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Drivers of onward HIV transmission risk among adolescent boys growing up with HIV: a longitudinal cohort study

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ABSTRACT

Introduction HIV transmission to sexual partners is determined jointly by viraemia and condomless sex, both of which are higher among adolescents living with HIV compared with adults. Moreover, decisions around condom use vary day to day. We are the first study to investigate both the stable and time-varying factors contributing to HIV transmission risk.

Methods The cohort study enrolled 251 adolescent boys 15–19 years old who were born with HIV and resided in Soweto, South Africa. Participants had viral load testing concurrently with completing baseline and 12-month follow-up surveys. Over the study year, participants completed repeated mobile surveys to capture time-variant exposures and condom use in the past 24 hours. Associations between baseline factors and high transmission risk (a composite of detectable viral load and any reported non-condom use) were analysed using logistic regression models. Associations between time-variant factors and condomless sex were analysed using generalised linear mixed-effect models.

Results Experiencing an additional adverse event in the last year (adjusted OR (aOR) 1.33; 95% CI 1.09, 1.64), intimate partner violence (IPV; aOR 6.07; 95% CI 1.69, 21.80) and depression (aOR 2.96, 95% CI 1.03, 8.57) each increased the adjusted odds of being in the high-risk group for HIV transmission. When we examined time-variant factors, we found that a 10% higher average experience of stress (aOR 1.23; 95% CI 1.04, 1.46) and anger (aOR 1.26; 95% CI 1.04, 1.53) was significantly associated with increased odds of having condomless sex. There was no evidence that day-to-day changes in exposure to potential risk factors influenced condom use decisions.

Discussion Global strategies largely focus on reducing HIV infection risk from the perspective of adolescent girls and young women. This study adds to the growing evidence that childhood adversity, IPV victimisation and depression are related to sexual transmission risk, and importantly extends this finding to the expanding population of adolescent boys born with HIV. Tailoring violence and mental health support services to the needs of adolescent boys may have important implications for their well-being and the health of their partners.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ There is evidence that violence, mental health and substance use may structure HIV transmission risk among adolescents living with HIV. However, the evidence base is mixed and, despite indications that risk factors may differ by gender, there are few studies that focus on boys.

WHAT THIS STUDY ADDS

⇒ We find that adolescent boys were at greater risk of transmitting HIV (ie, they had condomless sex with viraemia) if they experienced intimate partner violence, childhood adversity or depression. We also examined time-variant risk factors and found no evidence that day-to-day changes in exposure to violence, mood or binge drinking influenced the decision-making process.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Interventions to prevent HIV typically focus on adolescent girls and young women, neglecting what drives boys living with HIV to engage in high-risk sex. Reducing violence directed against boys—by families and partners—and attending to their mental health may be effective strategies to prevent onward HIV transmission.

INTRODUCTION

In South Africa and other middle-income countries, the emerging generation of adolescents living with HIV is the first to have grown up with publicly available access to treatment. However, adolescents are far less likely than adults to adhere to antiretroviral treatment (ART) and be virally suppressed.[1–3] Moreover, adolescents—including those living with HIV—report high levels of sexual risk-taking, such as inconsistent condom use.[4–8] Sexual transmission among this generation could reverse hard-won progress towards an AIDS-free generation. Yet current HIV prevention efforts are largely aimed at uninfected

adolescent girls[9]—a group with very different life histories and challenges than adolescents who have grown up with HIV. To inform an appropriately tailored prevention strategy we need to understand the factors contributing to transmission risk among this unique group.

Multiple studies highlight mental health[10–16] and substance use[16–18] as strong correlates of virological failure or non-adherence among adolescents. Similarly, exposure to violence—whether in the home or from an intimate partner—shows a strong association with adherence.[10 11 17 19] However, the relationship between violence and viral suppression is less consistent.[10 19 20] Moreover, Merrill *et al*[20]—in one of the few studies to disaggregated boys and girls—report gender differences in these associations.

