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Heterogeneous and decreasing HIV prevalence among women seeking antenatal care in Kinshasa, Democratic Republic of Congo

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Background We examined HIV prevalence trends over 4.5 years among women receiving antenatal care in Kinshasa, Democratic Republic of Congo, by geographic location, clinic management and urbanicity.

Methods Quarterly proportions and 95% confidence intervals (CIs) of pregnant women with HIV positive results were determined using aggregate service provision and uptake data from 22 maternity units that provided vertical HIV prevention services from October 2004 to March 2009**.** Assuming linearity, proportions were assessed for trend via the Cochran–Armitage test. Multivariable binomial regression was used to describe detailed prevalence trends.

Results HIV testing was offered to 220 006 pregnant women; 210 348 (95.6%) agreed to be tested and 191 216 (90.9%) received their results. A total of 3999 women were found to be HIV positive, a prevalence of 1.90% (95% CI: 1.84–1.96%). The median quarterly proportion of women testing positive for HIV was 1.94% (range: 1.44–2.44%). Prevalence was heterogeneous in terms of maternity management, urbanicity and geographic location. Modeling suggested that the overall prevalence dropped from 2.04% (95% CI: 1.92–2.16%) to 1.77% (95% CI: 1.66–1.88%) over 4.5 years, a relative decrease of 13.2% (95% CI: 3.53–22.9%). Trend testing corroborated this decline ($P < 0.01$).

Conclusions The decreasing HIV prevalence among Kinshasa antenatal care seekers is robust and encouraging. The relatively low prevalence and the weak existing healthcare system require prevention of mother-to-child transmission interventions that strengthen maternal and child healthcare service delivery. Complacency would be unwarranted: assuming a uniform national crude birth rate of 50/1000 and 1.8% antenatal HIV prevalence, approximately 7000 pregnant HIV infected women in Kinshasa, and 60 000 nationwide, are in need of care and prevention services yearly.

Keywords Prevention of mother-to-child HIV transmission, antenatal service delivery, Democratic Republic of Congo, HIV seroprevalance, HIV surveillance, time trends

Introduction

There is limited recent information on the prevalence of HIV, especially over time, in the Democratic Republic of Congo (DRC). Decades of deteriorating social, political, and economic conditions and civil wars resulting in the deaths of ~4 million[1] Congolese crippled healthcare systems and precluded the study of HIV prevalence trends. Although relative peace has returned to large parts of this nation of approximately 69 million citizens,[2] recovery and development of vital infrastructures has been slow. Public health continues to suffer—a survey published in June 2009 notes that the mortality rate in the DRC remains 55% higher than the reported baseline for sub-Saharan Africa, primarily because of post-conflict malnutrition and infectious disease.[3]

Serosurveys of approximately 11 000 pregnant women who delivered at the central hospital in the capital, Kinshasa, yielded an HIV prevalence of 5.8% in 1986 and 6.1% in 1989.[4] A prevalence of HIV of 3.1% was found in a 1997 serosurvey of 516 pregnant women receiving antenatal care (ANC) in Kinshasa.[5] In 2003, the prevalence was 4.1% among 1092 pregnant women tested for HIV at a single Kinshasa ANC clinic.[6] This clinic was also featured in another study, which reported that the prevalence among 2082 women presenting to two Kinshasa maternity units in 2004 was 1.9%.[7] The 2008 UNAIDS/WHO Epidemiological Fact Sheet on HIV and AIDS for the DRC states that prevalence ranged from 2.7 to 4.1% between 2002 and 2004 at one Kinshasa ANC site and between 3.2 and 4.3% at three other sites.[8] In 2006, a population-based serosurvey in Kinshasa found that 3.6% of 1338 women aged 15–49 years were HIV infected.[9]

Although these sources provide some information on HIV prevalence among pregnant women, they also highlight several gaps. For example, no studies specifically address prevalence over time, meaning that it is unknown whether the recently described decreasing HIV prevalence among women seeking ANC in countries such as Zambia,[10] Cameroon[11] and Botswana[12] is also occurring in the DRC. Research in sub-Saharan Africa has demonstrated that HIV prevalence within an area can differ by urbanicity[13–15] and geographic location,[16–18] factors that may serve to inform future prevention efforts. Whether HIV prevalence is heterogeneous within the city of Kinshasa remains to be elucidated.

