Is HIV Prevalence Declining in Southern India? Evidence From Two Rounds of General Population Surveys in Bagalkot District, Karnataka

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Objectives: To assess the levels and trends in the prevalence of HIV and sexually transmitted infections in the general population in Bagalkot district using 2 cross-sectional surveys undertaken in 2003 and 2009.

Methods: In both surveys, a target sample of 6600 adult males and females was selected systematically from a sample of 10 rural villages and 20 urban blocks in 3 of the 6 talukas (subdistrict units) in the district. Urine and blood samples were collected from all consenting participants for HIV and sexually transmitted infection testing. Changes in HIV prevalence in age subgroups were determined by logistic regression, taking into account the survey design.

Results: HIV prevalence fell not significantly from 3.2% to 2.5% during the 6-year study period. It decreased significantly (P = 0.023) among persons aged 15 to 24 years, from 2.4% in 2003 (95% confidence interval [95% CI]: 1.2–3.7) to 1.3% in 2009 (95% CI: 0.6 –2.0). However, among males aged 35 and above, HIV prevalence increased significantly (P = 0.008), from 3.0% (95% CI: 1.1–4.8) to 4.2% (95% CI: 1.8–6.6), a level similar to that found in the younger age-group in 2003.

Conclusions: We observed a significant decline in HIV prevalence among people aged 15 to 24 years, where HIV prevalence more closely reflects incidence. The increase in HIV prevalence among older males may have been because of the aging of a cohort of men among whom HIV prevalence was highest in the 2003 survey. It may also have in part reflected increased survival, as a result of the scaling up of antiretroviral treatment programs throughout the district and state.

Estimates from a recent report of the Joint United Nations Program on HIV/AIDS (UNAIDS) indicate that in 2009, an estimated 2.4 million people in India were infected with HIV, and 0.2 million died of acquired immune deficiency syndrome related illness.[1] The report also indicates that HIV incidence in India fell by 25% between 2001 and 2009. According to the Indian National AIDS Control Organization, national adult HIV prevalence declined from 0.41% in 2000 to 0.31% in 2009.[2]

The main source of HIV prevalence trend data in India, which is used for modeling the estimates above, is its national sentinel surveillance system, which samples women attending antenatal (ANC) clinics. ANC surveillance data suggest a decline in HIV prevalence among women aged 15 to 24 years after 2000.[3–5] HIV prevalence estimates based on antenatal surveillance data are used as a proxy for HIV prevalence in the general population, but this has several limitations, as the data are not truly representative of the general population.[6–11] In India, antenatal care coverage varies from being almost universal in states such as Kerala, Tamil Nadu, and Goa, to as low as 34% in Bihar.[12] In addition, surveillance data are mainly based on women visiting government hospitals, and the use of these hospitals for antenatal care varies across states[10,13] and by various sociodemographic characteristics, tending to be used by poorer, older, and higher parity women.[12]

To understand the true picture of HIV burden in the community as a whole, it is important to examine trends in HIV prevalence using data collected from the general population. However, to date, there are no general population trend data available in India. In this article, we examined levels and trends in HIV and sexually transmitted infection (STI) prevalence in Bagalkot district, Karnataka, from 2 cross-sectional behavioral and biologic surveys conducted in the general population between 2003 and 2009. Between the 2 surveys, HIV prevention, care, and support programmes, both for high-risk groups and the general population, were implemented in the district by the Karnataka Health Promotion Trust.

Bagalkot district is located in the northern part of Karnataka in India and has a geographical area of 6583 km^2. It has a population of 1.9 million; 32% urban and 68% rural. Heterosexual transmission is primarily responsible for HIV transmission in the district, associated largely with men buying sex from female sex workers (FSWs) and transmitting the infection to their wives and other partners. A recent mapping activity identified 5370 FSWs in the district.[14]

METHODS

Sampling

The study included 10 randomly selected rural areas and 20 randomly selected urban blocks in 3 of the 6 talukas (subdistricts) in Bagalkot district.[15] The same sampling procedure was adopted in both surveys. The 1991 Indian Census list of villages was used as the sampling frame for selecting the rural areas using probability proportional to population size.

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The National Sample Survey Organization's sampling frame of urban enumeration blocks for the period 1997–2002 was used for selecting a systematic random sample of urban blocks. However, in the 2009 survey, 6 urban blocks in Bagalkot city had to be replaced, as they had been submerged under a newly constructed dam. The new urban areas were selected using the National Sample Survey Organization sampling for the period 2002–2007. The targeted sample size for individual interview in both the surveys was 6600, with an equal rural-urban split.