There is perhaps less evidence on what structures sexual risk among adolescents living with HIV; a 2017 review found largely inconsistent evidence on predictors of sexual risk.[4] Since then, a study in South Africa has shown that both childhood adversity and intimate partner violence (IPV) are associated with sexual risk behaviours in adolescents living with HIV.[8 10] However, the literature on adolescents more generally raises the possibility that the consequences of violence may differ by gender. For example, studies from sub-Saharan Africa have shown that childhood adversity impacted sexual risk among girls but not boys.[21 22] Likewise, a South African study found that IPV victimisation was associated with lower condom use among girls, but greater use among boys.[23]

Finally, while HIV transmission is determined jointly by viraemia and sexual behaviour, only one study has examined a composite indicator. Toska *et al*[24] defined onward transmission risk as the presence of both viraemia (>1500/mL or self-reported non-adherence when viral load was not available) and past-year sexual risk (eg, unprotected sex and transactional sex) in South Africa. They found that substance use, food insecurity, parenthood, being in a power-inequitable relationship and having been sexually infected were significant predictors of transmission risk.

In this study, we use longitudinal data from adolescent boys who have grown up with HIV in Soweto, South Africa to examine predictors of transmission risk, where we define risk in line with the Toska *et al* composite.[24] While prior work has not been gender-disaggregated, we focus specifically on adolescent boys because HIV transmission is disproportionately male to female among this age group.[25] Moreover, boys exert greater control over condom use decisions,[26] may display different risk profiles than girls, and may experience different consequences.

METHODS

This study is part of the larger Tsamaisano study.[27–29] The study complemented traditional surveys with repeated mobile surveys delivered over the course of a year.[28] The latter represents a form of ecological momentary assessment (EMA).[30] EMA is a range of methods defined by three key aspects: first, data are captured when individuals are situated in their natural environment. In this study, boys are surveyed via mobile phone as they go about their regular daily lives, and thus data better reflects behaviour in real-world settings (increasing the ecological validity of the study).

Second, EMA captures discrete moments in time, and the risk factors and behaviours that are occurring at (or close to) that moment. It is thus uniquely well suited for capturing factors that are dynamic and may change moment to moment. This is important given that we expect there to be variation in whether an adolescent uses condoms across sexual encounters. Traditional surveys often ask a single question, such as whether a condom was used the last time a participant had sex. In contrast, with EMA, the recall period is short (in this case 24 hours) and thus reduces bias.

Third, these moments are assessed repeatedly over time. The repeated nature of EMA is likely to yield more accurate data on whether a participant engages in any condomless sex, rather than generalising from a single survey question. Most importantly, the repeat measures can be used to examine within-person processes. This is key for the current study: the within-person variation in condom use is of interest because we can better understand why a boy may use condoms in some circumstances and not in others. Participants were asked to complete a mobile survey on one randomly selected day each week for a year, yielding up to 52 discrete days of data. The mobile surveys capture experiences (eg, potential antecedents like violence or stress) that may co-occur in time with condomless sex.

While EMA has been used recently in high-income contexts to examine the predictors of sexual risk[31 32] and ART adherence,[33] it has rarely been employed in lower-resourced contexts. However, the widespread availability and familiarity with smartphones—especially among adolescents—now makes it feasible to capture EMA data across a variety of contexts.[34] By employing EMA, this study is uniquely able to investigate the factors contributing to onward HIV transmission behaviour, and to provide critical insight on how to intervene.

Participant and public involvement

Participants were not involved in the study design or research questions. However, procedures and instruments were informed by discussions with an adolescent advisory board (including members who were living with HIV) and with key stakeholders in the community. During the study, in-depth interviews were conducted with 20 participants in order to improve the mobile survey procedures.[28] Study findings were shared iteratively with the advisory board for guidance on interpretation and recommendations. Finally, participants and their caregivers were invited to a 1-day workshop to learn about the findings, including presentations designed with and led by the adolescent advisory board and by community stakeholders.

