant tradeoff between the utility from risky driving and the risk of running into an accident, and they are very likely to incur great utility costs by driving in the riskiest manner. In comparison, without MC, an individual who has consumed a moderate amount of risky sex may believe that he already has a very high chance of being HIV positive, and thus he will foresee little further loss of utility even if he engages in more risky sex.

The rest of this paper is organized as follows. Section 2 provides background information on MC in Sub-Saharan Africa. Section 3 presents a behavioral model that highlights how MC affects the tradeoff between sexual pleasure and risk of HIV infection. Section 4 introduces the RCT data and gives some descriptive statistics. Section 5 specifies the stages of the empirical analysis of the behavioral reponse to MC and shows major findings. Section 6 performs robustness check for the findings in Section 5. Section 7 briefly discusses the policy implications of our empirical results, and Section 8 offers concluding remarks.

2 Background on Male Circumcision in Sub-Saharan Africa

Although male circumcision as an HIV-prevention instrument has not been widely advocated until the last decade, the practice of MC has cultural roots in many regions in Sub-Saharan Africa. Marck (1997) describes the general cultural background of MC for the Bantu speaking peoples of sub-equatorial Africa, where traditional practices were commonly linked to the toughening, training and initiation of male adolescents into warrior status. One of the early studies on HIV/AIDS and MC is Moses et al. (1990), when policy-oriented MC campaigns have not started. The authors identify MC practices for over 700 African societies and obtain HIV seroprevalence in general adult populations from 140 distinct locations in 41 countries, and observe that HIV prevalence was considerably lower where MC was practiced. This negative association between HIV/AIDS and MC has persisted today in Sub-Saharan Africa, where the prevalence rates of both HIV and MC vary appreciably across countries. For example, WHO (2009b) records that Swaziland has one of the highest HIV prevalence rates (26%) and simultaneously one of the lowest MC rates (8%) in this region. Similarly, the HIV and MC prevalence rates in Tanzania are 5.7% and 70%, respectively.

Recent large-sample RCTs in HIV/AIDS prevention establishes that medically conducted MC significantly lowers the risk of HIV infection through sexual intercourse for men. Bailey et al. (2007) conducted an RCT of 2,784 HIV-negative men in Kisumu, Kenya and found a 53% (95% CI: 22% – 72%) reduction of HIV acquisition in circumcised men relative to uncircumcised men. Gray et al. (2007a) conducted another RCT in Rakai, Uganda of 4,996 HIV-negative men and estimated the efficacy of MC in reducing HIV infection risk to be 51% to 60%. The results of these two trials complemented those from a previous RCT conducted by Auvert et al. (2005) in South Africa. This earlier trial involved 3,274 HIV-negative young men and showed that circumcision reduced the risk of acquiring HIV by 60% (95%

CI: 32% – 76%).

These findings encouraged public health policy makers to promote MC as an important part of HIV/AIDS prevention programs. HIV/AIDS prevention is particularly urgent in Sub-Saharan Africa. In 2008, an estimated 1.9 million people living in this region became newly infected with HIV, bringing the total number of people living with HIV to 22.4 million and the HIV prevalence to 5.2% (UNAIDS 2009). In response to these findings about MC and the pressing need of HIV/AIDS prevention in Sub-Saharan Africa, global health organizations helped launch mass campaigns of MC in this region. In the Montreux (Switzerland) meeting in March 2007, the WHO/UNAIDS recommended that medically performed MC be part of a comprehensive HIV/AIDS prevention program. In particular, 13 priority countries with high prevalence of heterosexual epidemics and low MC rates were advised to focus on scaling up this intervention (WHO 2009b). WHO then provided financial and technical support to these priority countries that responded with cooperation.

In consequence, MC experienced its rapid rollout in some of the participating countries in the last few years. In particular, Kenya, where an estimated 85% of men are circumcised but only 40% of those in Nyanza, a province with the country's highest HIV prevalence, has distinguished itself as an enthusiastic participant (WHO 2009b). In 2008, the government launched a national campaign and, by the end of 2009, more than 90,000 men had been circumcised, 40,000 of them during a two-month "rapid results" initiative in Nyanza.[3] In the last few months of 2009, MC service delivery expanded from 41 to 230 clinics nationwide. In addition, the government aims to have all uncircumcised men - an estimated 1.1 million - undergo the procedure by 2013.[4] A few private organizations have also provided substantial

[3] Plusnews. March 02 2010. "AFRICA: Tracking the male circumcision rollout." `http://www.plusnews.org/report.aspx?ReportID=88286`

[4] *Ibid.*

support for the MC scale-up. For example, in June 2009, the Bill and Melinda Gates Foundation gave $50 million in order to circumcise up to 650,000 men in Swaziland and Zambia.[5]

However, the rollout of MC will not necessarily result in the desired outcome, i.e. a decline in HIV incidence and ultimately in its prevalence, if the lowered risk of acquiring HIV is associated with undesirable changes in individual risky behavior. Gray et al. (2007b) construct a stochastic simulation model with empirically derived parameters from Rakai, Uganda to estimate HIV incidence averted by the practice of MC. Although they reach encouraging predictions that MC could remarkably reduce HIV incidence in the population, they warn that adverse behavioral responses, i.e. an increased propensity for risky behavior, could offset any benefit of circumcision. Similarly, UNAIDS (2007) summarizes several models of the impact of MC on HIV incidence and prevalence, including Williams et al. (2006) and Nagelkerke et al. (2007), and warns policy makers of risk compensation. Although this report affirms that these models produce positive predictions, it recommends that detailed risk compensation behavior be incorporated in the models.

3 Behavioral Model

We construct a simple consumer demand model to illustrate how a male individual's choice of risky sexual behavior changes according to his circumcision status, which affects the probability of HIV transmission per coital act. To start with, we assume that the individual is uncircumcised and HIV-negative, and he is aware of his initial HIV status. For simplicity, we also assume that risky sex is the only good. Let $x \geq 0$ denote the amount of risky sex the

[5] Coghlan, Andy. 15 June 2009. "Bill Gates helps fund mass circumcision programme." *New Scientist, Health.* `http://www.newscientist.com/article/dn17312-bill-gates-helps-fund-mass-circumcision-programme.html`

individual chooses. We further assume that there exists a maximum amount of risky sex he can consume, and denote this upper bound by N with $0 \leq x \leq N$. This maximum amount can be interpreted as some technological constraint such as one's physiological capacity for sex or time constraint. The individual derives utility from risky sex with diminishing marginal utility. Let $V(x)$ be his utility from risky sex, and $\frac{\partial V}{\partial x} > 0, \frac{\partial^2 V}{\partial x^2} < 0$ for $x \in (0, N)$.

Despite the utility gain, risky sex can incur a considerable utility cost, i.e. HIV infection, and this cost is taken as a fixed parameter, θ. To calculate the cumulative probability of incurring this utility cost, P_+, we let p be the probability of acquiring HIV per unprotected coital act with an HIV-positive partner, and r be the probability that his sexual partner is HIV-positive. As stressed before, MC reduces p. The chance of acquiring HIV, which we denote by $P_+(x, p, r)$, is increasing on x, i.e. $\frac{\partial P_+}{\partial x} > 0$, and thus there exists a tradeoff between his utility gain from risky sex and his utility loss from the risk of HIV infection while $x \in (0, N)$.