In both survey rounds, a fresh census of all households was undertaken before each individual interview in all selected areas. The resulting household list was used as the sampling frame to select the required number of respondents in the age-group 15 to 49 years. First, the list of persons in this age-group was arranged according to sex, age, and marital status, and from this list the required number of individuals was selected systematically.

Field Work

Respondents were interviewed in their homes by trained male and female interviewers. After taking verbal witnessed informed consent, the interviewers conducted a lengthy face-to-face interview that collected details of knowledge of, and attitudes to HIV and other STIs, as well as potential risk behaviors. After the interview, laboratory technicians took venous blood samples (in 2009 we also took dried blood spot [DBS] samples and urine samples). No names or other contact information were recorded on the biologic samples collected. Instead, a bar code label was pasted on the biologic sample for linking with the questionnaire survey data. The Round 1 and Round 2 surveys were carried out from April to September 2003 and from June 2009 to January 2010, respectively.

Laboratory Testing

All serum samples were tested for HIV-specific antibodies using an enzyme-linked immunosorbent assay (ELISA), Detect-HIV (BioChem Immuno Systems, Montreal, Canada) in 2003, and Microelisa-HIV (J. Mitra & Company Private Ltd., New Delhi, India) in 2009. Reactive specimens were confirmed using a second ELISA test, Genedia-HIV (Green Cross Life Science Corporation, Kyunggi-do, South Korea) in both surveys. The same testing procedures and test kits were used on eluted DBS samples in 2009, for those who did not provide a serum sample. For those respondents who did not give a serum or DBS sample, but did provide a urine sample in Round 2, HIV tests were carried out on these samples. Aliquots of urine samples were kept refrigerated at 4°C until tested for HIV-1 antibodies using the Calypte ELISA (Calypte Biomedical Corporation, Berkeley), with confirmation of initially positive results by urine Western blot (Maxim Biomedical Inc, Rockville, MD). To be considered HIV positive, a sample needed to be positive on both tests.

Samples were also tested for syphilis using rapid plasma reagin (Span Diagnostics, Surat, India), and if positive, confirmed with the *Treponema pallidum* hemagglutination assay (Glaxo-Omega, Alloa, Scotland, United Kingdom). Herpes simplex virus (HSV)-2 testing was conducted using the ELISA-based Kalon Biological Kit (Kalon Biological Ltd, Guildford, United Kingdom). In the 2003 and 2009 surveys, HSV-2 testing was carried out on a random subsample of 25% and 12.5% of the serum samples, respectively.

Ethical Approval

Ethical approval for both 2003 and 2009 surveys was obtained from institutional review boards at the University of Manitoba, Winnipeg, Canada, and St. John's Medical College and Hospital, Bangalore, India.

Statistical Analyses

Sample weights were calculated based on design weights, adjusted for effect of differential nonresponse in the selected villages and urban blocks (details on the weighting procedure are given in the appendix). All analyses described later in the text were weighted and took into account the cluster effect of the sampling procedure. We compared the sociodemographic and behavioral variables as well as the syphilis, HSV-2, and HIV prevalences between both rounds, using univariate logistic regression, with the Wald test to assess the statistical significance of the variations observed. We plotted HIV prevalence by 5-year age-groups across the 2 surveys for all subjects and according to sex and place of residence. To formally assess the changes in HIV prevalence between the study rounds by age-group, we first used logistic regression with HIV as the outcome and round, dummy variables corre- sponding to 3 broader age-groups (15–24, 25–34, and 35– 49 years), and interaction terms between age-groups and round, as the independent variables. For multivariate analyses, we repeated the same procedure after controlling for selected sociodemographic characteristics. Five separate logistic models were considered for all subjects, according to sex and place of residence. The sociodemographic variables entered into the models were the taluka (subdistrict), religion, marital status, place of residence (for the analyses combining both urban and rural areas), and sex of the respondent (for the analyses including subject of both sexes). All statistical analyses were performed using Stata version 10.0 (StataCrop LP, College Station, TX, USA).

RESULTS

The response rates for interview and biologic specimens are shown in Table 1. In the 2003 survey, of the 6703 selected participants, 4008 (60%) agreed to be interviewed and also provided a biologic sample. In comparison, in the 2009 survey, the response rate for the interview and biologic samples was 77%. In the latter survey, 67.0% of respondents provided a serum sample, another 3.6% provided a DBS specimen, and another 6.4% provided a urine sample on which HIV testing was performed. The participation rate improved between the 2 rounds, irrespective of the place of residence and sex of the respondent, although it improved the most in rural areas and among female respondents. In both rounds, more respondents from urban areas participated in the survey than respondents from rural areas. Similarly, the response rate was higher among females than males, irrespective of place of residence. Although their response rate increased over the period, younger (15–19) subjects were less likely to provide biologic samples than older ones in both rounds.