Sample

As part of the Tsamaisano study, adolescents living with HIV were recruited from 34 public HIV care clinics in Soweto, a periurban settlement in South Africa, between November 2020 and June 2022. Inclusion criteria were male at birth, 15–19 years old at baseline, living in the greater Soweto area, aware of their HIV diagnosis, and a history of HIV infection before age 10 (indicating likely perinatal infection). To ensure adequate data on sexual behaviours, all participants had to either be dating someone or have had sex in the month prior to enrolment. Participants with acute psychiatric illness or cognitive impairment were excluded. For the latter, we assessed their ability to read and comprehend the assent or the informed consent during the screening visit. Potential participants were screened at the Perinatal HIV Research Unit, and 251 adolescents living with HIV enrolled. Of note, the larger Tsamaisano study also enrolled 247 HIV-negative adolescents; however, this paper focuses exclusively on participants with perinatally acquired HIV (PHIV).

Procedures

Following informed consent (for adolescents 18+) or assent with caregiver consent (for adolescents <18), each adolescent completed a baseline survey privately on a tablet computer. A counsellor or social worker was available to support the participant if they became distressed and to debrief them at the end of the survey. Where warranted, these professionals also linked participants to appropriate psychological services. At this visit, participants also provided blood for HIV RNA viral load testing if their last viral load test results were older than 7 days. Finally, participants were trained on how to complete the mobile survey. A smart phone with specific functionality was required; in most cases, this necessitated providing a study phone to participants. Over a 1-year observation period, each participant received a once-weekly prompt/text message to complete the mobile survey; valid surveys were those completed within 24 hours of the prompt. At the end of the mobile survey, there was an option to request that the social worker or counsellor reach out to the participant; a call was also initiated automatically if survey answers suggested the adolescent may be in danger. Participants returned to the clinic at the conclusion of the observation year to complete a follow-up survey and provide a sample for viral load testing. Participants received monetary reimbursement (~$26) for each in-clinic visit as well as airtime for each valid mobile survey received.

Variables

Composite HIV transmission risk

Following the approach of Toska *et al*,[24] we created a composite indicator of transmission risk defined as a detectable viral load and any reported non-condom use during the entirety of the study period. We drew data from the baseline and follow-up visits. To ensure the quality and completeness of the data, our study measured viral load directly, rather than extracting such from charts. We defined viral suppression as having fewer than 200 copies per mL (as in the PARTNER 1 and 2 studies[35]) at both time points (baseline and follow-up). This was the definition used by the original studies demonstrating that an undetectable viral load could prevent HIV transmission to sexual partners.[36] We drew on the condom use reports provided in the mobile study where participants were asked whether they had sex in the past 24 hours, and if so, whether a condom was used. Participants who were virally suppressed at both time points, who used a condom at every sexual act, or who never reported having sex were coded as having low transmission risk. Adolescents were considered high risk if they had a detectible viral load (≥200/mL) at either baseline or follow-up AND reported non-condom use in any mobile survey.

Daily risk behaviour

A second set of analyses focused on time-variant predictors collected during the mobile surveys. This necessitated use of a time-variant outcome captured each day they reported seeing a partner. Since viral load was not measured weekly, we only used reported condom use to define the outcome. Participants who reported condomless sex were considered high risk; those who either used a condom or did not have sex were considered low risk.

Potential predictors for composite HIV transmission risk

We used the following predictors from the baseline survey: violence exposure; physical, emotional, sexual IPV or any IPV; depression; alcohol/substance misuse; food insecurity and orphanhood. We captured past-year exposure to multilevel violence using the Adverse Childhood Experiences International Questionnaire[37]; we employed the binary coding and used the continuous value. IPV was captured with the WHO's Violence Against Women instrument,[38] modified slightly to be gender-neutral. Three separate indicators captured past-year physical, emotional and sexual IPV; we also created a dichotomous variable coded 1 if there was any type of past-year IPV. Depression was measured with the Beck Depression Inventory (dichotomised to indicate moderate or severe symptomology using a cut-off of 18).[39] Alcohol and other substance misuse were measured using the adolescent CRAFFT Screening Questionnaire.[40] Food insecurity was measured with the FANTA Household Hunger Scale and coded as moderate to severe hunger in the household versus none.[41] Finally, we used data on parental survival to define orphanhood as the death of either parent.