We assume that marginal utility loss will be low, while marginal utility gain from risky sex will remain relatively high, at high levels of risky sex consumption where the infection probability is high. To give an extreme example, if an individual believes that, after consuming a large amount of risky sex, he will have contracted HIV almost surely, then having additional risky sex will not result in substantial health cost.[6] Based on this assumption, we further assume that, beyond a critical level of risky sex, $\tilde{x}$, associated with a high infection probability, the marginal disutility from the risk of HIV infection is lower than the marginal utility from risky sex. It is noteworthy that all the probabilities we study are those in the individual's belief and can deviate from the actual ones. It is such probabilities he believes

[6] As an additional concern, if the individual is altruistic, spreading HIV after contracting the virus himself may carry additional disutility. For simplicity, we assume that such disutility is independent of the risky sex consumption, and adding this lump-sum disutility does not necessitate major modifications to our model.

that determine his choice of risky behavior.[7]

We proceed to constructing a specific behavioral model. Since he derives utility from sex regardless of his HIV status, we have his objective function,

$$\max_{0\leq x\leq N} U(x) = [1 - P_+(x,p,r)]V(x) + P_+(x,p,r)[V(x) - \theta] = V(x) - P_+(x,p,r)\theta \qquad (1)$$

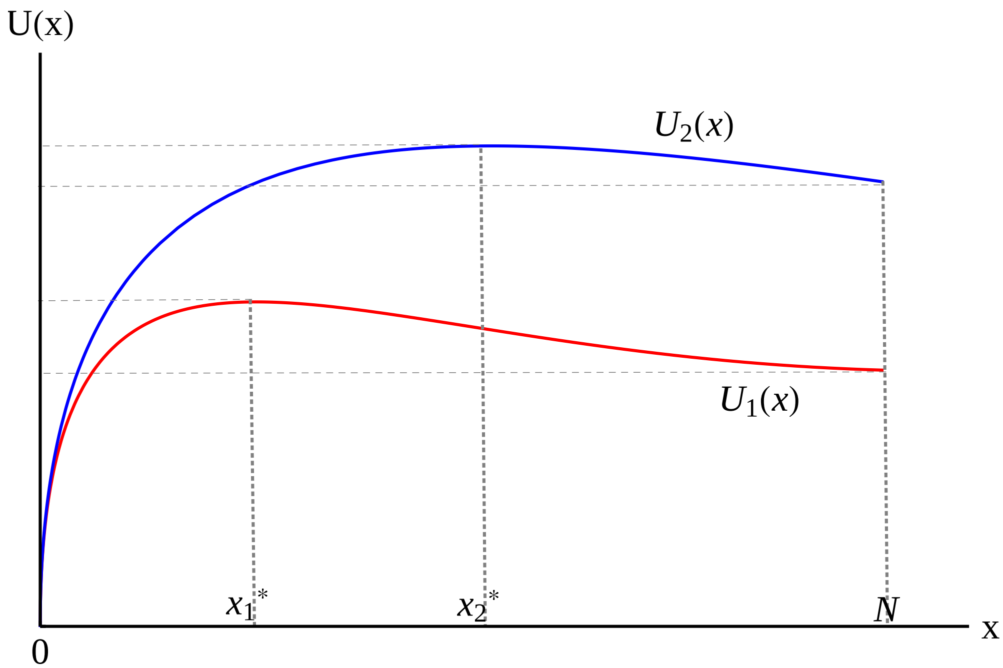
with an critical level of risky sex $\tilde{x}$ that satisfies

$$P_+(\tilde{x},p,r) \gg 0 \text{ and } \frac{\partial V}{\partial x} > \frac{\partial P_+}{\partial x}\theta \text{ for } x > \tilde{x} \qquad (2)$$

The change in the reference individual's risky sexual behavior in response to a decline in p depends crucially on the comparative values of several parameters, such as the unobservable N and $\tilde{x}$. We start with a simple case where the MC-induced reduction in the per-act probability of HIV transmission p will lead to an increase in the optimal consumption of risky sex, as shown in Figure 1. Given that the chance of HIV infection $P_+(x,p,r)$ is increasing on both p and x, a decrease in p together with an increase in x will not necessarily

[7]Though the probabilities that an individual believes may differ from the actual ones, it is helpful to give estimates of the actual ones. According to WHO (2009b), the HIV prevalence in Nyanza Province, whose capital city is Kisumu where the RCT for this study was conducted, is 15.3%, and we use this prevalence rate to approximate r, the probability of a random sexual partner being HIV positive (7% for Kenya). In addition, although the results from medical experiments measuring the probability of acquiring HIV per unprotected coital act, p, tend to vary by which population is engaged in the experiment, in general the estimates are very small. For example, Gray et al (2001) estimate the overall unadjusted probability of HIV-1 transmission per coital act to be 0.0011(95% CI $0.0008-0.0015$). If we assume that an individual is perfectly informed of the related probabilities, and he randomly matches a sexual partner for each intercourse so that his infection probability $P_+(x) = 1-(1-0.15*0.0011)^x$, then it will take approximately $4,200$ unprotected sexual acts for him to believe that he has a probability 0.5 of contracting HIV. If he expects to live 30 years from his sexual debut to death, this will average to about 140 unprotected acts per year. However, it is likely that individuals overweight low probabilities especially when their attention is called to the low-probability outcomes (Kahneman and Tversky, 1979), and it is reasonable that an individual believes that he will have contracted HIV after consuming a smaller amount of unprotected sex. For instance, Watkins et al (2007) record some anecdotal evidence that, in rural Malawi, the vast majority of residents believed that the transmission of HIV through one sexual act with an infected person was either certain or highly likely.

Figure 1: A simple case of the behavioral model, where MC leads to an **increase** in the optimal consumption of risky sex.



reduce $P_+(x, p, r)$.

In Figure 1, $U_1(x)$ is the expected utility from risky sex x, taking into account the possible health cost θ, before a decrease in p as a result of MC. $U_1(x)$ has a local maximum x_1^* such that $x_1^* \in (0, N)$ and $\frac{\partial U_1}{\partial x} = 0$. Below this local maximum x_1^*, the marginal utility from risky sex exceeds the marginal disutility from HIV infection risk, so expected utility keeps rising as x increases. Above x_1^*, $U_1(x)$ starts to fall and the expected utility at the maximum amount N satisfies $U_1(N) < U_1(x_1^*)$. In this situation, the optimal consumption of risky sex in the absence of MC is x_1^*, the local maximum.