When comparing sociodemographic characteristics (sex, age, religion, marital status, and education) during the 2 study rounds (data not shown), the only meaningful and statistically significant difference concerned the level of education: the proportion of illiterate subjects decreased from 44.2% to 33.3%, whereas the proportion with a completed secondary level increased from 27.6% to 36.4% ($P < 0.001$). In both rounds, the majority of participants (52%) were female, median age was 28 years, and about one-quarter of the participants had never been married.

We compared sexual behavior between the 2 surveys among the respondents according to sex and place of residence (Table 2). Most parameters did not change significantly over time, except for reported condom use, which increased overall, especially in urban areas and among women. Condom use increased from 8% (95% confidence interval [95% CI]: 6.5–9.6) in 2003 to 11% (95% CI: 8.6–13.6) in 2009. In both surveys,

TABLE 1. Sample Response Rates Between Round 1 and Round 2 Surveys, by Characteristics of the Respondents

Characteristics	Round 1, 2003 Not Interviewed	Both Interview and Any Biologic Sample	Only Interview Without Biologic Sample	Number	Round 2, 2009 Not Interviewed	Both Interview and Any Biologic Sample	Only Interview Without Biologic Sample	Number
Total	26.2	59.8	14.1	6703	18.4	77.0	4.6	6600
Rural	28.1	54.8	17.1	3403	19.4	75.4	5.2	3300
Urban	24.2	64.9	10.9	3300	17.5	78.6	3.9	3300
Male	29.9	58.6	11.5	3384	22.5	73.1	4.4	3328
Female	22.4	61.0	16.7	3319	14.3	80.9	4.7	3272
Rural male	30.8	55.0	14.1	1699	24.8	69.9	5.4	1672
Rural female	25.4	54.5	20.1	1704	13.9	81.1	5.0	1628
Urban male	29.0	62.3	8.8	1685	20.2	76.4	3.4	1656
Urban female	19.2	67.7	13.1	1615	14.8	80.8	4.4	1644
Age-group								
15–19	28.6	58.4	13.0	1356	21.0	75.3	3.7	1188
20–24	30.0	59.6	10.5	1215	18.3	78.3	3.4	1226
25–29	25.1	60.8	14.1	1113	18.4	77.9	3.8	1143
30–34	24.8	60.6	14.6	878	18.1	76.3	5.6	878
35–39	23.5	60.4	16.1	855	17.3	76.5	6.2	894
40–44	21.4	61.1	17.5	681	18.1	75.9	6.0	618
45–49	26.1	57.9	16.0	605	16.4	78.7	4.9	653
Marital status								
Currently married	25.6	60.0	14.3	4585	17.6	77.9	4.5	4383
Marriage dissolved	22.6	56.8	20.6	398	13.7	77.4	9.0	380
Never married	28.4	59.8	11.8	1720	21.3	74.7	3.9	1837

Note: For respondents those who were not interviewed, characteristics were obtained from the household census.

significantly more males than females reported multiple sex partners, irrespective of place of residence. Overall in 2009, about 13% (95% CI: 10.6–14.3) of males reported ever having had sex with >1 partner, compared with 2% (95% CI: 1.1–2.4) of females.

Likewise, indicators listed in Table 2 were compared between the subjects who provided a biologic specimen and those who did not. Although none of these comparisons was statistically significant (data not shown), subjects who provided a biologic sample tended to be slightly more at risk than those who did not. For example, in 2009, 7.0% (95% CI: 6.1–8.0) of specimen providers reported >1 lifetime sexual partner compared with 4.0% (95% CI: 1.2–6.9) among nonproviders, with corresponding proportions of 11.3% (95% CI: 8.8–13.9) and 8.3% (95% CI: 4.7–11.9) reporting ever having used a condom.

The prevalence of syphilis (0.5% in both rounds) and HSV-2 (22% and 20% in 2003 and 2009, respectively) was relatively stable across the 2 survey rounds (Table 3). In 2009, the prevalence of syphilis was slightly higher among females 0.8% (95% CI: 0.3–1.2) than males 0.3% (95% CI: 0.1–0.5). In contrast to syphilis prevalence, HSV-2 prevalence was significantly higher in rural areas than urban areas ($P = 0.02$ in 2003 and $P = 0.04$ in 2009) in both survey rounds.