Services to prevent mother-to-child HIV transmission (PMTCT), including provision of prophylactic single-dose nevirapine (sdNVP), were first initiated in 2003 in two Kinshasa maternity units. Additional public- and private-sector facilities joined our program in five subsequent waves, and by 2009 activities had been implemented in a total of 37 of the city's largest maternity units. Given that HIV counselling and testing is an integral component of PMTCT and that tens of thousands of women annually seek ANC at maternity units diverse in their management, urbanicity and location, these clinics provide an ideal setting to achieve our study aim: to provide novel insight on HIV prevalence among pregnant women in Kinshasa, both overall and within potentially important subgroups. We investigated trends between 2004 and 2009.

Methods

The 22 maternity units in Kinshasa that provided comprehensive vertical HIV prevention services between October 2004 and March 2009 provided data for the study. This period was selected because it maximized the period of continuous participation for a constant sample of facilities; data were available for 1155 of 1188 maternity months (97.2%). As depicted in Figure 1, the maternity units varied in terms of management (nine government, nine run by Catholic organisations, four run by Protestant organisations), urbanicity (17 urban, five peri-urban) and Kinshasa geographic sector (five Funa, eight Lukunga, five Mont Amba, four Tshangu). Urbanicity is defined by DRC governmental criteria; non-rural areas that are less developed and densely populated than that of urban areas are peri-urban.

On a monthly basis, individual clinics entered 75 distinct monitoring indicators into a central database. These indicators included counts of pregnant women who were offered HIV testing, tested for HIV, tested HIV positive, and took sdNVP during labour. After collapsing data into 18 quarterly periods to reduce individual estimate variability, secondary indicators such as HIV prevalence and uptake of HIV testing were calculated.

Prevalence trends, assumed to be linear on the basis of examination of the data and studies in other ANC settings in sub-Saharan Africa, were assessed with the Cochran–Armitage test (a left-sided P-value <0.05 was evidence against the null hypothesis of no decreasing trend). To further describe trends, we modelled the prevalence difference using multivariable binomial regression with an identity link. All models included month, which was coded discretely from 0 to 53. Other factors hypothesized to be associated with HIV prevalence, as well as interaction terms between month and these factors, were additionally included if the P-value for a likelihood ratio test comparing models with and without tested parameters was <0.10. Coded as categorical disjoint indicator variables, the maternity-level factors considered were management, urbanicity and geographic sector.

Wilson's method[19] was used to calculate point estimates and 95% confidence intervals (CIs) for proportions, which were compared by the chi-square test. Analyses were completed using Microsoft Excel 2003 (Microsoft Corporation, Redmond, WA) and SAS 9.1.3 (SAS Institute, Cary, NC). The research was approved

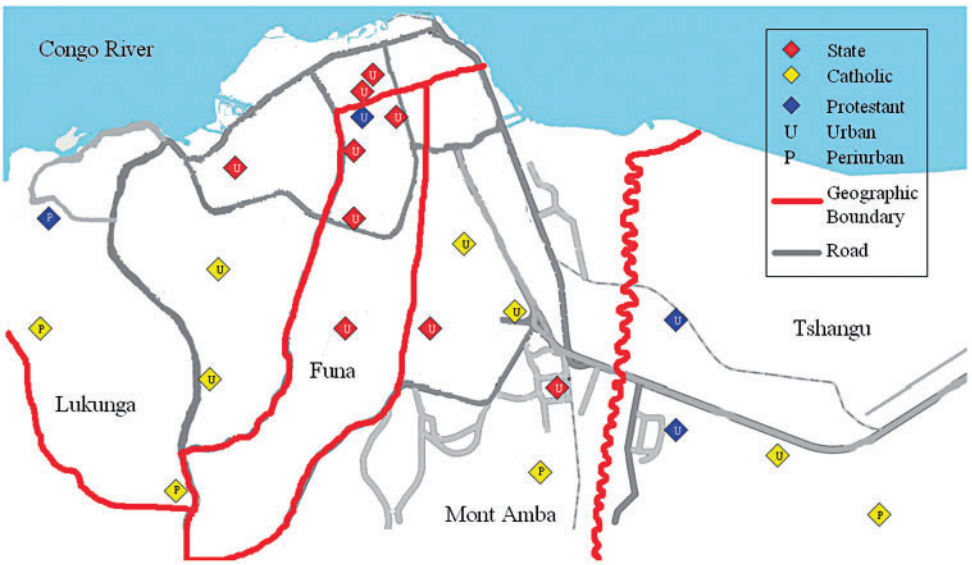

Figure 1 Locations and characteristics of 22 maternity units providing vertical HIV prevention services in Kinshasa, DRC, between October 2004 and March 2009

by the University of North Carolina at Chapel Hill Institutional Review Board and the Ethics Committee of the Kinshasa School of Public Health.

