Migration and risk of HIV acquisition in Rakai, Uganda: a population-based cohort study

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Summary

Background In sub-Saharan Africa, migrants typically have higher HIV prevalence than non-migrants; however, whether HIV acquisition typically precedes or follows migration is unknown. We aimed to investigate the risk of HIV after migration in Rakai District, Uganda.

Methods In a prospective population-based cohort of HIV-negative participants aged 15–49 years in Rakai, Uganda, between April 6, 1999, and Jan 30, 2015, we assessed the association between migration and HIV acquisition. Individuals were classified as recent in-migrants (≤2 years in community), non-recent in-migrants (>2 years in community), or permanent residents with no migration history. The primary outcome was incident HIV infection. We used Poisson regression to estimate incidence rate ratios (IRRs) of HIV associated with residence status with adjustment for demographics, sexual behaviours, and time. Data were also stratified and analysed within three periods (1999–2004, 2005–11, and 2011–15) in relation to the introduction of combination HIV prevention (CHP; pre-CHP, early CHP, and late CHP).

Findings Among 26 995 HIV-negative people who participated in the Rakai Community Cohort Study survey, 15 187 (56%) contributed one or more follow-up visits (89 292 person-years of follow-up) and were included in our final analysis. 4451 (29%) were ever in-migrants and 10 736 (71%) were permanent residents. 841 incident HIV events occurred, including 243 (29%) among in-migrants. HIV incidence per 100 person-years was significantly increased among recent in-migrants compared with permanent residents, for both women (1·92, 95% CI 1·52–2·43 *vs* 0·93, 0·84–1·04; IRR adjusted for demographics 1·75, 95% CI 1·33–2·33) and men (1·52, 0·99–2·33 *vs* 0·84, 0·74–0·94; 1·74, 1·12–2·71), but not among non-recent in-migrants (IRR adjusted for demographics 0·94, 95% CI 0·74–1·19 for women and 1·28, 0·94–1·74 for men). Between the pre-CHP and late-CHP periods, HIV incidence declined among permanent resident men (p<0·0001) and women (p=0·002) and non-recent in-migrant men (p=0·031), but was unchanged among non-recent in-migrant women (p=0·13) and recent in-migrants (men p=0·76; women p=0·84)

Interpretation The first 2 years after migration are associated with increased risk of HIV acquisition. Prevention programmes focused on migrants are needed to reduce HIV incidence in sub-Saharan Africa.

Funding National Institute of Mental Health, the National Institute of Allergy and Infectious Diseases, the National Institute of Child Health and Development, the National Institute for Allergy and Infectious Diseases Division of Intramural Research, National Institutes of Health; the Centers for Disease Control and Prevention; the Bill & Melinda Gates Foundation; and the Johns Hopkins University Center for AIDS Research.

Lancet HIV 2018; 5: e181–89

Published Online February 25, 2018 http://dx.doi.org/10.1016/S2352-3018(18)30009-2

See Comment page e158

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Introduction

Migration has long been recognised as a driver of HIV spread in sub-Saharan Africa, particularly in the early phases of the epidemic as it disseminated from central Africa.[1,2] Several reports since then have shown that HIV prevalence is higher among migrant populations than among longer-term resident populations continent-wide.[1,3–5] For example, in a study in Uganda in the early 1990s, HIV prevalence was 16% among individuals who had migrated in the past 3 years compared with 6% among non-migrants.[5] In a more recent study in Tanzania,[4] odds of HIV infection were more than two times higher among migrants than in non-migrants. Although these and other cross-sectional studies have established a positive link between migration and an individual's HIV status, little is known about the pathways linking them.[1] In particular, whether HIV acquisition is a cause or a consequence of migration, or both, is unclear. Establishing such causal mechanisms could help target HIV prevention and treatment resources more effectively.

Three main hypotheses potentially explain the higher HIV prevalence in migrants than in their non-migrating peers. First, migrants are inherently higher risk people, and regardless of them migrating they have a higher likelihood of acquiring HIV (hypothesis 1).[6] In a study from Rakai District, HIV-negative out-migrant youths (aged 15–24 years) had more HIV risk behaviours before migrating, including increased multiple and concurrent sexual partners, compared with those who did not migrate.[7] Second, individuals are more likely to migrate after becoming HIV-positive (hypothesis 2). In a

Research in context

Evidence before this study

We searched PubMed for studies on HIV among migrants in sub-Saharan Africa published up to Aug 22, 2017. Key search terms included "HIV", "human mobility", "migration", and "migrant". No language limitations were set. Since the early 1990s, several studies have reported higher HIV sexual risk behaviours among migrants. However, only two studies, done in Malawi and South Africa, have assessed HIV incidence among migrants. These studies did not assess the duration of time that individuals were at increased risk for infection after migration or changes in HIV risk among migrants over time with the scale-up of combination HIV prevention programmes.

