Assessment of population-level effect of Avahan, an HIV-prevention initiative in India

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Summary
Background The aim of Avahan, the India AIDS Initiative, was to reduce HIV transmission in the general population through large-scale prevention interventions focused on high-risk groups. It was launched in 2003 in six states with a total population of 300 million and a high HIV burden. We assessed the population-level effect of the first phase of Avahan (2003–08).

Methods Population prevalence was estimated by use of adjustment factors from the national HIV sentinel surveillance data obtained annually from antenatal clinics. A mixed-effects multilevel regression model was developed to estimate the association between intervention intensity and population HIV prevalence trends, taking into account differences in the underlying epidemic trends in states and other potential confounders, and to estimate the number of HIV infections averted with Avahan.

Findings 80 (61%) of 131 districts in the six Avahan states received funding from Avahan for HIV prevention, as the only or shared source. Greater intensity of Avahan, measured as amount of grant per HIV population (medians US$24–432 in the six states), was significantly associated with lower HIV prevalence in Andhra Pradesh (p=0·004), Karnataka (p=0·004), and Maharashtra (p=0·008) states; this association was not significant in Tamil Nadu (p=0·06), Manipur (p=0·62), and Nagaland (p=0·67). Overall, we estimated that 100 178 HIV infections (95% CI 25 897–207 713) were averted at the population level from 2003 up to 2008 as a result of Avahan.

Interpretation The results of our analysis suggest that Avahan had a beneficial effect in reducing HIV prevalence at the population level over 5 years of programme implementation in some of the states. With stagnating funding for HIV prevention globally, our findings support investment in well planned and managed HIV prevention programmes in low-income and middle-income countries.

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Introduction HIV prevention is crucial for the long-term control and management of the global HIV/AIDS epidemic. Results of small-scale studies have shown the potential of different strategies in HIV prevention, and evidence from cost-effectiveness studies have suggested scale-up of various prevention intervention strategies. An estimated tens of billions of US dollars have been invested in HIV-prevention programmes around the world over the past 5 years. However, national or large-scale success of HIV prevention has only been reported in a few studies, with the exception of Thailand, Uganda, and Zimbabwe. The perception that HIV prevention is challenging, with the increasing numbers of people needing antiretroviral treatment accounting for the major proportion of the global spending on HIV/AIDS and the slowing of global funding for health, makes understanding the effect of large-scale HIV-prevention programmes a necessity.

With an estimated 2·4 million people with HIV in 2009, India has one of the world’s largest infected populations. About 10 years ago, the number of HIV infections in India was predicted to rise to 20–25 million in 2010, which led to calls for an enhanced response. Subsequently, there was a rapid increase in funding for HIV control in India from US$460 million for the National AIDS Control Programme phase 2 (1999–2006) to $2·5 billion for National AIDS Control Programme phase 3 (2007–12) of which two-thirds were allocated for HIV prevention. In addition to the government’s efforts, Avahan, a high-profile HIV-prevention initiative in India, was launched in 2003 with $258 million in funding from the Bill & Melinda Gates Foundation until 2008; an additional $80 million was announced in 2009 to support the transition of this initiative to merge with the government’s HIV control effort by 2013. Avahan represents the Bill & Melinda Gates Foundation’s largest HIV-prevention support for one country.

Avahan aims to slow the transmission of HIV in the general population by raising the coverage of prevention interventions in high-risk groups—ie, female sex workers and their clients and partners, men who have sex with men, injecting drug users, and truck drivers. The interventions include peer outreach for safe-sex counselling; clinical services including treatment for sexually transmitted infections; distribution of free condoms; needle and syringe exchange; and community mobilisation and advocacy activities. Avahan operates in
four large states in south India—Andhra Pradesh, Karnataka, Maharashtra, and Tamil Nadu—and two small states in the northeast—Manipur and Nagaland. These six states were estimated to have the highest HIV prevalences in India, and a total population of 300 million, when the idea of Avahan was conceived in 2003.20-22