Results

During the 4.5-year study period, both testing uptake and receipt of test results were consistently high (Table 1). Of the 220 006 pregnant women offered HIV testing, 95.6% agreed to be tested. Between 9647 and 14 984 women per quarter (median: 11 388) accepted HIV testing; the median quarterly proportion of women who accepted HIV testing was 95.8% (range: 90.6–98.9%). Of women tested, 191 216 (90.9%) were informed of their test results. Between 8856 and 13 514 women per quarter (median: 10 453) received their results; the median quarterly proportion of women who received their results was 90.5% (range: 81.1–98.8%).

The overall prevalence of HIV was 1.90% (95% CI: 1.84–1.96%), with 3999 of 210 348 women testing seropositive. Between 169 and 274 women per quarter (median: 224) tested HIV positive. The median quarterly proportion of women testing positive for HIV was 1.94%, and fluctuated between 1.44% in the third quarter of 2008 and 2.44% in the second quarter of 2007.

The prevalence of HIV was heterogeneous in terms of maternity management, urbanicity and geographic sector (all $P < 0.01$). In government-run maternity units, 2.49% (95% CI: 2.35–2.63%) of women tested for HIV were seropositive. This prevalence was higher ($P < 0.01$) than that in facilities run by Protestant organisations (1.90%; 95% CI: 1.75–2.05%), which was higher ($P = 0.01$) than that in the Catholic network (1.69%; 95% CI: 1.62–1.76%). The prevalence in peri-urban maternity units was 1.08% (95% CI: 0.98–1.18%), substantially lower ($P < 0.01$) than that in urban maternity units 2.13% (95% CI: 2.06–2.20%). Although the HIV prevalence in Tshangu (1.96%; 95% CI: 1.86–2.06%) and Lukunga (1.85%; 95% CI: 1.76–1.93%) clinics were similar ($P = 0.10$), the prevalence of HIV in Mont Amba clinics (1.56%; 95% CI: 1.40–1.72%) was lower than that in Lukunga clinics ($P < 0.01$), and the prevalence in Funa clinics (2.33%; 95% CI: 2.13–2.53%) was higher than that in Tshangu clinics ($P < 0.01$).

Overall, the prevalence of HIV decreased over time (Cochran–Armitage $P < 0.01$; Figure 2). There was strong evidence of decreasing prevalence in peri-urban ($P < 0.01$) and government-run ($P < 0.01$) facilities; the trend was downward but less dramatic in urban facilities ($P = 0.08$) and those managed by Protestant ($P = 0.07$) and Catholic ($P = 0.06$) organisations. Prevalence decreased in Funa, Mont Amba and Tshangu clinics (all $P < 0.05$) but was constant in Lukunga clinics ($P = 0.15$). Receipt of test results increased over time ($P < 0.01$), as described in our prior study,[20] as did uptake of HIV testing ($P < 0.01$). All conclusions about trend were identical whether data were considered monthly or collapsed into quarters.

In a binomial regression model with month as the single independent variable, the HIV prevalence dropped from 2.04% (95% CI: 1.92–2.16%) in October 2004 to 1.77% (95% CI: 1.66–1.88%) in March 2009 (Table 2). This absolute decrease of 0.27% (95% CI: 0.07–0.47%) was equivalent to a 13.2% (95% CI: 3.53–22.9%) relative decrease.

Table 1 HIV prevalence monitoring indicators for 22 maternity units providing vertical HIV prevention services in Kinshasa, DRC, October 2004 to March 2009

	4.5 years total	Quarterly median	High quarter	Low quarter
Women counselled for HIV testing	220 006	11 879	15 690	10 072
Women tested for HIV	210 348	11 388	14 984	9637
Women informed of HIV test result	191 216	10 453	13 514	8856
Women tested positive for HIV	3999	224	274	169
HIV testing uptake (%)	95.6	95.8	98.9	90.7
HIV test result receipt (%)	90.9	90.5	98.8	81.1
HIV prevalence (%)	1.90	1.94	2.44	1.44