Added value of this study

This study is, to our knowledge, the first prospective study to provide evidence of an increased risk of HIV acquisition among sub-Saharan African migrants in the first 2 years after migration relative to permanent residents with no migration history regardless of sex. Additionally, we found that despite scale-up of prevention interventions in destination locations, HIV incidence has not declined among recent migrants in contrast to patterns of declining HIV incidence noted among permanent residents and non-recent in-migrants.

Implications of all the available evidence

Better understanding of HIV transmission dynamics among migrant populations in sub-Saharan Africa and early identification and linkage of recent migrants to appropriately tailored HIV prevention programmes are needed.

retrospective cohort study in Malawi,[8] odds of migration were significantly greater among HIV-positive than HIV-negative individuals. Third, individuals who migrate are at higher risk as a consequence of migrating, which destabilises personal social networks and affects an individual's HIV risk environment (hypothesis 3).[9] For example, in a South African study, individuals who migrated and then returned to their home communities (circular migrants) had significantly higher HIV incidence then individuals who spent no time outside their home community.[10] However, when these migrants acquired HIV in relation to the migration process or whether the findings extend to people who permanently leave their home communities is unknown.

The reasons for higher HIV prevalence in African migrants are poorly understood, in part because mobile populations are difficult to enrol and follow-up. Additionally, definitions of migration vary widely, with some studies assessing migration across international borders and others focusing on internal movement of people within countries and districts.[1,11] The Rakai Community Cohort Study (RCCS), an open population-based census and cohort of HIV incidence in Rakai, Uganda, captures in-migration and out-migration in study communities regardless of source or destination location, offering a rare opportunity to study the association between HIV and migration prospectively. We tested whether hypothesis 3 explains the increased HIV burden among migrants. Specifically, we used longitudinal data from the RCCS (1999–2015) to assess whether initially HIV-negative individuals are at higher risk of HIV after in-migration. We hypothesise that in-migrants, regardless of sex, are at higher risk of HIV acquisition than permanent residents with no history of migration, but that this elevated HIV risk among migrants has decreased over time with the scale up of combination HIV prevention (CHP) programmes in Uganda.

Methods

Study design and population

The RCCS is a population-based HIV incidence cohort in Rakai. As described previously,[12] household censuses are done with intervals of about 18 months to collect demographic data on all residents and to record all births, deaths, in-migrations, and out-migrations since the previous survey, with no age limitations. In the RCCS surveys, which occur about 2 weeks after the census, detailed sociodemographic and behavioural data as well as blood samples for HIV testing are collected from all residents aged 15–49 years. Individuals who migrate into (ie, in-migrants) and those who migrate out of study communities (ie, out-migrants) between surveys are documented in the census, and information on source, destination communities, and reason for migration is obtained via a survey or interview with family members. At the start of each survey, the RCCS opens enrolment to all new in-migrants, newly age-eligible participants, and any previous non-participant residents in the community.

Communities for the RCCS were originally selected as part of a community randomised trial on treatment of sexually transmitted infections for HIV prevention.[13] We used RCCS data from 30 communities that were surveyed continuously between April 6, 1999, and Jan 30, 2015, including 11 surveys for this study. Over the analysis period, study participation was 59–65% of the eligible population who completed the census and 74–98% of the eligible population present at the time of survey, with lower participation rates among men, people younger than 20 years, and residents in trading communities.[14]

This study was independently reviewed and approved by the Ugandan (Ugand Virus Research Institute Security and Ethics Committee; Protocol GC/127/13/01/16) and US (Western Institutional Review Board; Protocol 20031318) institutional review boards. All participants provided written informed consent at baseline and follow-up visits.

Antiretroviral therapy (ART) became available in Rakai in 2004. All HIV-positive individuals were referred to care and offered CD4 cell count testing and those who were eligible for ART were offered ART with CD4 cell count and viral load monitoring per WHO criteria, which changed over the course of the study.[15] As of 2013, HIV-positive people were eligible for ART if their CD4 count was 500 cells per mL or lower or if they were pregnant, in a serodiscordant relationship, or identified as a commercial sex worker or fisherfolk at the time of diagnosis.[15] By 2015, prevalence of self-reported ART use among all HIV-positive participants was 60%.[14]

With President's Emergency Plan for AIDS Relief (PEPFAR) funding, the Rakai Health Sciences Program has provided free voluntary medical male circumcision (VMMC) to men 13 years and older per WHO recommendations.[16] Between 1999 and 2015, population prevalence of male circumcision increased from 15% to 52%.[14]