Although the success of Avahan in achieving high coverage of interventions has been reported,23-25 and improved coverage has been associated with stable or declining HIV prevalence among female sex workers in some districts of Karnataka,26,27 the lack of a comprehensive, randomised, prospective assessment of the programme on HIV incidence is notable.28,29 If the programme had been rolled out in a manner that enabled a phased-in randomised assessment with data gathered at baseline and follow-up, it would have allowed for comparison between intervention and control districts, all of which would eventually receive the programme. Since this did not happen, another way to estimate the effect of Avahan is through an observational study. This approach has been used to assess the effect of large-scale programmes and interventions in different settings.30-34

Assessment of the effect of Avahan on the general population through an observational study has four main challenges. First is the lack of reliable estimates of population-level HIV prevalence, both before and during the implementation of Avahan. The only available data for approximating HIV prevalence in the general population over time come from antenatal-clinic sentinel surveillance sites that have higher prevalences than those reported in corresponding population-based surveys.35-38 To estimate population prevalence from these data, correction factors need to be used.

Second, the sentinel surveillance for HIV began in 1992 in urban locations in the six high-prevalence states, and over the years has expanded to include most districts in the country.26,39-42 One consequence of the expansion is that estimates of HIV prevalence are biased for the earlier years because they are from areas with higher prevalences. The problem is less severe from 2003 onwards in the six high-prevalence states because the number of antenatal-clinic sites has not varied greatly since. Nevertheless, reductions in HIV prevalence could be exaggerated, and the estimation of the effect of HIV-intervention programmes by use of uncorrected data could be biased. Hence, the estimation of the effect of HIV interventions needs correction for the changing composition of sentinel sites over time.

Third, the heterogeneity of the HIV epidemic in the country poses a challenge in the assessment of the effect of Avahan. Not only do states differ in terms of their HIV prevalences, they also differ in terms of the stage of epidemic at any timepoint.39,40,41 The differential dynamics of the epidemic in different geographic locations need to be taken into account in the comparisons of HIV prevalence between districts.

Fourth, the most crucial challenge in the assessment of the effect of Avahan is to differentiate the change in the HIV trend that is due to the natural course of the disease versus that due to the intervention.

Despite these challenges, assessment of the effect of Avahan on the general population is crucial because it is one of the largest HIV-prevention programmes worldwide. Here, we develop an analytical strategy to address each of the four challenges to quantify the effect of Avahan on HIV prevalence in the general population of India after adjustment for potential confounders and biases in the data.

Methods
HIV prevalence by district
We used antenatal-clinic HIV sentinel surveillance data gathered between 2003 and 2008 by the National AIDS Control Organisation of India, the only available data source with a fairly complete time series. Generally, each district in these states had two antenatal-clinic sites, one in the district hospital in the headquarters city or town and another in a public hospital in a smaller town. Annual HIV surveillance in India consists of consecutive sampling of first-time attendees (aged 15-49 years) at each antenatal-clinic surveillance site per calendar year until a sample size of 400 is reached or until the end of a predefi ned surveillance period.43 The districts selected for Avahan grants generally had higher HIV prevalence and a high estimated number of high-risk groups.

The information gathered included age, education level, marital status, childbirth history, residence, and occupation.40 In our analysis, we used HIV prevalence among antenatal-clinic attendees aged 15-49 years as an indicator of trends of HIV in the general population. Although HIV prevalence estimates from antenatal-clinic attendees are higher than in population-based studies, antenatal-clinic data can be used to estimate trends in the population.39,44,45

HIV prevalence in general population
The antenatal-clinic HIV prevalence data were adjusted by use of the HIV prevalence reported in the National Family Health Survey (NFHS)46 in India that was done during 2005–06 and included a representative sample of the population of each state. HIV results were reported for 102 946 adults in NFHS. We used the estimated prevalence for men and women from NFHS for the states where Avahan was implemented to adjust the prevalence estimated from antenatal-clinic data to the general population (webappendix p 1).