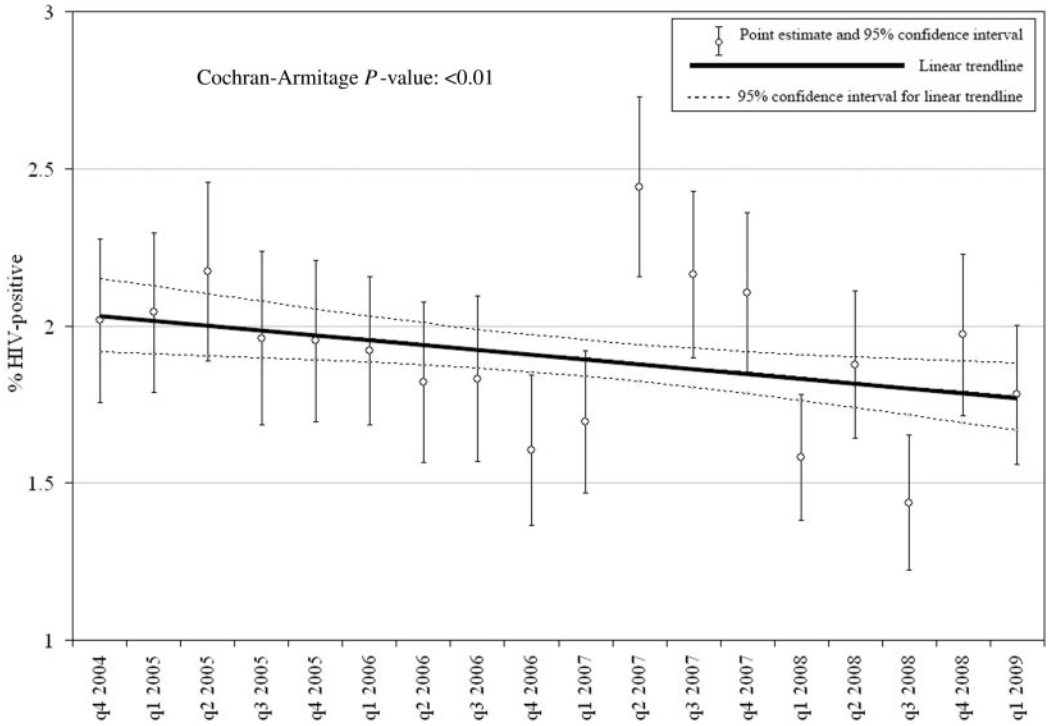

Figure 2 HIV prevalence at 22 Kinshasa maternity units, by quarter, 2004–2009

In addition to month, the multivariable model constructed to represent changes in prevalence with respect to other maternity-level factors included independent variables for management and urbanicity along with interaction terms between month and management as well as month and urbanicity. This analysis, which was corroborated by Cochran–Armitage trend testing, suggested that though the prevalence of HIV held steady in urban maternity units managed by Protestant and Catholic organisations, it fell in peri-urban and government-run facilities. The model indicated that government-run urban maternity units experienced the greatest absolute decline in prevalence during the study period, 1.26% (95% CI: 0.72–1.80%), whereas the greatest relative decline, 51.9% (95% CI: 27.7–76.1%), occurred in Catholic-managed peri-urban maternity units. Consistent with the finding of prominently different prevalences between urbanicity strata, the model conveyed that the October 2004 prevalence in peri-urban clinics was 0.51% (95% CI: 0.26–0.77%) lower (in absolute terms) than that in urban clinics, with this gap widening by an additional 0.02% per month.

Discussion

Data from 22 maternity units offering PMTCT services in Kinshasa, DRC, provide strong evidence that the prevalence of HIV declined between October 2004

Table 2 HIV prevalence trends in maternity units providing vertical HIV prevention services in Kinshasa, DRC, October 2004 to March 2009

Maternity management and urbanicity	Trend statistic[a]	Trend *P*-value	Predicted prevalence[b] (95% CI)		Predicted prevalence change (95% CI)	
			October 2004	March 2009	Absolute	Relative
All maternity units	−2.66	<0.01	2.04% (1.92–2.16%)	1.77% (1.66–1.88%)	−0.27% (−0.47% to −0.07%)	−13.2% (−22.9% to −3.5%)
Catholic, urban	0.19	0.43	1.91% (1.75–2.08%)	2.04% (1.89–2.20%)	0.13% (−0.14% to 0.40%)	6.77% (−7.63% to 21.0%)
Catholic, peri-urban	−4.34	<0.01	1.40% (1.19–1.61%)	0.67% (0.49–0.85%)	−0.73% (−1.06% to −0.39%)	−51.9% (−76.1% to −27.7%)
Protestant, urban	−0.55	0.29	2.21% (1.89–2.54%)	2.21% (1.93–2.49%)	0.00% (−0.52% to 0.52%)	−0.03% (−23.4% to 23.4%)
Protestant, peri-urban	−2.39	<0.01	1.70% (1.34–2.05%)	0.84% (0.57–2.05%)	−0.86% (−1.39% to −0.32%)	−50.5% (−82.1% to −18.9%)
Government, urban	−2.71	<0.01	3.16% (2.81–3.51%)	1.90% (1.62–2.17%)	−1.26% (−1.80% to −0.72%)	−39.8% (−57.0% to −22.7%)

[a]Z-score from Cochran–Armitage test for trend of the quarterly proportion of women tested for HIV who were seropositive. A negative statistic indicates declining prevalence over time. *P*-values are one-sided to test against a null hypothesis of no increasing trend or a null hypothesis of no decreasing trend.
[b]For the 'all maternity units' category, predicted values are from a binomial regression model with month as the single independent variable and an identity link. For the other categories, predicted values are from a model that additionally includes management and urbanicity as well as interaction terms to allow the effects of management and urbanicity to vary over time.

and March 2009 among women receiving ANC at these clinics. In addition to a decreasing proportion of seropositive women over time noted via trend testing, a linear model fit to the 18 quarterly data points indicated a reduction in prevalence during the study period. The precise drivers of this finding are up for debate, particularly given that essential age-specific prevalence estimates and trends are unknown.