Procedures

Participants provided finger stick blood for rapid HIV testing and venous blood was collected. Before 2011, HIV tests were done with a laboratory-based ELISA test with confirmation by western blot. Subsequent tests were done with a validated parallel three test rapid HIV testing algorithm.[17] Discordant results were confirmed by two EIAs (Vironostika HIV-1, BioMerieux, St Louis, MO, USA, and Recombigen, Cambridge Biotech, Wooster, MA, USA). Western blots (GS HIV-1 Western Blot, Bio-Rad Laboratories, Redmond, WA, USA, BioMerieux-Vitek) or PCR were used for confirmation of discordant EIAs and all seroconverters.[18]

We defined in-migrants as participants who had moved into an RCCS community at any point during the analysis period with intention to stay. We then estimated duration of residence in a community as the difference between an in-migrant's self-reported date of arrival to the midpoint of the interval between sequential study visits (ie, the mean length of time spent in that community during a visit interval at risk). Using these data, we first classified participants as either permanent residents with no migration history or in-migrants. Migrants were then further stratified by their length of residence in the community (0–1 years, >1–2 years, >2–3 years, >3–4 years, >4–5 years, and >5 years) as a time-varying variable. Permanent residents with no history of migration were defined as the reference group.

Other covariates were age, education, marital status, religion, occupation, and male circumcision status. Sexual behaviours were having partners outside the community, number of sexual partners in the past year, number of lifetime sexual partners, having non-marital sexual partners, consistent condom use with a non-marital partner, and alcohol use with sex.

Outcomes

The primary outcome was incident HIV infection, defined as a first HIV-positive test result preceded by an HIV-seronegative test at the previous visit allowing for only one missed visit. HIV acquisition was assumed to occur at the midpoint of the visit interval. Participants were censored if they missed more than one visit, and had a subsequent HIV-positive test result.

Statistical analysis

Baseline and sexual behaviour characteristics of in-migrants and permanent residents were compared with proportions for categorical and binary variables and medians with IQRs for continuous variables. Statistical differences were assessed using χ^2 tests for categorical and binary variables and Wilcoxon rank sum tests for continuous variables.

To assess changes in the risk of HIV acquisition with CHP scale-up, we constructed a categorical variable of three periods corresponding to phases in the roll-out of ART and VMMC programmes and did an analysis stratified by period. In the earliest period, there were no ART or VMMC programmes in Rakai (April 1999 to November 2004; pre-CHP). The second period (February 2005 to June 2011; early CHP) corresponded to early CHP scale-up, with modest coverage of ART and VMMC. The most recent period (August 2011 to January 2015; late CHP) included mature CHP programmatic efforts.

The unit of analysis was person-years of follow-up. Poisson regression models with generalised estimating equations were used to estimate incidence rate ratios (IRRs) and 95% CIs of HIV acquisition among in-migrants by duration of residence relative to permanent residents. In multivariate analyses, we first adjusted for demographics and period only and then included high-risk sexual behaviours in subsequent analyses. This two-stage approach was used because sexual behaviours could be mediators or confounders of the association between migration and HIV acquisition. Analyses were also stratified by age, sex, and CHP period. A sensitivity analysis was done to account for potential bias resulting from selective participation and loss to follow-up by inverse probability weighting (appendix p 1).[14,19] Lastly, HIV incidence was estimated by place of origin, distance travelled, and reason for migrating in a subanalysis including only in-migrants. Analyses were done with STATA (version 14; College Station, Texas) and R (version 3.3.3).

See Online for appendix

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. OO and MKG had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Between 1999 and 2013, the mean participation rate of all 53 933 census-eligible people, including HIV-positive