Potential predictors for daily risk behaviour

A second set of predictors was drawn from the mobile surveys. In large part, these evaluated the same concepts as above. However, we chose brief measures to facilitate delivery of a quick, low-burden mobile survey. Three indicators of mood (ie, sad, stressed and angry) in the past 24 hours were captured using the Screening Tool

for Psychological Distress (STOP-D)[42] and were coded as separate dichotomous indicators (1 if they had severe or moderate feelings and 0 if not at all or a little). Four questions captured exposure to violence victimisation in past 24 hours (physical, sexual, emotional and witnessing community violence); these were also combined to create a dichotomous indicator of any victimisation. A question on how many alcoholic drinks they had consumed in the past 24 hours was used to create a dichotomous indicator equalling 1 if the answer was 4 or more and 0 otherwise.

Analyses

Composite HIV transmission risk

HIV transmission risk was defined as a binary outcome at the person level. The association between potential predictors measured at baseline and high transmission risk was analysed using logistic regression models, with and without adjustment for adolescent age. As defined above, being in the high transmission risk group meant that the individual had both (1) a detectible viral load at either baseline or follow-up and (2) condomless sex in any mobile survey across the 1-year study period.

Daily risk behaviour

Associations between time-variant potential predictors and condomless sex were measured in the daily mobile surveys. We used all event records where a participant reported seeing a partner in their submitted mobile survey. Longitudinal data were analysed using generalised linear mixed-effect models (GLMMs) considering participants as random effects. Explanatory variables were dichotomised and divided into a between-person component and a within-person component. The between-person component was the participant mean over study period, which indicated the average conditions of the potential predictor. The within-person component was the deviation of the dichotomised predictor minus the subject mean, which indicated the daily variation from the average level. The unit of the between-person component was 0.1, and the unit of the within-person component was 1. Age and mobile survey week were included as confounders in the adjusted GLMMs.

Finally, we ran sensitivity analyses for each of the above modelling approaches. We recruited participants from 35 clinics, with good geographical variability across the Soweto area. Thus, we examined potential variation in the outcome by clinic site. For models predicting high transmission risk, site was included as a fixed effect (sites with fewer than 10 positive HIV patients enrolled were combined). In models predicting condomless sex, GLMMs with further adjustment of clinic site did not converge. Thus, instead of considering clinic site as a covariate, a random effect was specified to define the nesting relationship between participants and their clinic of recruitment.

Participants had the option to refuse to answer any question. Instruments with at least 80% of questions answered were scaled to retain records. Pairwise deletion was used to retain all possible records for each analysis. Significant level was set at 0.05 and statistical analysis was performed using SAS V.9.4 (SAS Institute).

Table 1 Distribution of viral suppression changes among adolescent boys over a 1-year period from baseline to follow-up (n=241)

Viral suppression trajectory	Participants (%)
Among those with both measures available	
Stayed suppressed	141 (58)
Suppressed → detectable	23 (10)
Detectable → suppressed	19 (8)
Stayed detectable	44 (18)
Among those missing the follow-up measure	
Suppressed at baseline	7 (3)
Detectible at baseline	7 (3)

RESULTS

Sample characteristics

Of the 251 PHIV adolescents enrolled, most (70%) were between the ages of 15 and 17 years at baseline, with the remainder aged 18–19 years. The majority (90%) self-reported their race as Black African. 241 participants had mobile data and were included in the analyses. 70 (29%) had a detectable viral load (≥200/mL) at baseline; this proportion (28%) was similar at follow-up (table 1). 14 participants were missing a follow-up viral load measure, and thus their baseline measure was used to determine their risk classification. Overall, 93 (39%) participants had a detectable viral load at least at one time point.