Intensity of Avahan by district
We used data from the Avahan programme for the total grant provided from 2003 to 2008 per district to agencies implementing HIV prevention because the data were well documented and available for all districts and years
since 2003. Since Avahan has been implemented by several different partners, the total expenditure represents a robust and comparable measurement of the intensity of interventions in each district.

For each district, we computed the cumulative grant for each year from 2003 to 2008. We then divided this amount by the total population in each district and the estimated population with HIV in each district. The population with HIV in each district was estimated by adjustment of the median HIV prevalence among antenatal-clinic attendees in a district between 2003 and 2008 with the NFHS correction factor as noted above, and multiplying this estimate with the district’s adult population aged 15–49 years, which was estimated by use of the 2001 census and subsequent growth rates.21

Effect of Avahan on HIV prevalence
We measured the effect of Avahan on the general population by assessment of the association between HIV prevalence trends and the intensity of Avahan intervention from 2003 to 2008. We used the following multilevel logistic regression model to capture the structure of the data:

\[
\logit(p_{i,c,d,s,t}) = \beta_0 + \beta_1 \text{Age}_{i} + \beta_2 \text{Rural}_{i} + \beta_3 I_{1–5\text{years},i} + \beta_4 I_{6–12\text{years},i} + \beta_5 I_{\text{IDU},i} + \beta_6 \text{Grant}_{d,t} + \beta_7 I_{\text{IDU},d} \text{Grant}_{d,t} + \tau_{\text{Astatus}d \times t} + \alpha_c + \eta_d + \delta_s + \gamma_s \text{Grant}_{d,t}
\]

The dependent variable in this model is whether an individual antenatal-clinic attendee in site c, district d, state s, and year t tested positive for HIV or not. We included three individual-level explanatory variables—age of the antenatal-clinic attendee; whether the attendee was residing in an urban or rural setting; and education level (no education, 1–5 years, 6–12 years, and more than 12 years). Grant is the cumulative Avahan grant in US dollars, per individual with HIV living in a district d between 2003 and year t.

A dummy indicator \((I_{\text{IDU}})\), in which IDU is injecting drug user, was included to differentiate districts located in the northeastern states, where the epidemic is primarily attributable to injecting drug use, from those in the southern states, where the epidemic is primarily attributable to sexual intercourse. Avahan offered preventive programmes that targeted the different high-risk groups in the two regions. An interaction term was included to take into account the distinct types of interventions and potential effect of Avahan in the northeastern states compared with the southern states.

To capture the potential differential effect of Avahan at the state level, we incorporated the state-specific random slope \((\gamma_s)\) for the grant variable. In view of the substantial heterogeneity in HIV prevalences in different geographic locations, three random intercepts on site \((\alpha_i)\), district \((\eta_d)\), and state \((\delta_s)\) were included. To take into account the changes in the trend for HIV prevalence over time that cannot be accounted for by the other variables and which might be attributed to the natural course of the epidemic, a time-specific and intervention-specific random intercept \((\tau_{\text{Astatus}d \times t})\) was used that allows for a different epidemic trend in districts with different sources of funding for HIV-prevention programmes. We also considered alternative model specifications that are presented in the webappendix pp 4–14.

We assessed various combinations of outcome variables, intensity measures, and subsets of the data. We assessed HIV prevalence among individuals aged 15–49 years and prevalence among those aged 15–24 years (this age group was a proxy for HIV incidence). We took into consideration cumulative grants per person and per HIV population; and we computed cumulative grants between 2003 and year t (model presented here), and also between 2003 and