	Women (n=8326)			Men (n=6861)		
	In-migrants (n=3055)	Residents (n=5271)	p value	In-migrants (n=1396)	Residents (n=5465)	p value
Age (years)	23 (18–31)	22 (19–27)	0·02	26 (21–31)	22 (17–30)	0·02
Age category (years)						
15–19	870 (28%)	1736 (33%)	<0·0001	230 (16%)	2186 (40%)	<0·0001
20–24	1061 (35%)	1178 (22%)	..	378 (27%)	1050 (19%)	..
25–29	605 (20%)	881 (17%)	..	353 (25%)	841 (15%)	..
30–34	255 (8%)	495 (9%)	..	191 (14%)	586 (11%)	..
35–39	139 (5%)	405 (8%)	..	122 (9%)	368 (7%)	..
≥40	125 (4%)	576 (11%)	..	122 (9%)	434 (8%)	..
Marital status						
Monogamous	1768 (58%)	2178 (41%)	<0·0001	634 (45%)	1974 (36%)	<0·0001
Never married	511 (17%)	1792 (34%)	..	562 (40%)	2941 (54%)	..
Polygamous	373 (12%)	606 (11%)	..	106 (8%)	325 (6%)	..
Previously married	401 (13%)	692 (13%)	..	92 (7%)	212 (4%)	..
Data missing	2 (<1%)	3 (<1%)	..	2 (<1%)	13 (<1%)	..
Educational status						
Primary	1692 (55%)	3158 (60%)	<0·0001	739 (53%)	3472 (64%)	<0·0001
Secondary	895 (29%)	1526 (29%)	..	342 (24%)	1414 (26%)	..
Technical or university	313 (10%)	266 (5%)	..	231 (17%)	334 (6%)	..
None	138 (5%)	289 (5%)	..	60 (4%)	159 (3%)	..
Data missing	17 (<1%)	32 (<1%)	..	24 (2%)	86 (2%)	..
Religion						
Catholic	1902 (62%)	3503 (66%)	<0·0001	806 (58%)	3619 (66%)	<0·0001
Muslim	403 (13%)	687 (13%)	..	164 (12%)	704 (13%)	..
Protestant	565 (18%)	879 (17%)	..	312 (22%)	895 (16%)	..
Saved or Pentecostal	145 (5%)	125 (2%)	..	73 (5%)	126 (2%)	..
None or other	23 (1%)	45 (1%)	..	17 (1%)	35 (1%)	..
Data missing	17 (<1%)	32 (<1%)	..	24 (2%)	86 (2%)	..
Occupation						
Agriculture	1271 (42%)	2573 (49%)	<0·0001	332 (24%)	1484 (27%)	<0·0001
Administrative or teaching or student	488 (16%)	1312 (25%)	..	369 (26%)	1889 (35%)	..
Bar	62 (2%)	79 (1%)	..	6 (<1%)	16 (<1%)	..
Trading	377 (12%)	453 (9%)	..	212 (15%)	744 (14%)	..
Other	857 (28%)	854 (16%)	..	477 (34%)	1332 (24%)	..
Male circumcision						
No	..	..		1048 (75%)	4438 (81%)	
Yes	..	..		346 (25%)	1012 (19%)	
Data missing	..	..		2 (<1%)	15 (<1%)	

Data are median (IQR) or number (%). Some percentages do not add up to 100 because of rounding.

Table 1: **Demographics and baseline characteristics**

people and those away for work or school, was 62% (103 013 study visits contributed of 167 043 census-eligible visits). Participation rates were similar between individuals who had migrated into study communities since the previous survey (61%, 90 435 study visits contributed of 147 098 census-eligible visits) and residents (63%, 12 578 study visits contributed of 19 945 census-eligible visits). Among 26 995 HIV-negative people who participated in the RCCS survey, 15 187 (56%) contributed one or more follow-up visits and were included in our final analysis: 8326 (55%) were women and 4451 (29%) were ever in-migrants. 3055 (69%) of in-migrants were women. Participants contributed 66 956 person-visits over 89 292 person-years and 841 incident HIV events were identified.

Among female in-migrants, movement to live with a friend or relative, a new marriage or consensual relationship, and work were the most common responses. By contrast, men most commonly reported migrating for work or to start a new household (appendix p 2). Over half of migrations among men and two-thirds of migrations among women were in-migrations from communities elsewhere in Rakai District. The most common places of origin outside Rakai were the neighbouring Masaka District and the capital city, Kampala.

The median age was similar for in-migrant and permanent resident women, whereas in-migrant men were older than permanent resident men (table 1). More in-migrant women than permanent residents were in a monogamous marriage ($p<0·0001$). In-migrant men were also more likely to be married than permanent resident men ($p<0·0001$). Most participants, regardless of migration status, had a primary education; however, a higher proportion of in-migrants than residents had technical or university education.

In-migrants of both sexes generally had more HIV-related risk behaviours (table 2). Among those who reported non-marital partnerships, in-migrants of both sexes were more likely to report having sexual partners who resided outside their community, and female migrants were less likely to use condoms consistently. A greater proportion of in-migrants also reported more sexual partners in the previous year and over their lifetime compared with permanent residents.

172 (35%) of 487 HIV incident events among women occurred in ever in-migrants; of these, 70 (41%) occurred within the first 2 years after migration (table 3). HIV incidence among recent in-migrant women during the first 2 years after in-migration was higher than in permanent resident women. This difference remained significant after adjustment for demographics alone and demographics and sexual behaviours. However, HIV incidence among longer-term in-migrants (>2 years) was similar to that of permanent residents (table 3; figure 1; appendix p 3). For men, 71 (20%) of 354 HIV incident events occurred among in-migrants (table 3). HIV incidence in the 2 years after migration was higher in in-migrant than in permanent resident men, even after adjustment. Beyond 2 years after migration, HIV incidence was comparable with the permanent residents (table 3; figure 1; appendix p 3). Sensitivity analyses with inverse probability weights did not change these inferences among men or women (appendix p 4).