The MC-induced reduction in p shifts the expected utility $U_1(x)$ to $U_2(x)$. We assume that the utility from risky sex, $V(x)$, stays the same as before MC based on the fact that

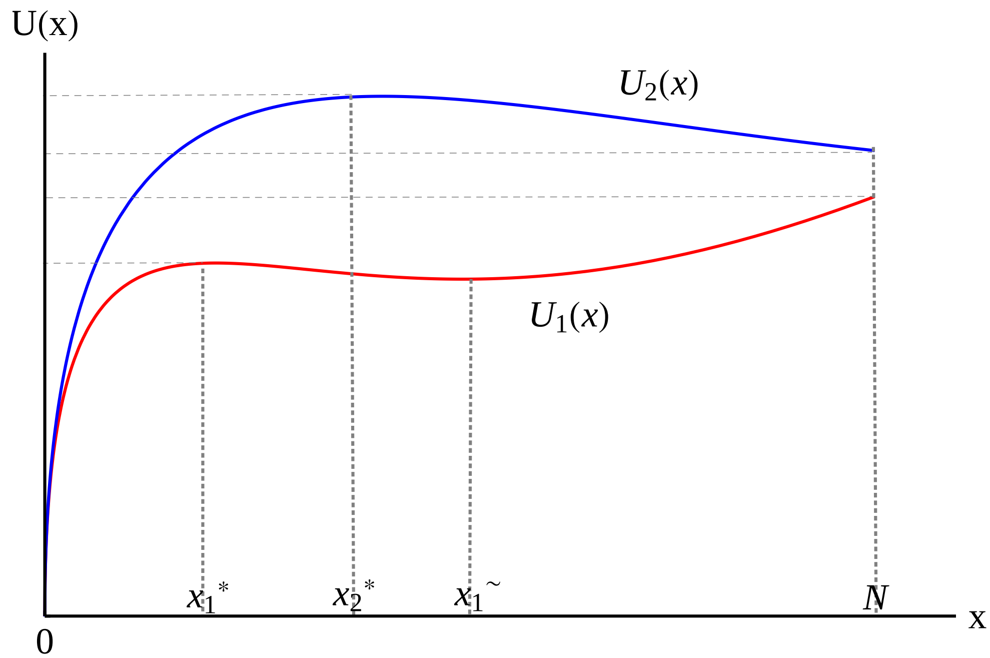
MC does not significantly affect sexual function,[8] and then a decrease in p will lead to the following consequences. First, $U_2(x) \geq U_1(x) \forall x \in (0, N)$ ($U_2(x) = U_1(x)$ if over some interval $P_+(p_1, x) = P_+(p_2, x) = 1$), since the utility from risky sex does not change, but given any x below the upper bound N, the probability of HIV infection is decreased by MC, and so is the expected health cost. Second, the local maximum x_2^* satisfies $x_2^* > x_1^*$. This can be easily deduced from the first-order necessary condition for the local maximum, $\frac{\partial U}{\partial x} = 0 \Rightarrow \frac{\partial V}{\partial x} = \frac{\partial P_+}{\partial x}\theta$. Since the marginal utility cost $\frac{\partial P_+}{\partial x}\theta$ is lowered for any $x \in (0, N)$, the marginal utility $\frac{\partial V}{\partial x}$ at the local maximum becomes smaller, which corresponds to a larger x^* given that $\frac{\partial^2 V}{\partial x^2} < 0$. As shown in Figure 1, if the expected utility at the maximum amount N satisfies $U_2(N) < U_2(x_2^*)$, then the optimal consumption is x_2^*. In this case, MC increases the optimal consumption from x_1^* to x_2^*, as individuals trade lowered risk of HIV infection for more risky sex.

Besides the intuitive case above, this model can also produce different predictions about the changes in the optimal consumption of risky sex if we allow changes in a few parameters. In Figure 2, we will illustrate a possible situation where MC will actually lead to a decline in the optimal consumption of risky sex x. Given that the chance of HIV infection $P_+(x, p, r)$ is increasing on both p and x, decreases in both p and x will lower $P_+(x, p, r)$ unambiguously.

As shown in Figure 2, $U_1(x)$ is defined in the same way as in Figure 1. Prior to MC, the critical $\tilde{x}_1$ satisfies $\tilde{x}_1 < N$. In other words, the individual expects to have a large probability of acquiring HIV before he reaches the maximum amount of risky sex. This is plausible, for example, if the individual thinks that unprotected sex is highly risky, i.e. a large p and/or r.

[8]In fact, there is inconclusive evidence that MC improves sexual performance, see for example, `http://www.cirp.org/library/sex_function/senkul1/`, but this does not affect the predictions of our model.

Figure 2: A specific case of the behavioral model, where MC leads to a **decline** in the optimal consumption of risky sex.



When $x \in (x_1^*, \tilde{x}_1)$, the marginal disutility from HIV infection surpasses the marginal utility from risky sex, and the expected utility starts to fall until the critical $\tilde{x}_1$. When $x > \tilde{x}_1$, the marginal disutility is very low since the individual believes that he is already very likely to be HIV positive. Thus, the marginal utility from risky sex dominates the marginal disutility, and the expected utility starts to rise until N. To explain why a decrease in the per-act infection probability leads to a decrease in the optimal consumption of risky sex, we need $U_1(N) > U_1(x_1^*)$, i.e. the expected utility from consuming the largest possible amount of risky sex is greater than that from consuming the local utility-maximizing amount. Under this particular condition, the optimal consumption of risky sex is N, the upper bound.

As MC shifts the expected utility from $U_1(x)$ to $U_2(x)$, the individual updates his belief about the critical level so that $\tilde{x}_2 > \tilde{x}_1$, because per-act transmission probability is lowered and an individual will believe that he can consume more risky sex before reaching a high chance of infection. We further assume that $U_2(x_2^*) > U_2(N)$, i.e. after accepting MC and updating his belief about p, the expected utility at the local maximum is higher than at the largest possible amount. This necessitates that $x_2^* < \tilde{x_2}$ and $x_2^* < N$, i.e. the individual reaches the local maximum before the critical level $\tilde{x_2}$ and the constraint N, so that the expected utility starts to fall right after x_2^*. Thus, the optimal consumption of risky sex is x_2^*. In this particular case, if an individual believes the efficacy of MC, he should decrease his consumption of risky sex from N to x_2^* after accepting MC.

Although counter-intuitve at first sight, this case is plausible under the following conditions. First, the individual believes that risky sex carries a very high chance of contracting HIV, and that he will probably acquire HIV before reaching his constraint of sexual consumption. In this case, when his consumption of risky sex reaches the point where he believes that he is highly likely to be infected, he will face little tradeoff between sexual pleasure and HIV infection risk, and would rather derive utility from risky sex as much as possible. This will make it likely that before MC, he will consume the maximum amount of risky sex. Second, MC reduces the risk of HIV infection dramatically. Since it is reasonable to assume that the utility from risky sex $V(x)$ is independent of MC, only if MC greatly lowers HIV infection risk will MC increase the expected utility by so much that $U_2(x_2^*) > U_2(N)$.

Besides the two cases above where MC either increases or decreases an individual's optimal consumption of risky sex, this flexible model allows many other cases depending on the values of the parameters. If we hold the expected utility functions $U_1(x)$ and $U_2(x)$ fixed (or holding fixed their components, including the utility from risky sex $V(x)$, the cumulative probabilities of HIV infection $P_+(x, p_1, r)$ and $P_+(x, p_2, r)$, and the utility cost of contracting HIV θ), the expected utility at the maximum amount $U(N)$ seems to determine the changes in risky sexual behavior. Recall that, in Figure 1, since $U_1(x_1^*) > U_1(N)$ and

$U_2(x_2^*) > U_2(N)$, MC increases the optimal consumption of risky sex from x_1^* to N; in Figure 2, since $U_1(x_1^*) < U_1(N)$ and $U_2(x_2^*) > U_2(N)$, MC decreases the optimal consumption from N to x_2^*. Moreover, if $N < x_1^* < x_2^*$ (thus $U_1(x_1^*) > U_1(N)$ and $U_2(x_2^*) > U_2(N)$), or $U_1(x_1^*) < U_1(N)$ and $U_2(x_2^*) < U_2(N)$, his optimal consumption will be N before MC and will remain at N after MC, i.e. MC will not change his risky sex consumption. Many more possibilities can be derived by allowing changes in functions like $V(x)$ and $P+(x, p, r)$, which will allow changes in parameters like $\tilde{x}$ and x^*.