Our results are remarkably in line with the findings of the Demographic and Health Survey (DHS) conducted in 2007.[21] The HIV prevalence study conducted on a subsample of the study population provided an overall prevalence of 1.6% (95% CI: 1.2–2.0%) in 4492 adult women countrywide. In Kinshasa, the HIV prevalence among 709 women was 2.3% (95% CI: 1.2–3.4%). The marked difference between these results and the 4.1% prevalence of HIV obtained by the national sentinel surveillance system in 2006 from 11 719 pregnant women throughout the country raised questions among Congolese health authorities regarding the reliability of the DHS data. Our data convey strong additional plausibility to the results of the DHS.

Although the DHS results and our data reinforce each other, the sustained decline of HIV prevalence over time, in the country and in Kinshasa in particular, cannot be explained easily. It is plausible that sexual behaviour change, proposed as an explanation for reduced antenatal prevalence in other sub-Saharan African locales,[17,22,23] plays a contributing role. Support for this theory, however, is limited—despite widespread risk-reduction campaigns[24] and increased condom sales[25] during the past decade, contraceptive use and knowledge of HIV prevention in the DRC remain extremely low.[21,26,27] In addition to prevention programs, high AIDS-related mortality because of very low coverage of antiretroviral treatment programs could explain the declining prevalence.

As there is a scarcity of knowledge about the prevalence in HIV in the DRC, this study contributes novel information about the Kinshasa epidemic's evolution in recent years. Furthermore, it demonstrates that HIV prevalence is heterogeneous in this setting, with variation by maternity management, urbanicity and geographic location. One particularly striking finding was that the HIV prevalence in peri-urban maternity units was approximately half of that in urban maternity units. This mirrors recent studies from Uganda that report lower prevalence in peri-urban ANC facilities relative to urban facilities.[13,14] We hypothesize that the underlying determinants[28] of this disparity include differentials in population density[29,30] (greater in urban Kinshasa than in peri-urban Kinshasa[31]), proximity to urban military and police camps (soldiers throughout Africa are more likely to be infected than the general population[32]) and socialization and economic opportunities,[33,34] which may affect sociosexual networks,

behaviours and HIV risk. Assessed geographic areas were similar in terms of prevalence trend, with three of four sectors decreasing over time, but were variable in terms of absolute prevalence. The same contextual factors thought to explain the dissimilarity by urbanicity, in addition to urbanicity itself, are believed to account for this difference. In the higher prevalence Funa and Tshangu sectors, sampled maternity units tended to be closer to the city centre or highly crowded communes,[31] whereas sampled maternity units in Lukunga and Mt. Amba were more often peri-urban.

We previously described not only that vertical HIV prevention programs at government-run facilities in Kinshasa have performed more poorly than programs at facilities managed by religious organisations in terms of testing uptake, receipt of test results, and successful provision of sdNVP to mother and infant, but also that ANC and delivery costs tend to be higher in government-run clinics.[20] These findings may help explain the noted prevalence differences by maternity management. DRC-specific evidence on the mobility and socio-economic status of HIV infected women (relative to uninfected women) does not exist. We can speculate that seropositive ANC seekers had on average decreased logistical and financial capacity to obtain care at lower-cost, higher-quality maternity units managed by religious organisations. The fact that government-managed maternity units tested a lower percentage of women than other types of maternity units strengthens the case that prevalence was truly higher at those facilities. If, indeed, testing is often refused because of denial and fear,[35] it is expected that untested women were more likely to be infected than that of tested women. A greater number of untested women might therefore bias the observed prevalence downwards, although the impact of non-tested subjects has been considered to have a small effect on the population prevalence estimate.[36]

Assuming that most women seek ANC in maternity units close to their homes,[14] meaning, for example, that women presenting at peri-urban maternity units live in peri-urban areas, the heterogeneities in prevalence observed in this study offer unique insight on specific HIV foci in Kinshasa. Although it is acknowledged that sentinel surveillance of ANC clients can overestimate the overall proportion of residents who are HIV positive,[37,38] there is a logical and likely correlation between patterns among pregnant women and the true prevalence in the overall population, which makes sentinel surveillance of pregnant women particularly appropriate to follow trends over time.