Although not statistically significant, we observed an overall decline in HIV prevalence from 3.2% (95% CI: 2.1–4.4) in 2003 to 2.5% (95% CI: 1.7–3.3) in 2009 (Table 3). In both survey rounds, HIV prevalence was higher in rural than in urban areas. It was slightly higher among females than males in rural areas in both rounds, whereas the opposite was observed in urban areas. HIV prevalence declined in both rural and urban areas and among males and females. We observed a borderline significant decline in HIV prevalence among all urban respondents ($P = 0.072$) as well as urban female respondents ($P = 0.086$) during the 6-year period.

Overall, HIV prevalence had declined by 2009 in all age-groups under 40 years and increased in older age-groups (Fig. 1). In 2003, HIV prevalence peaked in the 35 to 39 year age-group, whereas it was highest in the 40 to 44 year age- group in 2009. On the other hand, in rural areas, HIV prevalence was highest in the 35 to 39 year age-group in 2003, whereas 2 peak points, at ages 25 to 29 and 40 to 44 years, were observed in 2009. In urban areas, HIV prevalence in 2003 was highest in the 25 to 29 year age; in 2009, it was highest in the 35 to 39 year group. In males in 2003, we observed 2 peaks in the groups aged 25 to 29 and aged 35 to 39, with highest prevalence in the latter group. Similarly, in 2009 also, we noticed 2 peak points for males, one among the 25 to 29 year olds and another in 40 to 44 year olds. In 2003, the prevalence among women was highest in the 45 to 49 year age-group, whereas in 2009, it was highest in the 30 to 34 year age-group. Levels and trends in age-specific HIV prevalence during the 6-year period differed considerably according to sex and place of residence.

We grouped the population into 3 age-groups (15–24, 25–34, and 35+ years), and we conducted univariate and multivariate logistic regression models separately according to place

TABLE 2. Comparison of Specific Sexual Behaviors Between Round 1 and Round 2 Surveys

	Rural			Urban			Total		
Specific Sexual Behaviors	**Round 1, 2003 % (95% CI)**	**Round 2, 2009 % (95% CI)**	***P***	**Round 1, 2003 % (95% CI)**	**Round 2, 2009 % (95% CI)**	***P***	**Round 1, 2003 % (95% CI)**	**Round 2, 2009 % (95% CI)**	***P***
Male									
Had sex with more than 1 partner during the last 12 months	1.4 (0.5, 2.4)	2.2 (1.2, 3.2)	0.209	1.2 (0.5, 1.9)	0.9 (0.3, 1.4)	0.383	1.4 (0.7, 2.0)	1.7 (1.1, 2.2)	0.432
Had sex with more than 1 partner	14.3 (7.5, 21.1)	14.4 (11.6, 17.2)	0.958	11.4 (7.3, 15.4)	9.6 (7.0 12.1)	0.423	13.3 (9.0, 17.6)	12.5 (10.6, 14.3)	0.675
Ever paid/received money for sex	1.4 (0.5, 2.3)	2.0 (0.6, 3.4)	0.326	2.2 (1.1, 3.4)	2.7 (1.4, 3.9)	0.651	1.7 (1.0, 2.3)	2.3 (1.4, 3.2)	0.255
Ever used condom*	6.9 (4.0, 9.8)	8.7 (4.7, 12.7)	0.164	23.0 (18.2, 27.9)	26.7 (22.4, 30.9)	0.136	12.0 (9.4, 14.5)	15.5 (12.4, 18.6)	0.023
Number	1175	1258		1197	1322		2372	2580	
Female									
Had sex with more than 1 partner during the last 12 months	0.3 (0.0, 0.6)	0.5 (0.0, 1.2)	0.258	0.2 (0.0, 0.4)	0.0 (0.0, 0.1)	0.259	0.2 (0.0, 0.4)	0.4 (0.0, 0.7)	0.452
Had sex with more than 1 partner	2.9 (1.7, 4.1)	2.3 (1.1, 3.5)	0.346	1.4 (0.9, 1.9)	0.8 (0.3, 1.3)	0.116	2.4 (1.7, 3.1)	1.7 (1.1, 2.4)	0.119
Ever paid/received money for sex	1.4 (0.4, 2.3)	2.1 (0.6, 3.6)	0.139	0.2 (0.0, 0.5)	0.1 (0.0, 0.3)	0.345	1.0 (0.4, 1.5)	1.3 (0.5, 2.1)	0.232
Ever used condom*	2.4 (1.0, 3.8)	3.7 (1.0, 6.5)	0.247	11.2 (8.2, 14.2)	15.6 (11.6, 19.5)	0.044	5.2 (3.9, 6.5)	8.0 (5.6, 10.4)	0.026
Number	1272	1402		1305	1401		2577	2803	
Total									
Had sex with more than 1 partner during the last 12 months	0.8 (0.3, 1.4)	1.3 (0.7, 2.0)	0.188	0.7 (0.3, 1.0)	0.4 (0.1, 0.7)	0.270	0.8 (0.4, 1.1)	1.0 (0.6, 1.3)	0.385
Had sex with more than 1 partner	8.5 (4.8, 12.1)	8.0 (6.7, 9.3)	0.740	6.2 (4.2, 8.1)	5.0 (3.7, 6.4)	0.325	7.7 (5.4, 9.9)	6.8 (5.9, 7.7)	0.403
Ever paid/received money for sex	1.4 (0.6, 2.2)	2.0 (0.7, 3.4)	0.175	1.2 (0.6, 1.7)	1.4 (0.7, 2.0)	0.729	1.3 (0.8, 1.8)	1.8 (1.0, 2.6)	0.184
Ever used condom*	4.3 (2.7, 5.9)	5.8 (2.7, 8.9)	0.099	16.1 (12.6, 19.5)	20.3 (16.7, 23.9)	0.035	8.1 (6.5, 9.6)	11.1 (8.6, 13.6)	0.009
Number	2447	2660		2502	2723		4949	5383	