In applying this model to the experimental data from the RCT of MC, we need to be aware that this model describes an individual's consumption path of risky sex for his lifetime rather than a limited period. By reducing his risky sex consumption, the reference individual lowers his risk of HIV infection and gains a longer life expectancy. While the experiment could only capture the participants' sexual behavior in a relatively short period, the risk reduction associated with MC is permanent. If a man became less risky sexually in response to MC during the experiment, it is reasonable that he would remain at a lower level of risky sex consumption after the experiment.

4 Data and Descriptive Statistics

We will examine the behavioral response to male circumcision in a randomized controlled trial conducted in Kisumu, Kenya.[9] In Kisumu district, Kenya, between March 2004 and September 2005, 1780 male residents were systematically recruited in the randomized experiment of MC, and 1319 chose to participate in the study. All the participants would receive not only some monetary compensation, but also free HIV testing and counseling on risk reduction strategies. Prior to the experiment, these participants were sexually active within

[9]We thank Christine Mattson at the School of Public Health, the University of Illinois at Chicago for sharing the RCT data.

the last 12 months, HIV-negative, uncircumcised,[10] and 18-24 years old. The researchers who conducted this experiment adopted the timeline followback approach to obtain panel data on each participant's detailed sexual history. A certain type of sexual behavior was included in one's record of sexual history if previous epidemiological research established that it was a risk factor for HIV and could be affected by MC, e.g. multiple sexual partners and condom use.

During the experiment, every participant visited the site clinics for this RCT and received HIV testing and counseling on safety-enhancing strategies at the following times: 1, 3, 6, and 12 month. In the baseline sample, 620 (47%) men were randomly assigned to the treatment group to undergo MC and 689 (53%) were in the control group. At baseline and at 6- and 12-month follow-up visits, each participant was interviewed separately and provided personal information including his sexual history in the site clinics for this study. Henceforth, we will call the baseline visit Visit 1, the 6-month follow-up visit Visit 2, and the 12-month visit Visit 3. The researchers began an interview by recording detailed demographic and socioeconomic information from each participant. Some information assumed to change predictably or to be invariant during the experiment, such as age and education, was recorded only at baseline. Other more variable information, such as marital status and employment status, was updated at each visit. Most of the interview time was then devoted to obtaining each participant's sexual history. To help each participant recall his sexual history, each respondent was asked to enumerate all partners since sexual debut (Visit 1) or in the past 6 months (Visit 2 and Visit 3), and then tell his sexual experience with each partner, e.g. whether he used condom

[10]It is noteworthy that the predominant majority of the participants (98.9% of the baseline sample) are of Luo ethnicity, since this experiment was conducted where Luo people constitute the majority of local population. Although MC as a cultural practice is prevalent in Kenya, Luo people are among the few Kenyan tribes that do not traditionally circumcise their males as an initiation to manhood. `http://www.kenya-information-guide.com/luo-tribe.html`

the last time of sexual encounter with this partner. The reseachers also attempted to measure his risk of sexual relationships by collecting relevant information of each partner, such as the partner's age and type (wife, commercial sex worker, etc.). It is noteworthy that in the 1309-men sample, only 1001 (76%) returned for the 6-month follow-up and 1007 (77%) returned at 12 months, but the return rate did not differ significantly across the treatment and control groups.[11]

To examine the connection between individuals' beliefs and their sexual behavior, the researchers recorded each individual's belief about whether circumcision reduced HIV risk in the regular interviews during participants' visits to the RCT clinics. All men were informed that there was only inconclusive evidence that MC protected men from HIV/AIDS. The proportion of participants who believed that MC reduced the risk of HIV infection did not vary evidently across the circumcised group and the uncircumcised group, but the proportion increased over time in both groups. At baseline, 57% of circumcised men and 56% of uncircumcised men reported that they believed the risk reduction of circumcision. These two proportions rose to 68% and 70% respectively by Visit 2, and to 75% and 76% by Visit 3. This record allows us to investigate how an individual's belief affects his risky behavior in response to MC.

Table 1 reports some baseline comparative statistics across the circumcised and uncircumcised groups, based on what each participant reported at the baseline interview. We start with non-sexual characteristics, all of which refer to contemperaneous information at the time of interview. In particular, "Believed" is an indicator that is 1 if the interviewee believed that MC would decrease his risk of acquiring HIV, and 0 if he did not believe this

[11] In the final sample for empirical analysis, all participants who returned for the 6-month visit (Visit 2) or the 12-month visit (Visit 3) had completed the baseline visit (Visit 1). Among the baseline participants, 147 men returned for Visit 2 but did not return for Visit 3, while 153 men did not return for Visit 2 but returned for Visit 3.

fact. "Did not believe" entails 3 possibilities: an interviewee either believed that MC would increase or not influence the risk of HIV infection, or did not know if MC would affect that risk. There were only a very small number of individuals who believed that MC would increase the risk at baseline (12 out of 1300) and at later visits, and it is reasonable to assume that those who believed that MC would not influence the risk or did not know if MC would affect that risk did not believe that MC was effective in protecting them from HIV.[12]

We proceed to comparing sexual behavior data at baseline (Visit 1), all of which refer to a participant's sexual history since his sexual debut. Each participant was asked to first enumerate all the sexual partners he had had, up to 12, and then recall his sexual experiences with all the partners one by one. "Always used condom in sexual encounters" is calculated as follows. If he consistently used condoms with partner A at all sexual encounters, he would receive a 1, and 0 otherwise, and we replicate this for every partner he enumerated.[13] We then sum up the 1's and 0's that he received for every partner, and divide this sum by the number of his partners. For example, if an individual had two partners in total, and he always used a condom with partner A but did not always use with partner B, then he would receive $\frac{1+0}{2} = 0.5$ for this "Always used condom in sexual encounters" variable. Clearly, 0 indicates the highest sexual risk and 1 the lowest for this variable. If he had not had any partner by the time of the interview, he would receive a 1 for this variable as well. "Used condom the last time of sexual encounter" is defined similarly, except that the question becomes whether an individual used a condom at the most recent sexual encounter. "Number of sexual partners" is the number of partners a participant reported up to 12. In our view, 12 is a safe upper bound, and in fact only 14% of participants reported more than

[12]We did a second round of empirical analysis by treating "did not know" as missing values, and the results did not change much except that some coefficients became less significant.

[13]If, for a partner, he chose "don't know" or "refused to answer" to this question, then we take his answer as if he did not have this partner. Fortunately, there are very few cases in this category.

10 partners. "Multi-partnership" is an indicator that is 1 if a participant reported more than one partners, and 0 otherwise.