<table>
<thead>
<tr>
<th>Year</th>
<th>Andhra Pradesh</th>
<th>Karnataka</th>
<th>Maharashtra</th>
<th>Manipur</th>
<th>Nagaland</th>
<th>Tamil Nadu</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
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<td>13</td>
<td>10</td>
<td>16</td>
<td>9</td>
<td>4</td>
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<tr>
<td></td>
<td>Antenatal-clinic sites</td>
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<td>10</td>
<td>20</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
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<td>Women</td>
<td>5199</td>
<td>3998</td>
<td>8010</td>
<td>4005</td>
<td>1387</td>
</tr>
<tr>
<td>2003</td>
<td>Districts where antenatal-clinic surveillance was done</td>
<td>23</td>
<td>27</td>
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<td>9</td>
<td>8</td>
</tr>
<tr>
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<td>41</td>
<td>54</td>
<td>70</td>
<td>14</td>
<td>9</td>
</tr>
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<td></td>
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<td>27757</td>
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<td>27</td>
<td>35</td>
<td>9</td>
<td>8</td>
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<tr>
<td></td>
<td>Antenatal-clinic sites</td>
<td>44</td>
<td>54</td>
<td>72</td>
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<td></td>
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<td>21599</td>
<td>28801</td>
<td>5600</td>
<td>4883</td>
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<td>2006</td>
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<td>35</td>
<td>9</td>
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</tr>
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<td>73</td>
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<tr>
<td></td>
<td>Women</td>
<td>17563</td>
<td>21627</td>
<td>29151</td>
<td>5600</td>
<td>5725</td>
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<tr>
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<td>27</td>
<td>35</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Antenatal-clinic sites</td>
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<td>54</td>
<td>73</td>
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<td>19</td>
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<td></td>
<td>Women</td>
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<td>28957</td>
<td>5559</td>
<td>6790</td>
</tr>
<tr>
<td>2008</td>
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<td>27</td>
<td>35</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Antenatal-clinic sites</td>
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<td>58</td>
<td>72</td>
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<td>19</td>
</tr>
<tr>
<td></td>
<td>Women</td>
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<td>22192</td>
<td>27940</td>
<td>5541</td>
<td>7015</td>
</tr>
</tbody>
</table>

Data are numbers. *New districts were created from existing districts in Karnataka, Nagaland, and Tamil Nadu from 2004 onwards; for consistency, the districts in 2004–08 are shown as they existed in 2003.
year t–1 (model presented in webappendix). We undertook the analysis with different subsets of the data from different states. Furthermore, we assessed a district-level model in which the dependent variable was the adjusted (based on NFHS) HIV prevalence in a particular district year and covariates included several district-level characteristics, state fixed-effects, and the cumulative grants per HIV population (details are provided in webappendix pp 17–20). The district-level explanatory variables were the proportion of the population who were in the fourth wealth quintile; women aged 15–24 years; women aged 25–34 years; living in rural settings; women with less than 5 years of education; women with more than 12 years of education; in lower castes; and Muslims. We also included the log of the total population in each district as an explanatory variable.

We also assessed model validity in a simulation environment to ensure that the present model could be used to adequately estimate the effect of Avahan, the details of which are shown in the webappendix p 15.

Counterfactual analysis
To quantify the effect of Avahan in terms of the number of HIV infections averted in the general population by sex and state, we estimated counterfactual scenarios (webappendix p 3). First, we predicted HIV prevalence in antenatal-clinic attendees by state by use of the multilevel logistic regression model. Second, we replaced the value of the Avahan intensity variable with zero in the model and estimated the counterfactual HIV prevalence by state. This counterfactual prevalence simulates what would have happened, assuming that Avahan had not been implemented and that in the absence of Avahan the investments by the Government of India and other sources would have stayed at their reported levels. The difference between the actual prevalence and the counterfactual prevalence provides an estimate of the change in HIV prevalence in the antenatal-clinic attendees that can be attributable to Avahan. Third, we used the NFHS HIV prevalence in the Avahan states in men and women to obtain an adjustment factor to translate the estimated change in prevalence for antenatal-clinic attendees to an estimated change in prevalence for the general population. For each state, we took the ratio of HIV prevalence in men (and in women separately) aged 15–49 years to the predicted mean prevalence in all antenatal-clinic sites reported. We multiplied these ratios (for men and women) by the estimated change in prevalence among antenatal-clinic attendees in each state to estimate the predicted change in HIV prevalence in the general population as a result of Avahan. Fourth, we multiplied the change in prevalence for men (and women) by the size of the male (and female) population aged 15–49 years in each state to estimate the number of HIV infections averted by Avahan.