*This estimate is based on respondents who ever had sex.

TABLE 3. Comparison of Prevalence of Active Syphilis, HSV-2, and HIV Between Round 1 and Round 2 Surveys

	Round 1, 2003		Round 2, 2009		
Characteristics	% (95% CI)	Number	% (95% CI)	Number	*p*
Active syphilis					
Total	0.5 (0.2, 0.8)	4008	0.5 (0.3, 0.7)	4420	0.938
Rural	0.6 (0.1, 1.1)	1864	0.6 (0.3, 0.9)	2123	0.960
Urban	0.3 (0.0, 0.6)	2144	0.4 (0.1, 0.7)	2297	0.598
Male	0.5 (0.1, 0.9)	1984	0.3 (0.1, 0.5)	2126	0.235
Female	0.5 (0.0, 1.0)	2024	0.8 (0.3, 1.2)	2294	0.422
Rural male	0.6 (0.0, 1.2)	935	0.2 (0.0, 0.5)	998	0.310
Rural female	0.7 (0.0, 1.5)	929	0.9 (0.3, 1.5)	1125	0.600
Urban male	0.5 (0.0, 0.9)	1049	0.3 (0.1, 0.6)	1128	0.581
Urban female	0.2 (0.0, 0.4)	1095	0.5 (0.0, 1.0)	1169	0.222
HSV-2					
Total	22.1 (16.2, 27.9)	901	20.3 (14.7, 25.9)	550	0.653
Rural	26.1 (15.9, 36.3)	388	24.9 (16.3, 33.6)	264	0.847
Urban	15.2 (11.8, 18.6)	513	13.3 (6.6, 20.0)	286	0.589
Male	19.1 (12.4, 25.8)	446	15.2 (9.4, 20.9)	265	0.460
Female	25.1 (18.5, 31.7)	455	24.9 (15.7, 34.1)	285	0.972
Rural male	20.7 (9.5, 32.0)	197	15.9 (7.7, 24.1)	125	0.549
Rural female	31.9 (20.0, 43.8)	191	33.1 (18.3, 47.8)	139	0.896
Urban male	16.2 (11.1, 21.3)	249	14.0 (4.8, 23.1)	140	0.682
Urban female	14.3 (9.7, 19.0)	264	12.8 (5.3, 20.3)	146	0.716
HIV					
Total	3.2 (2.1, 4.4)	4008	2.5 (1.7, 3.3)	5081	0.214
Rural	3.7 (1.8, 5.6)	1864	3.2 (1.9, 4.5)	2488	0.575
Urban	2.4 (1.4, 3.3)	2144	1.5 (0.5, 2.4)	2593	0.072
Male	3.3 (1.8, 4.7)	1984	2.7 (1.8, 3.6)	2433	0.322
Female	3.2 (1.6, 4.7)	2024	2.4 (1.5, 3.3)	2648	0.351
Rural male	3.5 (1.1, 5.8)	935	3.1 (1.7, 4.5)	1168	0.665
Rural female	3.9 (1.3, 6.5)	929	3.3 (1.7, 4.9)	1320	0.640
Urban male	2.9 (1.6, 4.2)	1049	2.0 (0.8, 3.2)	1265	0.264
Urban female	1.9 (0.6, 3.1)	1095	1.0 (0.4, 1.7)	1328	0.086