The randomization of MC at baseline is key to the validity of the results from this RCT. According to Table 1, it is clear that neither in the observed demographic and socioeconomic factors nor in the recorded sexual activities was there significant difference across the cicumcised and uncircumcised groups. In addition, the experiment sample seemed to be at high risk of HIV infection: they were very sexually active (had had 5.8 sexual partners on average), probably because they were young (on average 20.5-year-old) and mostly unmarried (7% of them were married).

It is worth emphasizing that, although MC was randomly assigned at Visit 1 and was thus orthogonal to the participants' beliefs about MC initially, the changes in the beliefs about MC during the experiment might be correlated with one's MC status.[14] To evaluate the causal effect of MC on the risky sexual behavior of those who believed its efficacy, we are thus tempted to use the belief about MC at Visit 1. However, as described before, many participants changed their beliefs about MC during the experiment, and a non-trivial proportion of those who did not believe at Visit 1 that MC would reduce the chance of HIV infection turned to believing this fact at follow-up visits. Therefore, for the two 6-month-long window periods of the experiment, the first from Visit 1 to Visit 2 and the second from Visit 2 to Visit 3, we associate each participant's belief about MC recorded at Visit 1 with his sexual behavior that occurred in the first period, and their beliefs recorded at Visit 2 with his sexual history in the second period. In this way, we are able to identify a causal effect of MC on sexual behavior among those who believed that MC was protective in the

[14]Empirical evidence does not seem to support this hypothesis. The correlation between changes in beliefs and MC is negligible. Regressions of the changes in beliefs on MC status and other individual factors indicate that the changes in beliefs seem to be uncorrelated with MC and other factors.

first window period. However, beliefs recorded at Visit 2 might have changed differentially between the circumcised and uncircumcised groups, and therefore we need to be cautious in interpreting the association between MC and the behavioral changes of the believers in the second window period as causation.

Table 2 provides some descriptive statistics of the participants' personal characteristics and sexual behavior, with the observations divided into 4 categories by the participants' MC status and beliefs about MC: those who did not receive MC and did not believe that it was protective, those who received MC and believed that it was protective, etc. In comparison with Table 1, we exclude the factors that are considered to have remain unchanged or to have changed predictably during the experiment, such as age and years of school, from the non-sexual characteristics. In addition, following the logic why we associate pre-period beliefs with in-period behavior, the non-sexual characteristics that may be correlated with sexual behavior in a given period are also those reported at the pre-period visit. For example, under "12-month Visit"(Visit 3), the "Employed" variable actually reflects the participants' employment status as reported at the 6-month visit (Visit 2). Different from baseline, a participant's sexual behavior reported at later visits was restricted to the 6 months prior to a visit, and might have been influenced by his MC status and belief about MC. For instance, under "6-month Visit", "Multi-partnership" is one if a participant reported to have had more than one partners between Visit 1 and Visit 2, and zero otherwise. We notice that, for the entire sample in either 6-month period, over 30% last-time sexual acts were unprotected, and multi-partnership was common given that about 40% of all men reported more than one partner.

From Table 2, there is no clear association between one's non-sexual characteristics and MC status and belief about MC. However, we can observe some association between one's sexual behavior reported at later visits and MC status and belief about MC. Conditional on being circumcised, those who believed the health benefit of MC seem to have been less sexually risky. For example, in the first 6-month period, circumcised believers had 1.53 partners on average while circumcised non-believers had 1.64 partners. Conditional on being non-believers, those who were circumcised seem to have been more sexually risky. For example, in the second 6-month period, circumcised non-believers used a condom at 62% of their last-time sexual encounters, while the uncircumcised non-believers used at 76% of last-time encounters. Such signs of association point to studying how MC status and MC belief jointly affected risky sexual bahavior.

5 Empirical Framework and Results

To investigate how a man's circumcision status and his belief about circumcision affects his choice of risky behavior, we focus on the participants' sexual activities in the two 6-month-long periods after MC was randomly assigned. For each period, the main set of regressions will be as follows:

$$riskbhv_{i,t} = \beta_0 + \beta_1 MC_i + \beta_2 belief_{i,t} + \beta_3 MC_i * belief_{i,t} + \epsilon_{i,t} \tag{3}$$

where $riskbhv_{i,t}$ is a measure of participant i's risky sexual behavior in a 6-month period t, MC_i is his MC status that remained unchanged during the experiment, $belief_{i,t}$ is an indicator that is 1 if he believed in the protective effect of MC at the beginning of period t, and $MC_i * belief_{i,t}$ is the interaction between his circumcision status and belief. We run OLS regressions with robust standard errors.

The results for Eq.(3) are presented in Table 3. In general, MC significantly increased the sexual riskiness of those who were randomly assigned MC, as shown by the coefficients on the dummy "Circumcised". For instance, between Visit 1 and Visit 2, being circumcised led to an increase of 8.6 percentage points in the likelihood of having multiple sexual partners, while in this period 38.3% of all participants reported multi-partnership (see Table 2). Being circumcised and simultaneously believing in the protective effect of MC was associated with a significant reduction in risky sexual behavior, as evidenced by the coefficients on "Circumcised*Believe", an interaction term between MC and belief. For example, in the second 6-month period, being a circumcised believer was associated with having 0.32 fewer sexual partners on average.[15] This reduction in sexual riskiness is both statistically significant and numerically large: in the period concerned, an average participant had 1.53 partners (see Table 2). To give a second example, in the second 6-month period, being a circumcised believer was associated with an average increase of 14 percentage points in the proportion of condom-used last-time sexual acts. This result is also both significant and large, given that an average participant used condoms in 67.2% of his last-time sexual acts (also see Table 2). These results match one of the possible predictions of our behavioral model: it seems that the circumcised believers moved the optimal consumption of risky sex from the corner (maximum amount) to the interior, as compared to the circumcised non-believers. Note that we should relate the effect of MC on the sexual behavior of circumcised believers, not all circumcised men, to the efficacy of MC in reducing the risk of HIV infection.

There is sporadic evidence that believing that MC was protective was associated with a slight increase in sexual riskiness, as shown by the coefficients on "Believe". This is

[15] We perform a precautionary check since the dependent variables of condom use only have values in $[0, 1]$, and multi-partnership is a binary variable. For these dependent variables, we confirm that the predicted values from all the OLS regressions above are in $[0, 1]$. In addition, we redo the OLS regressions using probit and logistic regressions. The signs and significance of the OLS estimates are preserved, and the predicted values from both probit and logistic regressions are close or identical to those from OLS regressions.

possibly because the free consulting on risk reduction offered at the clinic visits called the participants' attention to high-risk sexual practices. As a result, those who believed that MC would protect them but did not receive MC lowered the expectation of their lifespan and chose to derive utility from risky sex as soon as possible in their remaining life. It is also possible that being a believer was associated with some unobserved variables that were associated with increased sexual riskiness. This is not our main concern though, as the related evidence is weak.