All analyses were done with R (version 2.10.1). All estimates and the code used in the analyses are available from the authors on request.

Role of the funding source
The sponsor of the study had no role in the study design, data gathering, analysis, and interpretation, or writing the report. Avahan staff provided data for the annual amounts of grants provided per district to agencies implementing Avahan interventions. The corresponding author had full access to all the data and had final responsibility for the decision to submit for publication.

Results
Table 1 provides a summary of the number of districts and antenatal-clinic sample sizes available for this study in the six Avahan states from 2002 to 2008. Figure 1 shows the distribution of districts that received funding for HIV prevention from Avahan and other sources during 2003–08 in the six states where Avahan was implemented. In 2003, 41 (31%) of 131 districts in these six states received funding exclusively from Avahan and 39 (30%) from both Avahan and other sources (mainly the State AIDS Control Societies).
The cumulative amount of Avahan grant per HIV population in each district varied greatly (webappendix p 2). Districts in Maharashtra and Andhra Pradesh received the lowest median amounts of Avahan grants per HIV-infected person ($23·8 [IQR 14·8–43·0], respectively), whereas the small northeastern states of Manipur and Nagaland received much higher amounts of funding per HIV-infected person ($230·2 [43·4–412·7] and $432·5 [368·1–720·3], respectively).

Table 2 shows HIV prevalence in 2003 in antenatal-clinic sites based on data from a comparison of districts that received Avahan support with those that did not, and that Avahan was generally initiated in districts that had higher levels of prevalence in 2003.

Table 3 shows the results from the multilevel regression model that included individual, site, district, and state level variables for the six Avahan states by use of HIV prevalence in all antenatal-clinic attendees as the outcome variable and cumulative grants per HIV population between 2003 and year t as the intensity measure. The results from the alternative model specifications were consistent with the model presented here and are presented in the webappendix pp 4–14. Within the reproductive age range (15–49 years), the odds ratio of HIV infection increased significantly by 3% (95% CI 2–4) per year of age (table 3). We noted no significant difference in the odds ratios of HIV infection for women residing in rural versus urban areas (table 3). The odds ratios for having HIV were 21% (15–26), 24% (20–29), and 31% (21–41) lower for a woman with 1–5 years, 6–12 years, or more than 12 years of education, respectively, than for a woman without education using the logistic regression model.

The coefficients for grants indicating the effect of Avahan on HIV prevalence suggested that greater intensity of Avahan was associated with a reduction in HIV prevalence (table 3). In the southern states, every $100 increase in Avahan investment was associated with a 4·4% (–5·8 to 13·8) reduction in the odds ratio of HIV infection.

Figure 2 shows the state-specific coefficients for cumulative grants per HIV population. The effect of Avahan varied between the states. The mean effect for the four southern states was –0·0023 (–0·0040 to –0·0006), whereas the mean effect for the two northeastern states was –0·0005 (–0·0015 to 0·0005). The coefficients for Andhra Pradesh, Karnataka, and Maharashtra indicated
that Avahan had a significant effect on reducing HIV prevalence at the population level in these three states (figure 2). The estimated effect of Avahan in the other three states was not significant (figure 2).

Figure 3 shows the actual and estimated counterfactual HIV prevalences in the six states. The HIV prevalence would have been higher without Avahan, most notably in Andhra Pradesh and Karnataka, and the rate of decline in HIV prevalence would have been slightly slower.