of residence and sex of the respondent. HIV prevalence and the crude and adjusted odds ratios for the specific age categories are provided in Table 4. Overall, among respondents aged 15 to 24 years, we observed a statistically significant reduction of 47% in HIV prevalence during the 6-year period, with a decline from 2.4% to 1.3%. A significant decline in HIV prevalence was also observed among urban respondents aged 25 to 34, from 3.5% to 1.7%. However, among males aged 35+ years, HIV prevalence increased significantly from 3.0% (95% CI: 1.1–4.8) in 2003 to 4.2% (95% CI: 1.8–6.6) in 2009. Finally, among women, no significant increase or decrease in HIV prevalence was observed in any age-group, although we identified a decrease in the youngest and oldest groups, and an increase in the 25 to 34 years age-group.

DISCUSSION

In Bagalkot district, during the 6-year period, we observed an overall, but not statistically significant, decline in HIV prevalence. However, we found a statistically significant reduction in HIV prevalence among younger people (15–24), where most infections are likely to be relatively new, suggesting a decline in HIV incidence. The reduced HIV prevalence identified in the young population in Bagalkot between the 2 survey rounds is consistent with the results of other studies based on sentinel surveillance data of young ANC attenders.[3,4]

We also found a statistically significant increase in HIV prevalence among males aged ≥35. This may be in part because of a cohort effect, as the respondents aged over time, since HIV prevalence was highest in 2003 in the 30 to 39 year age-group. This effect may also in part reflect increased survival in that age-group, as a result of the scaling up of antiretroviral treatment (ART) programmes throughout the state.[16] Emerging evidence has shown associations between rolling out ART and reduced population mortality, particularly in high HIV prevalence settings. For instance, recent estimates of UNAIDS suggest that, worldwide, about 14.4 million adult life-years have been gained because of ART provision between 1996 and 2009, including 233,000 in India.[1] After the provision of free ART by the Karnataka government in 2004, the number of ART users increased from 549 in 2004 to 40,320 in 2009.[17] In 2009, the total number of people living with HIV in Bagalkot was estimated to be 24,040,[14] of whom 16,018 had registered at public ART centers and 8924 had started on ART (Suresh Shastri, personal communication). We thus estimate that about 37% of people with HIV in the district were using ART at the time of the survey, likely confounding estimates of changes in HIV prevalence over time and probably therefore