It is noteworthy that for most regressions in Table 3, a t-test (or a 1-dimensional F-test) can not reject the null hypothesis that the sum of the three coefficients on Circumcised, Believe, and the MC-belief interaction is 0. As reported in the last row of Table 3, the linear sum of the three coefficients for most regressions is small and insignificant. In other words, the reduction in sexual riskiness induced by MC among believers seems to be offset by the increase in sexual riskiness induced by MC alone, and the net effect of MC on the sexual behavior of those who believed the efficacy of MC was not significantly different from 0. Two exceptions are the two variables of condom use in the second 6-month period: it seems that in this period, circumcised believers used condom less often. As we stressed before, for this period, the belief reported at Visit 2 that we associate with sexual behavior might be correlated with MC, and we have to be cautious in interpreting the effect of MC on the behavior of circumcised believers as causal. Overall, since the circumcised believers did not engage in more risky sex, the HIV incidence among these individuals should fall because of the decrease in per-act tranmission probability due to MC.

Having studied how an individuals' belief about MC influenced his behavioral response, we proceed to examining the demographic and socioeconomic factors associated with this belief. The regressions for this purpose will be as follows for each of the 3 visits:

$$belief_{i,t} = \beta_0 + \beta_1 MC_i + \beta_t \mathbf{X'}_{i,t} + \epsilon_{i,t} \tag{4}$$

where $\mathbf{X'}_{i,t}$ is a vector of demographic and socioeconomic factors. Examples of such factors are age, marital status, years of school attended, etc. The results for Eq.(4) are presented in Table 4, where in each regression, the correlates and belief were recorded at the same visit (except for circumcision status, age, education, and income that were only recorded at baseline). For the beliefs recorded at all 3 visits, there seems to be little association between belief and the other variables. An exception is that an individual's age seems to be negatively correlated with belief. This could be explained by the fact that MC was not well known as an HIV-prevention instrument in the early 2000s when the RCT was conducted, and younger people might have more access to lastest health information, say, if they were more used to obtaining information from the internet. It is not surprising that MC belief was positively associated with income (although only at Visit 2), since rich people were more likely to have good sources of information. However, whether significant, all the coefficients on the correlates are numerically very small.

6 Robustness

The successful randomization of MC in the RCT reduces the need to control for individual characteristics besides MC and belief, but we will still add $\mathbf{X'}_{i,t}$, a vector of personal non-sexual characteristics, to the right-hand side of Eq.(3) as a robustness check. The relevant results are presented in Table 5. In comparison with Table 3, being circumcised is still positively associated with sexual riskiness, the negative correlation between the MC-belief interaction and riskiness remains, and the magnitude of the coefficients are generally preserved. Although the coefficient estimates become somewhat less precise, in general they remain significant at 90% level. Many non-sexual factors are significantly associated with condom use, although the coefficients are numerically small except those on the indicator "Married/cohabit". It is puzzling, however, that these non-sexual factors turn out to be insignificant to number of partners. This suggests that these non-sexual factors may be correlated with condom use through some omitted variable.

While MC is orthogonal to individual characteristics at baseline, it is possible that one's belief about MC is a proxy for some other factor that conditions the behavioral response to MC. For instance, as in Table 4, younger males were more likely to believe in the efficacy of MC, and it might be the case that even with the same belief, young men responded to MC differently from older men. To check this possibility, we interact MC with a control variable of individual characteristics, and add this control and the interaction to the right-hand side of Eq.(3). Table 6 presents the relevant results, with one control added to the right-hand side of Eq.(3) each time. Note that we only show results for two variables of Visit 2 sexual behavior, "Number of partners Visit 2" and "Multi-partnership Visit 2", because MC is orthogonal to baseline beliefs that we associate with Visit 2 behavior. We observe that adding a control and its interaction with MC brings little change to the results obtained without the control and interaction: the sign and magnitude of coefficients and the standard errors are well preserved. In comparison with those in Table 5 where we control for individual characteristics, the coefficients and standard errors of the control variables do not change much either. The interaction between MC and any control is never slightly significant, and the corresponding coefficient is generally much smaller than the one on the MC-belief interaction. Moreover, the results for Visit 2 condom use and Visit 3 variables of sexual behavior are similar: adding a control and its interaction with MC makes little difference. In short, it is unlikely that the observed effect of one's belief about MC on his sexual behavior was due to some factor other than belief.

7 Policy Implications

Although the RCT shows that MC made the participants sexually riskier whether they believed the safety-improvement of MC, MC did have an effect of reducing men's sexual riskiness by making the circumcised believers optimize against the reduced risk of acquiring HIV. In addition, overall, circumcised believers did not become sexually riskier in response to MC. This finding provides empirical support for the scale-up of MC for HIV/AIDS prevention. In such mass MC campaigns as those taking place in a few Sub-Saharan African countries, the organisers of the MC campaigns typically emphasize that MC protects men from HIV/AIDS in order to persuade men to accept MC. Thus, it is likely that those who agree to undergo MC believe the protective effect of MC and will take into account the lowered risk of acquiring HIV when choosing the amount of risky sex they engage in. If, as in the RCT, circumcised believers do not engage in more risky sex in response to MC, then since MC reduces the probability of HIV transmission per coital act, the HIV incidence among these circumcised believers will fall. This also points to the importance of informing the target population in MC scale-up of the efficacy of MC.

As for the observed positive effect of MC on sexual riskiness, if this effect is indeed due to the fact that MC lowered the incidence of non-HIV STIs, then this effect may diminish as the prevalence rates of non-HIV STIs decrease in countries where MC campaigns are in progress. This is because as men contract STIs less often, they are less likely to have the experience that MC protects them from the STIs, and the STI-related effect of MC on men's sexual behavior will become weaker. Moreoever, it is possible that in the RCT, sexual partners' preference for circumcised men, who were less likely to carry STIs, contributed to the positive effect of MC on sexual riskiness. This effect due to partners' preference will become trivial, however, in mass MC campaigns that aim to circumcise a very large male population. If the STI-related effect of MC on sexual riskiness becomes insignificant, then the HIV-risk-related effect of MC can dominate and overall the target population in MC campaigns can become less sexually risky, contributing to the decline in HIV incidence. Following this argument, public health campaigns against non-HIV STIs may complement MC campaigns in reducing HIV incidence.

Whereas we would recommend MC as an effective intervention for HIV/AIDS prevention based on the results from this RCT, we need to be aware of some caveats. A concern about applying the findings from this RCT to the MC campaigns is that the experiment sample was not representative of the target population in the scale-up process. First, all participants were HIV-negative at baseline, while a non-trivial proportion of the male population, either in Kisumu locally or in Kenya nationwide, was HIV-positive. For HIV-negative men, accepting MC and understanding the associated health benefit may help reduce their risky sexual behavior, as this RCT shows. However, for an HIV-positive man, MC is unlikely to have an impact on his sexual behavior. Second, all participants were 18 to 24 years old at baseline, while the male life expectancy in Kenya was 53.0 years.[16] Young male adults are less likely to be HIV positive than older men, and hence face a higher marginal cost of risky sex. As a result, young men are more likely to adjust sexual behavior in response to risk-reducing instruments such as MC. These two arguments suggest that in large-scale MC campaigns, the male population may appear less responsive to MC than the sample in this RCT did.

[16] United Nations World Population Prospects: 2006 revision, Table A.17 for 2005-2010. `http://www.un.org/esa/population/publications/wpp2006/WPP2006_Highlights_rev.pdf`

Last but not least, those who agreed to participate in the RCT might be more likely to believe the efficacy of MC, since some participants might have chosen to participate for the chance to be offered free circumcision and to protect themselves.