HIV transmission risk

To assess sexual risk, we used data reported in 6870 valid mobile surveys submitted by 241 participants. Of the 241 participants, 126 (52%) did not report having sex over the study period; 74 (31%) reported having sex and consistently using condom, and 41 (17% of all and 36% of those having sex) reported sex without a condom at least once. Overall, 17 participants (7%) fell into the high-risk category of having both a detectible viral load and condomless sex. This translates into 15% of all sexually active participants having both a detectible viral load and condomless sex. Table 2 presents the distribution of high risk by potential explanatory factors. Notably, of the 44 participants who reported in the baseline survey that they used a condom at their last sexual encounter, 18 reported condomless sex in at least one mobile survey.

Past-year correlates of HIV transmission risk

Each additional past-year adversity was associated with a 33% increase in the adjusted odds of being in the high-risk group for HIV transmission (adjusted OR (aOR) 1.33 (95% CI 1.09, 1.64); p=0.0056; table 2). Reported IPV victimisation similarly resulted in significantly higher odds of high-risk behaviour (aOR 6.07 (95% CI 1.69,

Table 2 Associations between potential predictors and high HIV transmission risk

Variable	Level	Frequency			Bivariate association with high risk		Adjusted association with high risk*	
		Total (N=241)	Low risk (N=224, 93%)	High risk (N=17, 7%)	OR (95%CI)	P value	OR (95%CI)	P value
ACEs	Unit=1 ACE	4±4	4±4	7±3	**1.33 (1.09, 1.62)**	**0.0047**	**1.33 (1.09, 1.64)**	**0.0056**
Any IPV victimisation	Yes	110 (46%)	96 (43%)	14 (82%)	**6.12 (1.71, 21.92)**	**0.0053**	**6.07 (1.69, 21.80)**	**0.0057**
Emotional IPV victimisation	Yes	81 (34%)	70 (32%)	11 (65%)	**3.93 (1.40, 11.05)**	**0.0095**	**3.91 (1.37, 11.11)**	**0.0106**
Physical IPV victimisation	Yes	38 (16%)	33 (15%)	5 (29%)	2.36 (0.78, 7.14)	0.1282	2.37 (0.78, 7.17)	0.1272
Sexual IPV victimisation	Yes	47 (20%)	37 (17%)	10 (59%)	**7.07 (2.53, 19.76)**	**0.0002**	**7.02 (2.50, 19.72)**	**0.0002**
Depression symptomology†	Moderate to severe	66 (30%)	58 (28%)	8 (53%)	**2.94 (1.02, 8.46)**	**0.0462**	**2.96 (1.03, 8.57)**	**0.0448**
Substance misuse‡	Yes	80 (35%)	71 (33%)	9 (53%)	2.27 (0.84, 6.12)	0.1068	2.22 (0.80, 6.18)	0.1280
Food insecurity	Moderate to severe hunger	46 (19%)	40 (18%)	6 (35%)	2.51 (0.88, 7.18)	0.0865	2.50 (0.87, 7.15)	0.0886
Orphanhood	Yes	143 (60%)	133 (60%)	10 (59%)	0.95 (0.35, 2.58)	0.9123	0.92 (0.33, 2.52)	0.8661

Bolded values are those with a p-value <0.05.
*Adjusted for age.
†19 out of 241 participants had at least 20% depression related questions not answered, their depression scores were treated as missing.
‡10 out of 241 participants had at least 20% CRAFFT Questionnaire questions not answered, their substance misuse scores were treated as missing.
IPV, intimate partner violence.