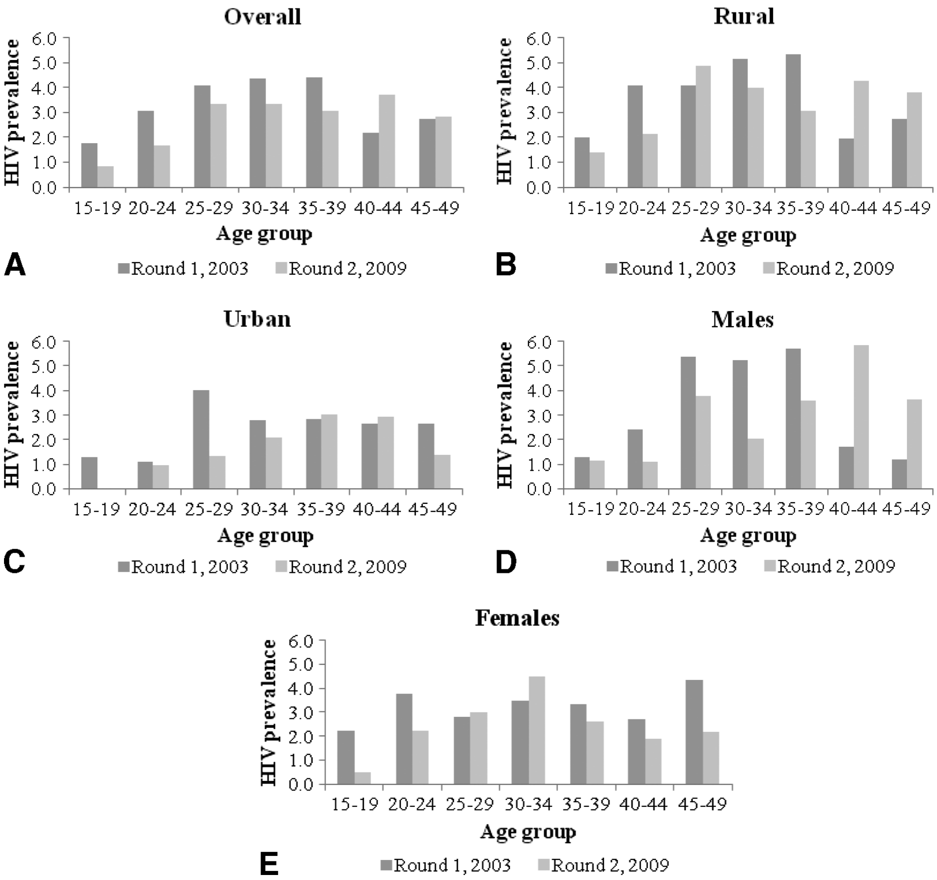

Figure 1. Trends in age-specific HIV prevalence rates according to sex and place of residence, general population survey, Bagalkot district. Panel A presents the results for the oveall study sample. Panel B presents the results for subjects from rural areas. Panel C presents the results for subjects from urban areas. Panel D presents results for male subjects. Panel E presents the results for female subjects.

TABLE 4. HIV Prevalence and Adjusted Odds Ratios in Specific Age-Groups Between Round 1 and Round 2 Surveys

					Multiple Logistic Regression With Interaction Between Round and Age	
Subgroup	**Age-Group**	**Round-1, 2003 HIV Prevalence % (95% CI)**	**Round-2, 2009 HIV Prevalence % (95% CI)**	**Crude Odds Ratio and 95% CI, 2009 vs. 2003**	**Adjusted Odds Ratio and 95% CI, 2009 vs. 2003**	***P***
Overall	15–24	2.4 (1.2, 3.7)	1.3 (0.6, 2.0)	0.52 (0.30, 0.91)	0.53 (0.31, 0.91)	0.023
	25–34	4.2 (2.0, 6.4)	3.3 (2.4, 4.3)	0.79 (0.49, 1.27)	0.79 (0.48, 1.30)	0.348
	35–49	3.2 (2.2, 4.2)	3.2 (1.6, 4.7)	0.99 (0.62, 1.58)	1.13 (0.75, 1.72)	0.552
Rural	15–24	3.1 (1, 5.1.0)	1.8 (0.5, 3.0)	0.57 (0.29, 1.14)	0.56 (0.29, 1.10)	0.086
	25–34	4.6 (1.0, 8.2)	4.4 (2.7, 6.1)	0.97 (0.47, 1.98)	0.95 (0.44, 2.04)	0.876
	35–49	3.5 (2.0, 5.0)	3.6 (1.0, 6.3)	1.05 (0.53, 2.09)	1.17 (0.64, 2.15)	0.575
Urban	15–24	1.2 (0.4, 2.0)	0.5 (0.1, 0.9)	0.39 (0.13, 1.20)	0.43 (0.14, 1.31)	0.130
	25–34	3.5 (1.7, 5.2)	1.7 (0.7, 2.7)	0.47 (0.28, 0.80)	0.45 (0.28, 0.72)	0.002
	35–49	2.7 (1.2, 4.2)	2.5 (0.9, 4.1)	0.91 (0.47, 1.76)	1.04 (0.58, 1.86)	0.890
Male	15–24	1.9 (0.4, 3.3)	1.1 (0.2, 2.0)	0.59 (0.16, 2.19)	0.62 (0.17, 2.29)	0.462
	25–34	5.3 (2.8, 7.8)	3.0 (1.6, 4.4)	0.55 (0.28, 1.10)	0.54 (0.28, 1.07)	0.077
	35–49	3.0 (1.1, 4.8)	4.2 (1.8, 6.6)	1.43 (0.94, 2.19)	1.78 (1.17, 2.70)	0.008
Female	15–24	3.0 (0.6, 5.4)	1.4 (0.4, 2.5)	0.46 (0.14, 1.54)	0.47 (0.15, 1.49)	0.190
	25–34	3.1 (0.4, 5.9)	3.7 (2.2, 5.2)	1.19 (0.53, 2.67)	1.32 (0.55, 3.16)	0.528
	35–49	3.4 (2.0, 4.9)	2.3 (0.8, 3.7)	0.66 (0.30, 1.46)	0.70 (0.35, 1.39)	0.295

underestimating the reduction in prevalence that would have taken place in the absence of ART.