Suppositions like higher urban prevalence, reasonable but heretofore empirically undemonstrated, are strongly supported if not confirmed. The findings of the 2007 DHS also showed that HIV prevalence among women was substantially higher in urban than in rural areas: 2.4% (95% CI: 1.8–3.1%) versus 1.0% (95% CI: 0.7–1.5%).[21] Since 33% of the total Congolese population lives in urban areas, and Kinshasa alone accounts for one-third, it makes sense to develop PMTCT interventions in the capital city.

At ~2%, the prevalence of HIV among women receiving ANC in Kinshasa is markedly lower than in various other sub-Saharan African settings—in Botswana, in 2006, almost 40% of tested pregnant women were HIV infected.[39] It may seem injudicious to highlight mother-to-child HIV transmission as an urgent local issue when antenatal prevalence is so much higher elsewhere, but focusing on the disparity underemphasizes the extent of the problem. Vertical HIV transmission is an important public health problem in the DRC given the large population coupled with a birth rate that is the highest in the world.[40] PMTCT service delivery is low in the DRC. Although 37 of the larger maternity units in Kinshasa now offer HIV testing and sdNVP, coverage is much worse outside of the capital. In 2007, only a third of health zones nationwide had at least one PMTCT facility, and although >85% of the Congolese population does not live in Kinshasa, 70% of antenatal HIV tests were completed outside the city.[9] Assuming a uniform national birth rate of 49.6/1000 and the model-predicted March 2009 antenatal HIV prevalence of 1.77%, there are approximately 7000 HIV positive pregnant women in Kinshasa, and 60 000 in the country, annually in need of HIV prevention and care services. These figures contrast with our program that identifies approximately 1000 seropositive women per year, of whom fewer receive effective prophylaxis due to inevitable attrition at each step of the cascade.[41] Given that the risk of vertical transmission may reach 45% in the absence of intervention,[42] it can be calculated that at least 5% of the world's new paediatric HIV cases (an estimated 370 000 in 2007)[43] occur in the DRC. Far fewer children are infected in higher prevalence nations with better PTMCT coverage.

Compared with other African nations, including countries surrounding the DRC, the low HIV prevalence coupled with a considerable burden of health problems resulting from poor healthcare services and poverty may suggest that PMTCT is a relative luxury. However, PMTCT is closely associated with many aspects of maternal and child healthcare, from ANC to safe delivery to postnatal care. In addition to preventing paediatric HIV, PMTCT programs can be an opportunity for strengthening existing services, e.g. by training and supervising healthcare providers and developing infrastructure to improve reproductive health and maternal and child healthcare. We documented at the outset of our program in 2003 that PMTCT should be delivered in settings like DRC through a comprehensive approach that improves existing service delivery.[44]

Our study has several strengths. First, we utilized a large, geographically diverse sample of maternity units that collectively serve a considerable number of ANC clients. This raises the likelihood that the women considered were representative of all pregnant women in Kinshasa, and thereby improves internal generalizability. Our data were remarkably complete as well as derived from a sample of clinics that was constant over time, which reduces the possibility of biased or invalid inferences about trend. In addition, high uptake of testing contributed to the robustness of results. If the seroprevalence among women not tested for HIV was uniformly 5 or 0.5%, the prevalence would have been 2.04 or 1.84%, close to the 1.90% observed. In a scenario of a uniform 5% prevalence among untested women, extreme given its constancy and magnitude, the overall relative decrease during the study period would have been 17.4%, similar to the actual decrease of 13.2%. One study limitation was a lack of individual-level data, which prevented informative subgroup analyses and investigations of associations between infection and personal demographic factors.

In conclusion, the prevalence of HIV among women receiving ANC at 22 clinics in Kinshasa decreased between October 2004 and March 2009, with clear differences noted by maternity management, urbanicity and geographic location. The relative decrease of 13% was remarkably similar to the 13% relative decrease observed among more than 243 000 pregnant women tested during a recent 4.5-year period in Zambia.[10] Although this finding of decreasing prevalence is encouraging, further understanding and mitigation of the epidemic in the DRC will require sustained local and international commitment to strengthen and scale-up HIV prevention and treatment programs. Although this will be challenging in Kinshasa and even more difficult in other parts of the country, consideration of apparent trends alongside recent expansions and successes in PMTCT and HIV care and treatment service provision provide hope for continued progress.