	Women (n=8326)			Men (n=6861)		
	In-migrants (n=3055)	Residents (n=5271)	p value	In-migrants (n=1396)	Residents (n=5465)	p value
Non-marital partnership						
No	2123 (69%)	3627 (69%)	0·52	585 (42%)	2710 (50%)	<0·0001
Yes	932 (31%)	1644 (31%)	..	811 (58%)	2755 (50%)	..
Sex with a partner residing outside the community in the past year						
Not sexually active in past year*	250 (8%)	1252 (24%)	<0·0001	220 (16%)	1635 (30%)	<0·0001
No	2089 (68%)	3166 (60%)	..	617 (44%)	2353 (43%)	..
Yes	714 (23%)	849 (16%)	..	556 (40%)	1473 (27%)	..
Data missing	2 (<1%)	4 (<1%)	..	3 (<1%)	4 (<1%)	..
Consistent condom use with non-marital partner or partners						
No	706/932 (76%)	1180/1644 (72%)	0·03	525/811 (65%)	1745/2755 (63%)	0·468
Yes	226/932 (24%)	464/1644 (28%)	..	286/811 (35%)	1010/2755 (37%)	..
Number of lifetime sexual partners						
1	655 (21%)	1409 (27%)	<0·0001	125 (9%)	563 (10%)	<0·0001
2–3	1711 (56%)	2250 (43%)	..	324 (23%)	1162 (21%)	..
4–5	451 (15%)	616 (12%)	..	275 (20%)	864 (16%)	..
>5	138 (5%)	201 (4%)	..	359 (26%)	1073 (20%)	..
Can't remember or unknown	22 (1%)	61 (1%)	..	215 (15%)	650 (12%)	..
Never sexually active	71 (2%)	708 (13%)	..	96 (7%)	1131 (21%)	..
Data missing	7 (<1%)	26 (<1%)	..	2 (<1%)	22 (<1%)	..
Number of different sexual partners in the past year						
1	2484 (81%)	3803 (72%)	<0·0001	618 (44%)	2136 (39%)	<0·0001
2–3	313 (10%)	208 (4%)	..	484 (35%)	1442 (26%)	..
4–5	4 (<1%)	3 (<1%)	..	46 (3%)	148 (3%)	..
>5 or cannot remember	2 (<1%)	2 (<1%)	..	28 (2%)	102 (2%)	..
Not sexually active in past year*	250 (8%)	1252 (24%)	..	220 (16%)	1635 (30%)	..
Data missing	2 (<1%)	3 (<1%)	..	0	2 (<1%)	..
Alcohol with sex†						
No	2325/2984 (78%)	3430/4563 (75%)	0·02	918/1300 (71%)	2900/4334 (67%)	0·01
Yes	654/2984 (22%)	1127/4563 (25%)	..	376/1300 (29%)	1424/4334 (33%)	..
Data missing	5/2984 (<1%)	6/4563 (<1%)	..	6/1300 (<1%)	10/4334 (<1%)	..

Data are number (%) or n/N (%). Some percentages do not add up to 100 because of rounding. *Includes people who were never sexually active. †Excludes participants who were not sexually active.

Table 2: **Sexual risk behaviours at baseline**

HIV risk among in-migrants and permanent residents was also stratified by age groups (15–24, 25–34, ≥35 years; appendix p 5). Among women aged 25 years and older, HIV incidence was higher in recent in-migrants than in permanent residents and increased with age; no significant difference was noted for those aged 15–24 years. There was no evidence of effect modification by age on the association between migration and HIV incidence among men.

Between 2005 and 2011, median community-level ART coverage was 19% (IQR 12–27) and VMMC coverage was 33% (22–42). In the most recent period (2011–15), median community-level ART coverage was 43% (33–56) and VMMC coverage was 50% (43–57). HIV incidence declined significantly in permanent residents (both sexes) and in non-recent in-migrant men with greater coverage of ART and VMMC, but incidence remained high among recent in-migrant men and women (figure 2; appendix p 6). Before combination prevention scale-up (1999–2004), HIV incidence was higher among recent in-migrants than among permanent residents for women, but not for men (appendix p 6). In the most recent period with mature ART and VMMC programmes (2011–15), HIV incidence was higher in recent in-migrants than in permanent residents for both women and men. After adjustment for demographics, HIV incidence declined by 32% in resident women (adjusted IRR 0·68, 95% CI 0·47–0·94) and 47% in resident men (0·53, 0·37–0·76) between the pre-CHP and late-CHP periods. There were no significant changes in HIV incidence among non-recent in-migrants of either sex after adjustment.