Table 3 Distribution of risk factors by whether adolescent boys living with HIV engaged in condomless sexual activity

Variable	Total (O=2508)	Condomless sex (O=106)	No/protected sex (O=2402)
Any victimisation	266 (11%)	11 (10%)	255 (11%)
Physical victimisation	53 (2%)	3 (3%)	50 (2%)
Verbal victimisation	131 (5%)	5 (5%)	126 (5%)
Sexual victimisation	35 (1%)	6 (6%)	29 (1%)
Witnessed violence	117 (5%)	4 (4%)	113 (5%)
Sad	264 (11%)	14 (13%)	250 (10%)
Stressed	343 (14%)	16 (15%)	327 (14%)
Angry	231 (9%)	16 (15%)	215 (9%)
Alcohol use—4+glasses	192 (8%)	8 (8%)	184 (8%)

21.80); p=0.0057). When we examined each type of IPV separately, sexual IPV victimisation demonstrated the strongest association with risk group (aOR 7.02 (95% CI 2.50, 19.72); p=0.0002). Depression was likewise significantly and positively associated with being in the high-risk group (aOR 2.96 (95% CI 1.03, 8.57), p=0.0448). Finally, food insecurity was borderline significant (aOR 2.50 (95% CI 0.87, 7.15), p=0.0886). There was no evidence that substance misuse or orphanhood was significantly associated with transmission risk. As a sensitivity analysis, we ran the above analyses focusing on only those participants who were sexually active. The strength of some associations was slightly attenuated (see online supplemental table 1), but the findings are qualitatively unchanged. Finally, high transmission risk did not vary significantly by clinic site. Thus, accounting for clinic site in the models did not change the findings in any substantive way (see online supplemental table 2).

Daily correlates of condomless sexual activity

Within the 6870 valid mobile surveys, 2535 contained reports of seeing a partner. There were 621 reports of sexual activity within the past 24 hours; 106 (17%) of these cases represent condomless sex. As seen in table 3, there was little difference in the distribution of potential risk factors by whether they engaged in condomless sex in the same 24-hour period.

Table 4 presents the individual GLMM regression models predicting condomless sex based on the same-day factors. We modelled both the between-person component (the effect of the participant's average level of the predictor) and the within-person component (the effect of the participant's daily variance from their average, such as imbibing alcohol when they typically do not drink). Due to the small number of people reporting each type of violence exposure, we focus only on the composite measure of violence. Having a 10% higher

Table 4 The relationship between potential predictors and condomless sex based a on generalised linear mixed effect model among adolescent boys living with HIV

			Bivariate association with condomless sex		Adjusted association with condomless sex*	
Predictor	Component	Unit	OR (95% CI)	P value	OR (95% CI)	P value
Any victimisation	Between-person	0.1	1.20 (1.00, 1.45)	0.0532	**1.26 (1.03, 1.53)**	**0.0242**
	Within-person	1	0.45 (0.19, 1.05)	0.0645	0.52 (0.22, 1.24)	0.1433
Sad	Between-person	0.1	1.13 (0.95, 1.35)	0.1543	1.16 (0.96, 1.39)	0.1207
	Within-person	1	0.98 (0.47, 2.06)	0.9585	1.03 (0.49, 2.17)	0.9385
Stressed	Between-person	0.1	**1.21 (1.04, 1.42)**	**0.0167**	**1.23 (1.04, 1.46)**	**0.0141**
	Within-person	1	0.57 (0.28, 1.13)	0.1072	0.60 (0.30, 1.21)	0.1518
Angry	Between-person	0.1	**1.23 (1.03, 1.47)**	**0.0256**	**1.26 (1.04, 1.53)**	**0.0176**
	Within-person	1	1.09 (0.52, 2.28)	0.8197	1.17 (0.56, 2.47)	0.6729
Alcohol use—4+glasses	Between-person	0.1	0.91 (0.68, 1.21)	0.5051	0.88 (0.64, 1.20)	0.4275
	Within-person	1	1.38 (0.56, 3.40)	0.4797	1.34 (0.53, 3.36)	0.5348

Bolded values are those with a p-value <0.05.
*With adjustment for age and mobile survey week.

average exposure to any type of violence, stress and anger were each significantly associated with about a 25% increase in the odds of having condomless sex. However, none of the within-person exposures were significantly associated with condomless sex, similar to the crude figures in table 3. To illustrate, this means that having more anger generally (the average exposure) is associated with condomless sex; however, being in an unusually angry mood on a particular day doesn't seem to influence condom use that same day. As earlier, the outcome (here, condomless sex) did not vary significantly by clinic site and results from models that included a random effect to define the nesting relationship between participants and clinics were not qualitatively different (see online supplemental table 3).