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References

[1] Coghlan B, Brennan RJ, Ngoy P *et al*. Mortality in the Democratic Republic of Congo: a nationwide survey. *Lancet* 2006;**367:**44–51.

[2] CIA. *The World Fact Book*. Washington, DC: The United States Central Intelligence Agency, 2006.

[3] Coghlan B, Ngoy P, Mulumba F *et al*. Update on mortality in the Democratic Republic of Congo: results from a third nationwide survey. *Disaster Med Public Health Prep* 2009;**3:** 88–96.

[4] Batter V, Matela B, Nsuami M *et al*. High HIV-1 incidence in young women masked by stable overall seroprevalence among childbearing women in Kinshasa, Zaire: estimating incidence from serial seroprevalence data. *AIDS* 1994;**8:**811–17.

[5] Mulanga-Kabeya C, Nzilambi N, Edidi B *et al*. Evidence of stable HIV seroprevalences in selected populations in the Democratic Republic of the Congo. *AIDS* 1998;**12:** 905–10.

[6] Mwandagalirwa K, Jackson EF, McClamroch K, Bollinger R, Ryder RW, Weir SS. Local differences in human immunodeficiency virus prevalence: a comparison of social venue patrons, antenatal patients, and sexually transmitted infection patients in eastern Kinshasa. *Sex Transm Dis* 2009;**36:**406–12.

[7] Kinoshita-Moleka R, Smith JS, Atibu J *et al*. Low prevalence of HIV and other selected sexually transmitted infections in 2004 in pregnant women from Kinshasa, the Democratic Republic of the Congo. *Epidemiol Infect* 2008;**136:**1290–96.

[8] UNAIDS/WHO. *UNAIDS/WHO Epidemiological Fact Sheets on HIV and AIDS, 2008 Update, Democratic Republic of Congo*. Geneva, Switzerland: UNAIDS/WHO, 2008.

[9] *Programme National de Lutte contre le SIDA. Rapport annuel d'activités*. Kinshasa, 2007.

[10] Stringer EM, Chintu NT, Levy JW *et al*. Declining HIV prevalence among young pregnant women in Lusaka, Zambia. *Bull World Health Organ* 2008;**86:**697–702.

[11] Kuate S, Mikolajczyk RT, Forgwei GW, Tih PM, Welty TK, Kretzschmar M. Time trends and regional differences in the prevalence of HIV infection among women attending antenatal clinics in 2 provinces in Cameroon. *J Acquir Immune Defic Syndr* 2009;**52:**259–64.

[12] Stover J, Fidzani B, Molomo BC, Moeti T, Musuka G. Estimated HIV trends and program effects in Botswana. *PLoS One* 2008;**3:**e3729.

[13] Kipp W, Chapman E, Jhangri GS *et al*. Fourteen years of surveillance of HIV-1 prevalence among pregnant women attending antenatal care clinics in western Uganda. *Int J STD AIDS* 2009;**20:**499–502.

[14] Rice BD, Batzing-Feigenbaum J, Hosegood V *et al*. Population and antenatal-based HIV prevalence estimates in a high contracepting female population in rural South Africa. *BMC Public Health* 2007;**7:**160.

[15] Swai RO, Somi GG, Matee MI *et al*. Surveillance of HIV and syphilis infections among antenatal clinic attendees in Tanzania-2003/2004. *BMC Public Health* 2006;**6:**91.

[16] Msamanga G, Fawzi W, Hertzmark E *et al*. Socio-economic and demographic factors associated with prevalence of HIV infection among pregnant women in Dar es Salaam, Tanzania. *East Afr Med J* 2006;**83:**311–21.

[17] Kirungi WL, Musinguzi J, Madraa E *et al*. Trends in antenatal HIV prevalence in urban Uganda associated with uptake of preventive sexual behaviour. *Sex Transm Infect* 2006;**82:**i36–41.

[18] Tsegaye A, Rinke De Wit TF, Mekonnen Y *et al*. Decline in prevalence of HIV-1 infection and syphilis among young women attending antenatal care clinics in Addis Ababa, Ethiopia: results from sentinel surveillance, 1995–2001. *J Acquir Immune Defic Syndr* 2002;**30:**359–62.

[19] Agresti A, Coull BA. Approximate is better than ''exact'' for interval estimation of binomial proportions. *Am Stat* 1998;**52:**119–26.

[20] Behets F, Mutombo GM, Edmonds A *et al*. Reducing vertical HIV transmission in Kinshasa, Democratic Republic of Congo: trends in HIV prevalence and service delivery. *AIDS Care* 2009;**21:**583–90.

[21] Ministère du Plan et Macro International. *République Démocratique du Congo: Enquête Démographique et de Santé (EDS-RDC) 2007*. Calverton: Ministère du Plan et Macro International, 2008.