HIV incidence rates by reason for in-migration, place of origin, and distance travelled, stratified by gender are shown in the appendix (p 7). HIV incidence was highest among women moving to start a new household and men who were newly married. We

	Number of events/ person-years at risk	Incidence per 100 person-years (95% CI)	Crude IRR (95% CI)	IRR adjusted for demographics (95% CI)*	IRR adjusted for demographics and sexual behaviours (95% CI)†
Women (n=8326)					
Permanent residents	315/33 730	0·93 (0·84–1·04)	1	..	..
In-migrants, 0–2 years since arrival	70/3646	1·92 (1·52–2·43)	2·04 (1·58–2·63)	1·75 (1·33–2·33)	2·35 (1·61–3·43)
In-migrants, >2 years since arrival	102/11 703	0·87 (0·72–1·06)	0·93 (0·75–1·16)	0·94 (0·74–1·19)	0·99 (0·69–1·42)
Men (n=6861)					
Permanent residents	283/33 849	0·84 (0·74–0·94)	1	..	..
In-migrants, 0–2 years since arrival	21/1384	1·52 (0·99–2·33)	1·81 (1·17–2·81)	1·74 (1·12–2·71)	1·89 (1·13–3·20)
In-migrants, >2 years since arrival	50/4980	1·00 (0·76–1·32)	1·20 (0·89–1·62)	1·28 (0·94–1·74)	1·26 (0·84–1·87)
Total (n=15 187)					
Permanent residents	598/67 579	0·88 (0·82–0·96)	1	..	..
In-migrants, 0–2 years since arrival	91/5031	1·81 (1·47–2·22)	2·03 (1·64–2·53)	1·76 (1·40–2·23)	2·11 (1·57–2·83)
In-migrants, >2 years since arrival	152/16 682	0·91 (0·78–1·07)	1·02 (0·86–1·23)	1·00 (0·83–1·21)	1·03 (0·79–1·36)

IRR=incidence rate ratio. *Adjusted for the following variables in addition to migration history: age in years, marital status, education, religion, time period, occupation, and male circumcision. †Adjusted for sex with partners residing outside the community in the past year, number of different sexual partners in the past year, number of lifetime sexual partners, having a non-marital sexual partner, consistent condom use with a non-marital partner, and alcohol use with sex.

Table 3: **HIV incidence and crude and adjusted HIV incidence rate ratios**

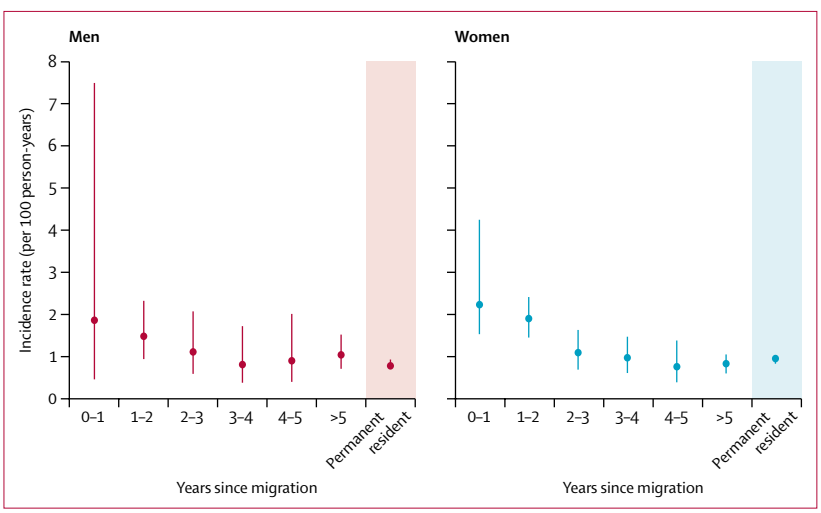

Figure 1: **HIV incidence by year since migration**
Bars are 95% CIs.

observed no trends in HIV risk by distance travelled or place of origin.

Discussion

In this longitudinal population-based study, in-migrants had more sexual risk behaviours and higher HIV incidence after migration to a new community than did permanent residents with no history of migration. We also show that this elevated HIV incidence among in-migrants is concentrated during the first 2 years after migration. Despite significant declines in HIV incidence in residents with scale-up of ART and VMMC programmes, HIV incidence has remained high among recent migrants. To our knowledge, this is the first study to use longitudinal population-based data to assess the duration of time that migrants are at risk for HIV after migration or risk before and during CHP scale-up in sub-Saharan Africa. Active surveillance, to identify migrant populations and to engage them in prevention and treatment programmes, is urgently needed to reduce the burden of HIV in sub-Saharan Africa.

We noted significantly higher incidence of high-risk sexual behaviours among in-migrants than among residents, which is consistent with findings from previous studies showing migrants typically have higher HIV risk profiles.[3,11,20] Compared with permanent residents, both male and female in-migrants reported more sexual activity, greater numbers of lifetime sexual partners and more sex with partners outside the community. They were also less likely to report consistent condom use with a non-marital partner. In an earlier study from Rakai,[18] sex with extracommunity partners was associated with substantially increased risk among women.