Albeit we stress the role of an individual's belief about MC in affecting his sexual behavior, there are imperfections with the belief variable that may point to future work investigating MC-induced behavioral response. The beginning-of-period beliefs are not the only ones that affected individuals' risky sex consumption in the period concerned. As many participants changed their beliefs about MC in the course of the experiment, the changes in beliefs were likely to account for some changes in risky behavior as well, and such changes in beliefs that were developed over a 6-month period were not fully captured by the beliefs recorded on a specific interview day. The noise in beliefs were largely due to the uncertainty about the protective effect of MC, since the RCT was conducted when there was only sporadic evidence that MC protected men from HIV infection, and it is possible that the participants adjusted their beliefs according to their sexual experiences after being circumcised. Unfortunately, we do not have data on the strength of an individual's belief about MC, and those who believed firmly that MC would protect them from HIV/AIDS might exhibit different behavioral response from those who only weakly believed this fact. Given that the protective effect of MC is a well-established fact nowadays, it is recommended for the investigation of MC-related behavioral response to conduct another RCT in which we convince the participants that MC is effectively protective, eliminating much uncertainty about this fact. Such a RCT seems to be coherent with the typical setting of MC campaigns, in which those who promote MC stress the health benefits of MC in order enroll people in MC scale-up.

To evaluate the effect of MC campaigns on HIV/AIDS prevention in the general population, it is necessary to understand the behavioral response of both men and women.

Although it is widely accepted that MC protects men from HIV infection, a number of studies have indicated that MC does not equivalently protect women. Wawer et al (2009) find in an Uganda-based RCT that circumcision of HIV-infected men did not reduce HIV transmission to female partners over 24 months. Likewise, based on one RCT and six longitudinal analyses, Weiss et al (2009) perform a random-effects meta-analysis of data and find little evidence that MC directly reduces risk of HIV for women (summary relative risk 0.80, 95% CI: $0.53-1.36$). Nonetheless, many women may not be well informed of the gender difference in the efficacy of MC. Women who overestimate the protective effect may engage in more risky sex, which facilitates the transmission of HIV, and thus diminishes the contribution of MC scale-up to HIV prevention. Whether women understand that the effect of MC differs by gender, as long as they learn that MC well protects men, they may infer men's sexual behavior and the related risk of heterosexual intercourse based on this fact, and may adjust their own sexual behavior accordingly.

8 Conclusion

In this paper, we investigate men's behavioral response to male circumcision using data from a large-sample randomized controlled trial that randomly assigned MC to the participants. We emphasize that the protective effect of MC on HIV/AIDS will induce behavioral response only among the circumcised men who believe this risk reduction. We find that, regardless of the participants' beliefs about MC, MC positively affected their sexual riskiness in the RCT through some channel unrelated to the risk of HIV infection. However, compared with the participants who were circumcised but did not believe the efficacy of MC, those who were circumcised and believed the health benefits of MC exhibited significant and large decreases in risky sexual behavior, and overall MC had an insignificant effect on the circumcised believers' risky behavior. This result supports MC scale-up as a policy instrument for HIV/AIDS prevention in countries with high HIV prevalence, although we need to be aware that the sample population in the RCT is not necessarily representative of the target population in MC campaigns. To better approximate men's behavioral response to MC campaigns, a RCT that recruits a sample male population representative of the policy target population and that confirms the protective effect of MC with every participant is desirable. In addition, it will be interesting and important to study women's behavioral response to MC, since the fact that MC only protects men against HIV infection may influence women's perception of men's willingness to engage in risky sex and the risk of heterosexual intercourse.

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Table 1: Baseline Descriptive Statistics by MC Status

Baseline Visit (Visit 1)	**N=1300**			
	Circumcised (n=616)		Uncircumcised (n=684)	
Variable	**Mean**	**SD**	**Mean**	**SD**
Non-sexual characteristics				
Age	20.44	1.60	20.49	1.67
Married/cohabit	0.07	0.25	0.07	0.26
Education (years of school attended)	10.90	2.44	10.99	2.39
Employed	0.50	0.50	0.48	0.50
Average monthly income (thousands of Kenyan shillings)	2.60	2.91	2.56	3.89
Believed that MC decreases HIV infection risk	0.57	0.49	0.56	0.50
Sexual behavior				
Always used condom in sexual encounters	0.61	0.43	0.60	0.43
Used condom the last time of sexual encounter	0.66	0.41	0.67	0.41
Number of sexual partners	5.78	3.30	5.75	3.35
Multi-partnership	0.95	0.22	0.94	0.23

Notes:

1. *Non-sexual characteristics* were contemporaneous information at the time of the baseline visit. *Sexual behavior* refers to one's sexual history from his sexual debut to the baseline visit.
2. For each variable, we report the mean value and standard deviation.
3. What each variable represents specfically is explained in **Section "Data and Descriptive Statistics"**, where the explanation of the meaning of variables applies to subsequent tables.

Table 2: Follow-up Visits, Descriptive Statistics by MC Status and Belief about MC

	6-month Visit (Visit 2), N=998				12-month Visit (Visit 3), N=867			
	Circumcised (n=469)		Uncircumcised (n=529)		Circumcised (n=410)		Uncircumcised (n=457)	
Variable	Believe (n=265)	Not Believe (n=204)	Believe (n=287)	Not Believe (n=242)	Believe (n=280)	Not Believe (n=130)	Believe (n=322)	Not Believe (n=135)
Non-sexual characteristics								
Married/cohabit	0.08	0.10	0.08	0.09	0.11	0.12	0.12	0.08
	(0.27)	(0.30)	(0.27)	(0.29)	(0.32)	(0.33)	(0.33)	(0.27)
Employed	0.48	0.49	0.52	0.45	0.49	0.46	0.53	0.45
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
Sexual behavior								
Always used condom	0.62	0.61	0.64	0.63	0.60	0.56	0.63	0.71
in sexual encounters	(0.47)	(0.47)	(0.46)	(0.47)	(0.47)	(0.48)	(0.47)	(0.43)
Used condom the last time	0.69	0.68	0.70	0.70	0.66	0.62	0.67	0.76
of sexual encounter	(0.45)	(0.45)	(0.44)	(0.45)	(0.45)	(0.47)	(0.46)	(0.41)
Number of sexual partners	1.53	1.64	1.58	1.40	1.38	1.66	1.58	1.33
	(1.37)	(1.53)	(1.47)	(1.24)	(1.20)	(1.25)	(1.55)	(1.38)
Multi-partnership	0.38	0.43	0.40	0.34	0.34	0.46	0.39	0.33
	(0.49)	(0.50)	(0.49)	(0.48)	(0.47)	(0.50)	(0.49)	(0.47)

Notes:

1. *Non-sexual characteristics* were contemporaneous information at the time of the respective visit. *Sexual behavior* refers to one's sexual history from the previous visit to the current visit. For example, under "Visit 2", "Number of sexual partners" shows how many partners an individual had in the 6-month period between Visit 1 and Visit 2.
2. For each variable, we report the mean value and standard deviation (in parentheses).