Table 4 shows the actual decline in HIV prevalence, the estimated counterfactual decline in HIV prevalence, and our estimated contribution of Avahan to the overall

**Figure 3: Actual and counterfactual HIV prevalence in the six Avahan states**

<table>
<thead>
<tr>
<th>State</th>
<th>Reduction in HIV prevalence from 2003 to 2008</th>
<th>HIV infections averted (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual* Counterfactual† Associated with Avahan‡ Women Men Women and men</td>
<td></td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>16.6% 9.5% 7.1% 12 893 (4188–26 052) 21 124 (6927–43 089) 34 217 (11 115–69 141)</td>
<td></td>
</tr>
<tr>
<td>Karnataka</td>
<td>33.9% 21.3% 12.7% 15 791 (4659–30 873) 25 893 (7640–50 624) 41 683 (12 299–81 496)</td>
<td></td>
</tr>
<tr>
<td>Maharashtra</td>
<td>47.1% 44.7% 2.4% 4921 (892–10 789) 8783 (1591–19 255) 13 704 (2483–30 043)</td>
<td></td>
</tr>
<tr>
<td>Manipur</td>
<td>33.2% 27.3% 5.9% 290 (0–1262) 619 (0–2691) 909 (0–3954)</td>
<td></td>
</tr>
<tr>
<td>Nagaland</td>
<td>44.8% 40.7% 4.1% 250 (0–1121) 573 (0–2556) 823 (0–3686)</td>
<td></td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>51.4% 47.6% 4.4% 5247 (0–11 508) 3596 (0–7886) 8842 (0–19 394)</td>
<td></td>
</tr>
<tr>
<td>Total NA</td>
<td>NA NA NA 39 392 (9739–81 604) 60 786 (16 158–126 109) 100 178 (25 897–207 713)</td>
<td></td>
</tr>
</tbody>
</table>

NA=not applicable. *Refers to the overall relative reduction in HIV prevalence in the general population from 2003 to 2008, using 2003 as the baseline. †Refers to our estimated reduction that would have occurred if Avahan had not been implemented. ‡Estimated as the difference between the actual and the counterfactual prevalences.

**Table 4: Reduction in HIV prevalence in the six Avahan states and infections averted from 2003 to 2008**
decline from 2003 to 2008. During the period of observation, there were substantial reductions in HIV prevalence across all six states from 2003 to 2008, ranging from 16.6% in Andhra Pradesh to 51.4% in Tamil Nadu, which were largely attributable to the natural course of the epidemic. In terms of the contribution of Avahan to the overall reduction in HIV prevalence in the general population, there was huge variation between the states. The largest effect was noted in Karnataka, where Avahan was associated with a 12.7% decline in HIV prevalence (table 4).

Overall, 100,178 HIV infections were averted as a result of Avahan, with 61% in men (table 4). Notably, the estimated number of infections averted was associated with a large 95% CI, showing the uncertainty associated with the variables in the model and the underlying data. In the large southern states, the estimated number of infections averted was highest in Karnataka and Andhra Pradesh. The estimated numbers of infections averted were much larger in the northeastern states, with 95% CI overlapping zero.

With the district-level model that did not use individual-level and site-level variables, the overall estimate was 175,187 infections (95% CI 77,137–292,935) averted with the largest effects seen in Karnataka and Andhra Pradesh (webappendix pp 17–20). Overall, the findings from the two models are consistent and suggest that even though Avahan seems to be associated with significant numbers of infections averted, the actual estimate of the magnitude of the effect has a lot of uncertainty associated with it.

Discussion

Overall, Avahan had a beneficial effect at the population level, which was heterogeneous in the six states where it was implemented. We estimate that implementation of Avahan averted 100,178 HIV infections at the population level during its first phase of operation from 2003 to 2008, and that the programme was most successful in the states of Andhra Pradesh and Karnataka, with varying success in the other four states (table 4). The reduction in HIV prevalence in the general population up to 2008 associated with Avahan was 2.4–12.7% of the 2003 level in the six states, whereas the overall HIV prevalence declined by 16.6–51.4% during the same period. In view of the findings of previous ecological and modelling studies, our findings are credible (panel).58

There is some evidence to suggest an association of large-scale prevention efforts with HIV decline at the population level in a few generalised HIV epidemics in sub-Saharan Africa.59,60 However, evidence showing the effect of large-scale prevention efforts in reducing HIV at the population level in non-generalised HIV epidemics, such as the one in India, is sparse. The reason is largely attributable to the lack of available evidence to undertake rigorous assessments of the effects of such programmes.