In-migrants also had significantly higher HIV risk compared with permanent residents, but only during the first 2 years after migration. Similar findings were reported in a cross-sectional study of HIV prevalence in Tanzania,[4] in which the odds of HIV infection were significantly higher among recent migrants, but not non-recent migrants, compared with residents. This higher HIV risk among migrants soon after moving might be due in part to higher incidence of sexual risk behaviours during the migration process; however, we found migration remained associated with increased HIV acquisition even after adjustment for sexual behaviours, suggesting causal pathways independent of individual-level behaviours. The immediate period after migration is

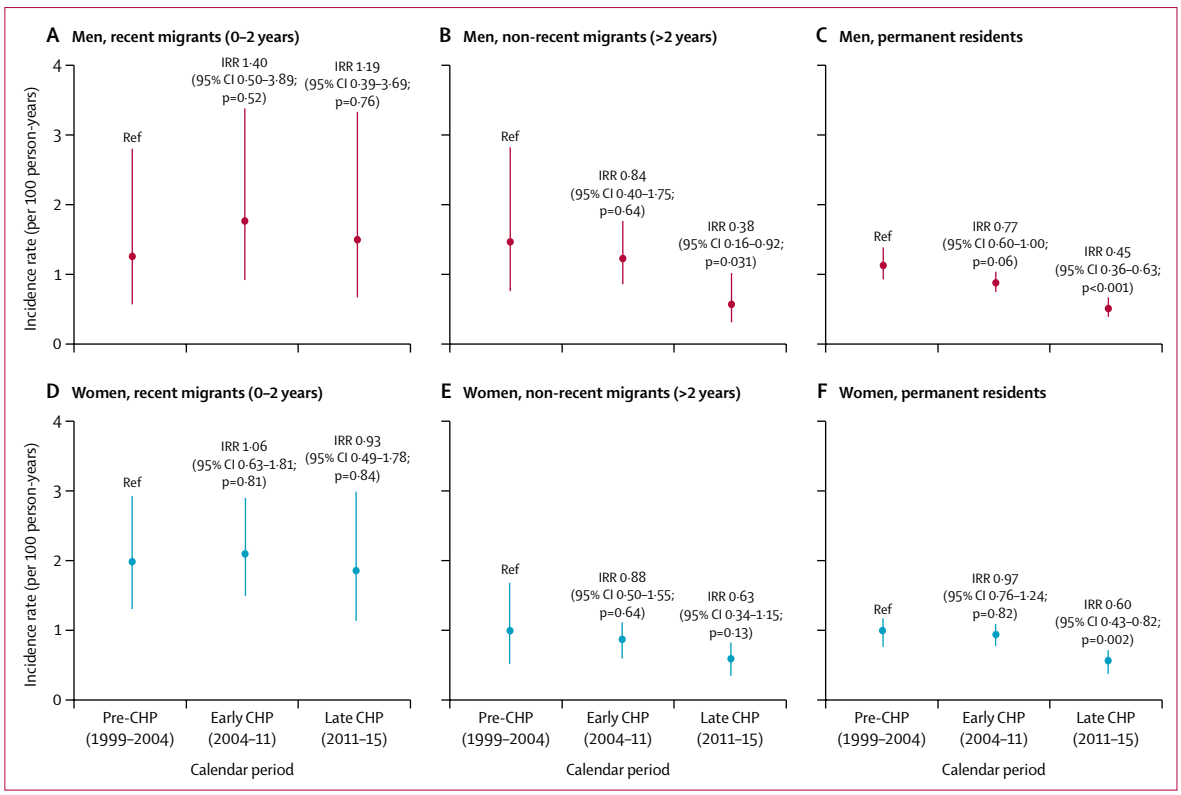

Figure 2: **HIV incidence among recent in-migrants, non-recent in-migrants, and permanent residents**
Bars are 95% CIs. IRR=incident rate ratios. CHP=combination HIV prevention.

associated with instability; detachment from family, friends, and previous community; and less constraints by social norms governing risk behaviours. Migrant women might be more vulnerable to sexual exploitation and male migrant workers (eg, fishermen) may congregate in high-risk environments with exposure to commercial sex and alcohol.[21,22] The excess HIV incidence noted among migrant women was largely concentrated in women over 25 years, whereas young African women (15–24 years) are at highest risk for HIV in sub-Saharan Africa overall.[23] We did not observe an association between distance travelled and HIV risk, unlike in a previous study of circular (ie, return) migration in KwaZulu-Natal, South Africa,[10] which found higher risk with greater distances migrated.

Our results, taken together with previous research from Rakai and elsewhere in sub-Saharan Africa, provide support for each of the three hypotheses potentially explaining the higher HIV prevalence observed among migrants. In this study, HIV-negative migrants reported more HIV sexual risk behaviours (hypothesis 1). Earlier studies from Uganda and Malawi also showed that HIV-positive individuals were more likely to migrate than were HIV-negative people (hypothesis 2).[8,24] Furthermore, we found that migrants were more likely to acquire HIV in the first 2 years after migration compared with residents with no migration history, suggesting that HIV is a consequence of migration, at least in some cases (hypothesis 3).