Table 3: MC, Belief about MC, and Risky Sexual Behavior

	Visit 2 Observations: 998				Visit 3 Observations: 867			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	Always used condom	Used condom last time	Number of sexual partners	Multi-partnership	Always used condom	Used condom last time	Number of sexual partners	Multi-partnership
Circumcised	-0.018	-0.017	0.233*	0.086*	-0.149***	-0.145***	0.328**	0.128**
	(0.045)	(0.043)	(0.134)	(0.046)	(0.056)	(0.054)	(0.162)	(0.060)
Believe	0.015	-0.003	0.174	0.052	-0.082*	-0.097**	0.251*	0.058
	(0.041)	(0.039)	(0.117)	(0.042)	(0.046)	(0.043)	(0.147)	(0.049)
Circumcised*Believe	-0.020	-0.021	-0.317*	-0.121*	0.116*	0.140**	-0.537***	-0.180**
	(0.060)	(0.058)	(0.177)	(0.062)	(0.068)	(0.066)	(0.197)	(0.072)
Circumcised+Believe+	-0.023	-0.041	0.090	0.016	-0.115**	-0.102**	0.042	0.006
*Circumcised*Believe*	(0.042)	(0.041)	(0.111)	(0.043)	(0.047)	(0.044)	(0.139)	(0.050)

Notes: (same for subsequent tables of regression results)

1. "Visit 2, Number of sexual partners" refers to the number of sexual partners that an individual reported, at the second visit (Visit 2), to have had during the 6 months between Visit 1 and the Visit 2. The same notation for other variables of sexual behavior.
2. *Circumcised+Believe+Circumcised*Believe* is the linear sum of the coefficients on Circumcised, Believe, and Circumcised*Believe, as an estimate of the net effect of MC on the sexual riskiness of the circumcised believers.
3. For regression results, OLS coefficients reported, robust standard errors in parentheses.
4. *** statisitically significant at 99% confidence interval; ** significant at 95%; * significant at 90%.

Table 4: Correlates of Individuals' Beliefs about MC

Dependent Variable	(1) Believe Visit 1	(2) Believe Visit 2	(3) Believe Visit 3
Circumcised	0.011	-0.022	0.009
	(0.027)	(0.029)	(0.030)
Age	-0.026***	-0.020**	-0.009
	(0.009)	(0.010)	(0.009)
Married/cohabit	-0.039	0.035	-0.016
	(0.056)	(0.047)	(0.047)
Education (years of	-0.002	-0.007	0.000
school attended)	(0.006)	(0.006)	(0.007)
Employed	0.040	0.034	0.010
	(0.030)	(0.031)	(0.032)
Average monthly income	-0.000	0.007***	0.002
(1,000 Kenyan shillings)	(0.004)	(0.003)	(0.003)
Observations	1,300	998	867

Notes:

1. "Believe Visit 1" is a dummy that indicates if an individual believed that MC decreased the risk of HIV infection, as he reported at the first visit (baseline). The same notation for beliefs reported at later visits.

Table 5: MC, Belief about MC, and Risky Sexual Behavior, Controlling for Individual Characteristics

	Visit 2 Observations: 998				Visit 3 Observations: 867			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	Always used condom	Used condom last time	Number of sexual partners	Multi-partnership	Always used condom	Used condom last time	Number of sexual partners	Multi-partnership
Circumcised	-0.011	-0.011	0.235*	0.087*	-0.129**	-0.124**	0.315*	0.130**
	(0.043)	(0.040)	(0.133)	(0.047)	(0.054)	(0.052)	(0.162)	(0.059)
Believe	0.025	0.007	0.174	0.051	-0.044	-0.057	0.221	0.055
	(0.040)	(0.038)	(0.122)	(0.043)	(0.043)	(0.040)	(0.149)	(0.049)
Circumcised*Believe	-0.040	-0.040	-0.317*	-0.125**	0.084	0.107*	-0.513***	-0.180**
	(0.058)	(0.055)	(0.177)	(0.062)	(0.065)	(0.062)	(0.198)	(0.071)
Age	-0.003	-0.002	0.015	-0.000	0.019**	0.019**	0.023	0.009
	(0.009)	(0.009)	(0.028)	(0.010)	(0.009)	(0.009)	(0.030)	(0.011)
Married/cohabit	-0.276***	-0.301***	0.063	-0.083	-0.470***	-0.503***	0.137	-0.105*
	(0.053)	(0.055)	(0.207)	(0.058)	(0.043)	(0.044)	(0.192)	(0.054)
Education (years of	0.024***	0.025***	-0.016	0.002	0.018***	0.017***	-0.011	-0.005
school attended)	(0.007)	(0.006)	(0.018)	(0.007)	(0.007)	(0.006)	(0.021)	(0.007)
Employed	-0.100***	-0.094***	0.170*	0.052	-0.070**	-0.074**	0.162*	0.036
	(0.032)	(0.031)	(0.101)	(0.035)	(0.032)	(0.030)	(0.098)	(0.036)
Average monthly income	-0.006	-0.008**	0.021	0.006	-0.008***	-0.008***	0.013	0.004
(1,000 Kenyan shillings)	(0.004)	(0.004)	(0.013)	(0.006)	(0.003)	(0.003)	(0.013)	(0.005)

Table 6: MC, Belief about MC, and Risky Sexual Behavior, MC Interacted with Individual Characteristics

Interacted Control	No interacted control	Age	Married or cohabit	Education (years of school)	Employed	Average income/month
Dependent Variable: Number of partners Visit 2	(1)	(2)	(3)	(4)	(5)	(6)
Circumcised	0.233*	-0.124	0.257*	0.270	0.151	0.193
	(0.134)	(1.162)	(0.139)	(0.417)	(0.147)	(0.143)
Believe	0.174	0.185	0.178	0.162	0.161	0.186
	(0.117)	(0.123)	(0.119)	(0.117)	(0.118)	(0.119)
Circumcised*Believe	-0.317*	-0.318*	-0.319*	-0.309*	-0.298*	-0.344*
	(0.177)	(0.180)	(0.177)	(0.177)	(0.176)	(0.178)
Control	--	0.022	0.308	-0.023	0.176	0.022
		(0.037)	(0.284)	(0.021)	(0.119)	(0.018)
Circumcised*Control	--	0.017	-0.265	-0.004	0.153	0.021
		(0.056)	(0.379)	(0.035)	(0.175)	(0.025)

Dependent Variable: Multi-partnership Visit 2	(1)	(2)	(3)	(4)	(5)	(6)
Circumcised	0.086*	-0.265	0.091*	0.038	0.080	0.062
	(0.046)	(0.395)	(0.048)	(0.152)	(0.054)	(0.052)
Believe	0.052	0.049	0.052	0.051	0.048	0.054
	(0.042)	(0.043)	(0.042)	(0.043)	(0.042)	(0.042)
Circumcised*Believe	-0.121*	-0.116*	-0.125**	-0.120*	-0.117*	-0.128**
	(0.062)	(0.063)	(0.062)	(0.062)	(0.062)	(0.062)
Control	--	-0.005	-0.034	-0.002	0.050	0.004
		(0.013)	(0.075)	(0.009)	(0.042)	(0.006)
Circumcised*Control	--	0.017	-0.052	0.004	0.006	0.011
		(0.019)	(0.113)	(0.013)	(0.062)	(0.009)

Number of observations for all regressions in this table: 998.