[22] Msellati P, Sakarovitch C, Bequet L *et al*. Decrease of human immunodeficiency virus prevalence in antenatal clinics in Abidjan, Cote d'Ivoire, 1995–2002. *Int J STD AIDS* 2006;**17:**57–60.

[23] Sandoy IF, Michelo C, Siziya S *et al*. Associations between sexual behaviour change in young people and decline in HIV prevalence in Zambia. *BMC Public Health* 2007;**7:**60.

[24] Population Services International. *Association de Santé Familiale (ASF) Social Marketing in Congo/Kinshasa*. Washington: Population Services International, 2008.

[25] Population Services International. *Sales reports, 2002–2006. Internal document*. Washington: Population Services International.

[26] Kayembe KP, Mapatano MA, Busangu FA *et al*. Correlates of ever had sex and of recent sex among teenagers and young unmarried adults in the Democratic Republic of Congo. *AIDS Behav* 2008;**12:**585–93.

[27] Kayembe PK, Fatuma AB, Mapatano MA, Mambu T. Prevalence and determinants of the use of modern contraceptive methods in Kinshasa, Democratic Republic of Congo. *Contraception* 2006;**74:**400–6.

[28] Boerma JT, Weir SS. Integrating demographic and epidemiological approaches to research on HIV/AIDS: the proximate-determinants framework. *J Infect Dis* 2005;**191 (Suppl 1):**S61–67.

[29] Meidany F, Horikoshi Y, Rohde J. HIV prevalence rate and population density: Eastern Cape experience, South Africa. *Int Conf AIDS* 2000 Jul 9–14;13:(abstract no. MoPeC2316).

[30] Barcellos C, Acosta LM, Lisboa EP *et al*. Estimate of HIV prevalence in pregnant women by means of spatial analysis in Southern Brazil. *Rev Saude Publica* 2006;**40:** 928–30.

[31] Census Report. *Institut National de la Statistique*, Kinshasa.

[32] Ba O, O'Regan C, Nachega J *et al*. HIV/AIDS in African militaries: an ecological analysis. *Med Confl Surviv* 2008;**24:** 88–100.

[33] Bloom SS, Urassa M, Isingo R, Ng'weshemi J, Boerma JT. Community effects on the risk of HIV infection in rural Tanzania. *Sex Transm Infect* 2002;**78:**261–66.

[34] Weir SS, Pailman C, Mahlalela X, Coetzee N, Meidany F, Boerma JT. From people to places: focusing AIDS prevention efforts where it matters most. *AIDS* 2003;**17:**895–903.

[35] Stringer EM, Chi BH, Chintu N *et al*. Monitoring effectiveness of programmes to prevent mother-to-child HIV transmission in lower-income countries. *Bull World Health Organ* 2008;**86:**57–62.

[36] Mishra V, Barrere B, Hong R, Khan S. Evaluation of bias in HIV seroprevalence estimates from national household surveys. *Sex Transm Infect* 2008;**84:**i63–70.

[37] Montana LS, Mishra V, Hong R. Comparison of HIV prevalence estimates from antenatal care surveillance and population-based surveys in sub-Saharan Africa. *Sex Transm Infect* 2008;**84(Suppl 1):**i78–84.

[38] Michelo C, Sandoy I, Fylkesnes K. Antenatal clinic HIV data found to underestimate actual prevalence declines: evidence from Zambia. *Trop Med Int Health* 2008;**13:**171–9.

[39] UNAIDS/WHO. *UNAIDS/WHO Epidemiological Fact Sheets on HIV and AIDS, 2008 Update, Botswana*. Geneva: UNAIDS/WHO, 2008.

[40] United Nations Population Division. *World Population Prospects: The 2008 Revision*. New York: United Nations Population Division, 2008.

[41] Stringer JS, Sinkala M, Maclean CC *et al*. Effectiveness of a city-wide program to prevent mother-to-child HIV transmission in Lusaka, Zambia. *AIDS* 2005;**19:**1309–15.

[42] De Cock KM, Fowler MG, Mercier E *et al*. Prevention of mother-to-child HIV transmission in resource-poor countries: translating research into policy and practice. *JAMA* 2000;**283:**1175–82.

[43] UNAIDS. *Report on the Global HIV/AIDS Epidemic 2008*. Geneva: Joint United Nations Program on HIV/AIDS, 2008.

[44] Behets FM, Matendo R, Vaz LM *et al*. Preventing vertical transmission of HIV in Kinshasa, Democratic Republic of the Congo: a baseline survey of 18 antenatal clinics. *Bull World Health Organ* 2006;**84:**969–75.

Appendix 1

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