DISCUSSION

Key findings

This paper focuses exclusively on a cohort of South African adolescent boys, aged 15–19 years, living with PHIV. While much of the focus has been on risk factors for HIV acquisition among girls, we take a unique perspective and examine the modifiable social determinants that structure onward transmission risk among boys already living with HIV. Using a composite of condomless sex plus a detectible viral load to define sexual risk, we estimated that 7% of the adolescents were at risk of transmitting HIV to a sexual partner during the observation year; this rose to 15% among those who were sexually active. Our estimate of onward transmission risk is a bit lower than Toska *et al*,[4] but this is likely a result of focusing on adolescents who acquired HIV perinatally, as opposed to sexually. Experiencing recent IPV, childhood adversity, depression, stress and anger each increased the odds of being in the high-risk group for onward HIV transmission. We had hypothesised that time-variant factors—including experiencing violence—would influence an individual's choice to use a condom that same day. However, we found no evidence that day-to-day changes in exposure to violence, mood or binge drinking influenced the decision-making process.

Much has been written about the link between boys' perpetration of IPV and HIV risk behaviour.[43] However, few studies have acknowledged that boys are often victims of IPV and asked how this structures risk behaviour. To our knowledge, this is the first study to demonstrate an association between IPV victimisation and sexual risk in male adolescents living with HIV. We use prospective data to examine viral load and condom use together as a composite indicator of transmission risk. Any reported IPV victimisation in the past year resulted in six times the odds of being in the high-risk group for HIV transmission. Sexual IPV victimisation—often a stigmatised and neglected topic among males—demonstrated the strongest association with transmission risk, followed by psychological IPV; physical IPV was not statistically significant. This joins a growing literature showing psychological violence (from partners or family) can be a more powerful influence on HIV-related behaviours than physical IPV,[20 44] despite the latter receiving far more attention.

While the latest UNAIDS Global AIDS Strategy notes that gender-based violence has continued to drive the AIDS epidemic, and sets a goal ending such violence, most considerations centre around adolescent girls and young women (AGYW).[45] Likewise, so do the most prominent interventions for violence prevention (eg, the PEPFAR-funded DREAMS programme[9]; the DFID-UK Aid funded What Works to Prevent Violence against Women and Girls Global Programme[46]). This reflects the reality that AGYW are disproportionately affected by violence. Yet 46% of male adolescents in our sample reported being a victim of IPV in the last year, and victimisation was strongly associated with onward transmission risk. Thus, while IPV victimisation among girls may fuel the HIV epidemic, we provide evidence that IPV victimisation among boys does too. Programmes that explicitly address IPV victimisation among adolescent boys and provide tailored support services may generate duel benefits for both IPV and HIV prevention.

Our study also examined other forms of violence and adversity. Past studies have demonstrated the association of childhood adversity and violence with viral load[20 47] and condom use,[8 10] though there are also examples where associations did not reach significance.[19] In this study, adolescents who reported an additional four adversities in the past year (the sample SD) had three times the odds of being in the high-risk group for HIV transmission. The association persisted when we examined current exposure to violence (inclusive of that from family, peers and partners) as measured in the daily surveys: those who report more victimisation also report more condomless sex.