HIV epidemics in India are considered to be concentrated,[18] where intervention programmes aimed at high-risk populations should have significant impact in preventing infections in the general population,[19] through reduced infections in the bridging population (sex worker clients). Analysis using sentinel surveillance data from ANC populations in southern India indicated a significant decline in HIV prevalence between 2001 and 2008 among young (aged 15–24) ANC attenders in districts with high-intensity targeted preventive interventions (TIs), whereas in low TI intensity districts, changes in prevalence over time were not significant.[20] Mathematical modeling suggests that during the initial periods of TI implementation, the impact in reducing HIV infection is highest in the young (aged 15–19 years) ANC population.[21] Another analysis using data from HIV sentinel surveillance among ANC attenders has suggested a strong association between intensive targeted preventive interventions among high-risk groups and reductions in HIV prevalence at the population level, particularly in Karnataka.[22] Although we did not observe any significant changes in reported sexual behaviors (except an increase in condom use), or reductions in the prevalence of other STIs in the general population, we observed an increase in reported condom use by sex workers with their last client, from under 20% in 2003 to 83% in 2011 (Karnataka Health Promotion Trust unpublished data). Although ART use may reduce the likelihood of sexual transmission of HIV from infected individuals to their sexual partners,[23,24] the reduced HIV prevalence observed in this study among the youngest age-group (15–24) was unlikely to be due to ART use alone, unless the majority of the ART users preferentially have younger sexual partners. Since an average of 7 years age difference was found between married men and their wives, ART use might though have helped in decreasing the HIV prevalence in women aged 15 to 24.

The current study shares some of the methodological limitations of similar cross-sectional studies. Social desirability might have affected the self-reported sexual-risk behaviors examined in the study. Although nonresponse rates declined over the period, nonresponse can skew outcome estimates. The observed decline in HIV prevalence over the period might actually have been underestimated, due to the participation of more respondents from the higher risk-segment of the population in Round 2. For example, we observed that a higher percentage of participants in Round 2 reported paying for or being paid for sex than in Round 1. In addition, the possible lack of coverage of the most at-risk populations in household surveys (e.g., FSWs, men who have sex with men, prisoners, etc.) can bias HIV prevalence estimates. However, a study examining population data from various countries has suggested that nonresponse bias and noninclusion of certain populations tend to have small effects on HIV prevalence estimates obtained from household surveys.[25] We also had to substitute a few new urban blocks in the 2009 survey. However, as this was done randomly, and as the overall samples were similar, we do not believe that this would have had an important effect on the results. We unfortunately had to use different screening HIV tests, as the test used in 2003 was no longer available in India in 2009; however, the sensitivity and specificity of both tests are similar,[26,27] thus it is unlikely that this would have affected the results. As obtaining blood samples had been difficult in 2003, we also decided to offer respondents the option of DBS and urine testing for HIV in 2009. As well as having a much higher overall response rate in 2009, there was also an increase in the proportion of respondents providing a biologic sample from 60% to 77%, but this did not significantly alter the composition of respondents. In fact, in 2009 we identified a significant difference in HIV prevalence among those who provided a serum sample versus those who provided a DBS or urine sample, the latter having a higher HIV prevalence than subjects providing serum (data not shown). Consequently, if we had only tested serum samples in 2009, the observed prevalence would have been lower and the decreasing trend greater.

In summary, we believe that the wide coverage and intensive targeted HIV preventive interventions among high-risk groups, which has led to their consistent use of condoms, along with general population health education and scaled-up treatment services for the majority of HIV-infected people in the district, has had a significant impact on reducing the HIV prevalence in this general population over time. However, the use of HIV prevalence as an indicator of incidence reduction will increasingly be confounded by the widespread use of ART. A better indicator of progress in tackling the HIV epidemic in this district is the significant reduction in HIV in the younger age-groups. It is important to continue to monitor these trends, and to obtain better estimates of ART use, to model the real changes in HIV incidence and prevalence.

APPENDIX

Sample Weights

Sample weights were calculated based on design weights, adjusted for effect of different nonresponse in each primary sampling unit (these units are the villages and the urban blocks). Let R_i be the proportion of the sample that was interviewed in each primary sampling unit. Then, the sample weight w_i was calculated as follows:

$$w_i = \frac{W_{Di}}{R_i}$$

where, W_{Di} is the design weight for the ith sampling unit and is given as:

$$W_{Di} = \frac{f}{f_{1i} \times f_{2i}}$$

where, f is the overall sampling fraction, f_{1i} is the probability of selecting the ith primary sampling unit, and f_{2i} is the probability of selecting an individual from the ith primary sampling unit.

After adjustment for nonresponse and design effect, the weights were normalized so that the total number of weighted cases was equal to the total number of unweighted cases. The final weight used for each primary sampling weight is given as:

$$W_i = \frac{\sum n_i}{\sum w_i \times n_i} \times w_i$$

where, n_i refers to the actual number of cases who were interviewed in the ith primary sampling unit. Because the non-response rates for interviews and biologic samples differed considerably, we computed separate weights for biologic specimen and questionnaire items.

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