Contrary to our initial hypothesis and of crucial importance to ongoing HIV control efforts, we found that HIV incidence in recent migrants remained higher than in permanent resident women, despite substantial scale-up of CHP services. HIV incidence was also higher in recent in-migrant than in resident men in the late-CHP period. These results suggest that prevention programmes have had minimal effect in recently migrating populations, perhaps because services in destination locations do not reach recent migrants upon arrival or because migrants are dissociated from treatment and HIV prevention services at their place of origin. Migrants might also maintain sexual relationships with outside partners in areas with lower service coverage or initiate relationships with riskier partners less likely to use CHP and treatment services. Although we found no significant differences in circumcision rates between groups in migrant men in this study, in a previous analysis of the HIV care cascade from 2013 to 2015 in Rakai, HIV-positive in-migrants were significantly less likely to be enrolled in HIV care and on ART than were residents.[25] Assortative sexual mixing within the migrant community, which has lower rates of viral suppression, could explain some of the increased risk of HIV acquisition among migrants.

From the broader public heath perspective, our findings imply that identifying recent migrants and effectively

linking them to prevention and treatment services in a timely manner are important for HIV control. Pre-exposure prophylaxis (PrEP) is likely to be particularly important for HIV-negative migrants; however, PrEP is not yet widely available in sub-Saharan Africa. Programmatic tools to rapidly identify migrants and link them to HIV services are also in short supply. Application of mobile technology might be an effective strategy to increase linkage of hard-to-reach mobile populations with health services.[26] Travelling community health workers have been used in some settings to increase retention of HIV-positive people in treatment and care and might be effective for engaging migrant populations irrespective of HIV status.[27] Cultural or language barriers and social dislocation facing migrants in their new communities, as well as participatory approaches including migrant populations, should be considered during planning and implementation of services.[28]

This study has limitations. Demographic and sexual behaviour data were self-reported and may be subject to measurement error or desirability bias. Insufficient study participation and loss to follow-up might have biased results; however, sensitivity analyses with inverse probability weights to account for selective participation did not affect our inferences. Although we adjusted for demographics and sexual behaviours, we cannot rule out the possibility of residual confounding due to unmeasured or poorly measured confounding variables. Given there is a short period after infection in which antibodies to HIV are not detected in the blood, a few participants might have been infected before migration. However, of the 243 incident cases among in-migrants, only two occurred in people who had arrived in the previous month. We did not assess circular migration or identify migrants who moved in and out of study communities between censuses, so our results might not apply to all migrant populations. Results from this study may not be generalisable to other settings. Although we know of no unique social or cultural practices related to migration in Rakai and the RCCS, demographic and behavioural data are similar to results from other surveys done in south-central Uganda.[29] Migration patterns in Rakai are also similar to other rural African settings in so much that migration is pervasive and more common among women than men.[1–3,5,8,10] Furthermore, results from PEPFAR's population-based HIV impact assessments survey in Uganda and other countries suggest that scale-up of CHP is occurring continent-wide.[30]

In conclusion, the first 2 years after migration were associated with substantially increased HIV risk and HIV incidence remains high among migrant populations compared with residents despite scale-up of combination HIV prevention programs. Active surveillance, to identify migrant populations and to engage them in prevention and treatment programmes, is urgently needed to reduce the burden of HIV in sub-Saharan Africa.

Contributors
OO, AART, and MKG conceptualised and designed the study. JK, JMB, BN, JN, FN, GN, GrK, GoK, RHG, MJW, RS, JSS, SJR, LWC, and DS oversaw data collection and laboratory testing. OO and MKG did the statistical analysis. All authors participated equally in revising and the final approval of the manuscript.

Declaration of interests
We declare no competing interests.

Acknowledgments
Presented in part at the Conference on Retroviruses and Opportunistic Infections, Seattle, WA, USA, Feb 13–17, 2017. Supported by the National Institute of Mental Health (R01MH107275), the National Institute of Allergy and Infectious Diseases (R01AI110324, U01AI100031, U01AI075115, R01AI110324, R01AI102939, R01AI128779, and K01AI125086-01), the National Institute of Child Health and Development (RO1HD070769 and R01HD050180), the Division of Intramural Research of the National Institute for Allergy and Infectious Diseases, the World Bank, the Doris Duke Charitable Foundation, the Bill & Melinda Gates Foundation (#08113, 22006.02), the Johns Hopkins University Center for AIDS Research (P30AI094189), and the President's Emergency Plan for AIDS Relief through the Centers for Disease Control and Prevention (NU2GGH000817). We also appreciate data management support provided in part by the Office of Cyberinfrastructure and Computational Biology at the National Institute for Allergy and Infectious Diseases. The findings and conclusions in this report are those of the authors and do not represent the official position of the funding agencies. We thank the cohort participants and the staff and investigators who made this study possible.

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