Moreover, our data provide further confirmation that mental health is related to risk, extends this to a population of adolescent boys living with HIV, and focuses on a composite outcome that better captures the risk of onward transmission. Prior research has shown that depression is associated with adolescent virological failure in Africa.[15 16] A parallel stream of research has shown that depression is associated with risky sexual behaviours among adolescents from low-income and middle-income countries generally,[48] though the literature on adolescents living with HIV is more sparse. We combine these two streams and find evidence that depression triples the odds of being in the high-risk group for HIV transmission. One-third of the sample had symptomology consistent with moderate or severe depression (similar to other African studies of adolescents living with HIV[14 49–51]); this rose to over half among adolescents who were at high risk for sexual HIV transmission. Similarly, when we examined other indicators of emotional distress—specifically reports of daily stress and anger—these too were associated with condom use. This underscores the need for mental health screening and

accessible, adolescent-friendly treatment to be integrated into HIV services.

Finally, we did not find evidence that substance use increased the risk of sexual transmission. This contrasts with some limited prior studies reporting an association between these factors and viral suppression,[16] sexual risk[52] or both.[24] We note that samples vary substantially between studies and may explain some of the heterogeneity. Toska *et al* studied a broader sample of adolescents living with HIV,[24] including females and those who were behaviourally infected—a group that may well have a different risk profile.[53] Even subtle differences may determine whether a factor is associated with risk. Several US-based studies highlight this heterogeneity. Sullivan *et al*[32] found no association between substance use and condom use in their overall sample of adults living with HIV. When they disaggregated their data, however, there was a negative within-person effect of substance use for those with a detectable viral load, but a positive effect for those with an undetectable viral load. Similarly, two studies[54 55] found that alcohol use had no impact on same-day condom use with a steady partner but did influence use with a new partner. Given the limited evidence for adolescents and general lack of prospective assessment of the above relationships,[4] further work is still needed to establish durable patterns.

Strengths and limitations

We improve on prior studies by using timely viral load data; longitudinal data that allow for measurement of baseline predictors prior to the outcome (though this alone is insufficient to draw causal conclusions), and repeated, daily mobile data that enable study of within-person variation in condom use. While this study did not identify influential factors at the event level, it demonstrates the feasibility of this approach for studying how changing circumstances may alter an individual's sexual decision-making. This study showed that mobile data collection for EMA is feasible among a hard-to-reach but critical population: adolescent boys growing up in an environment characterised by high levels of violence. Other studies have found that EMA may generate more accurate reporting than traditional surveys, particularly for behaviours that may not be socially desirable.[56 57] In our study, for example, over 40% of participants who were classified as using condoms at the baseline survey actually reported condomless sex in at least one mobile survey.

Despite these advantages, the mobile surveys did not establish the order of events within the past day, and many of the exposures (eg, violence) may have followed, rather than preceded, sexual activity. The lack of temporal clarity could bias within-person associations towards the null. In future endeavours, capturing timing could strengthen a potentially important tool for understanding risk behaviour. Moreover, there was uneven submission of mobile surveys. Critically, the number of mobile surveys submitted by each participant was negatively associated with several baseline covariates, including past-year physical, sexual and any victimisation, household hunger, substance misuse and a higher viral load (>200 copies/mL). This may have introduced some selection bias into our study. Finally, findings reflect the specific group under study. This sample was drawn from adolescents currently engaged in HIV care, with 75% reporting that someone at a health clinic had ever talked to them about how to prevent transmitting HIV. Moreover, all adolescents in this study reported being in a relationship or sexually active at study entry.

CONCLUSIONS

While there has been acknowledgement that the experience of violence—from family or partners—contributes to HIV transmission, the spotlight has been on adolescent AGYW. Yet in our study, both IPV victimisation and child adversity were common among boys, and strongly associated with transmission risk. This suggests that adolescent boys are another underserved population that needs violence victimisation support services, and that reducing violence directed against boys may lower their likelihood of onward HIV transmission.

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Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and approval was obtained for all local ethics committees. Procedures were approved by the Stony Brook University Institutional Review Board (Approval ID: FWA#00000125, IRB2019-00567) and the University of the Witwatersrand's Medical Human Research Ethics Committee (Approval ID: 191001), representing the home institutions of the two principal investigators. Participants gave informed consent to participate in the study before taking part.

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