By use of methods to adjust for the different stages of the HIV epidemic and other potential confounders, we noted that the Avahan prevention efforts were associated with a small but significant reduction in HIV prevalence at the population level in three of six states—namely, Andhra Pradesh, Karnataka, and Maharashtra, with larger effects in the first two states. The prevention efforts of Avahan focused on high-risk groups, namely female sex workers and their clients, men who have sex with men, injection drug users, and truck drivers, whereas we were estimating the effect of the programme on HIV prevalence in the general population. On the basis of the types of interventions that have been implemented, we would expect the effect of Avahan on men in the general population to be notable sooner than in women because the effect of interventions aimed at female sex workers and their clients, men who have sex with men, and truck drivers would manifest in men first. The results of our analysis suggest that 61% of the HIV infections averted up to 2008 by Avahan were in men. Overall, the reduction in HIV prevalence at the population level in the six states over a fairly short period of programme implementation is encouraging (table 4).

Panel: Research in context

Systematic review

We searched PubMed and Google Scholar with search terms “Avahan” and “India AIDS Initiative” and obtained relevant information and data directly from the Avahan initiative. The implementation of Avahan has generally been reported to be successful.16,23–25 A 56% reduction in standardised antenatal-care HIV prevalence was reported in an ecological analysis in 18 districts in Karnataka in which Avahan was implemented from 2003 to 2007 compared with 5% in nine districts in which Avahan was not implemented.46 Although the HIV prevalence in the districts at the start of the study was included in the analytical model, the analysis did not adjust adequately for the different stages of the epidemic in Avahan districts, which had higher starting HIV prevalence than did the non-Avahan districts. Boily and colleagues48 who undertook a mathematical modelling analysis noted that this big reduction in HIV prevalence among antenatal-clinic attendees could not be entirely attributed to Avahan.

Interpretation

Our analysis suggests that Avahan had a significant beneficial effect on population-level HIV prevalence in the states of Andhra Pradesh, Karnataka, and Maharashtra, but not in Tamil Nadu, Manipur, and Nagaland. The HIV prevalence in the general population between 2003 and 2008 was reduced with the implementation of Avahan, ranging from 2.4% in Maharashtra to 12.7% in Karnataka. We estimate that in the six states, Avahan prevented 100,178 HIV infections (95% CI 25,897–207,713) at the population level from 2003 to 2008. This beneficial effect of Avahan is encouraging but the heterogeneity in the effect across the states indicates the need for better understanding of which aspects of Avahan have been successful for adoption on a larger scale.
Nevertheless, the estimated effect of Avahan is very heterogeneous across the states where the programme was implemented. Because Avahan’s business model encouraged local adaptation and innovation in its implementation, we need to understand the contributors to success in states like Andhra Pradesh and Karnataka, and identify practices that worked well in these settings and that could be applied to other settings too. This understanding is particularly important because reports about the coverage and quality of interventions suggest that implementation of the programme has generally been successful in all states.31-35 Since Avahan has entered its second phase of implementation, during which activities will be transferred to the Government of India, understanding which types of interventions and which modes of delivery of these interventions have worked is important so that they can be adopted and adapted during this next phase of the programme. The lessons learned from Avahan are important for other countries that are also embarking on HIV prevention efforts. The heterogeneous performance in Indian states suggests that even though well planned HIV prevention efforts can be effective, careful consideration needs to be given to which types of interventions work best and in what settings.

In view of the limitations of our analysis, our findings need to be interpreted with caution. First, in our model, we were not able to include variables that measured the intensity of HIV-prevention interventions other than Avahan, such as those funded by the Government of India. Our simulations suggest that exclusion of the intensity of these interventions in the models could have resulted in a slight overestimation of the effect of Avahan (webappendix p 16). If these data become available, the effectiveness of Avahan and the prevention efforts jointly supported by the Government of India should be assessed. Second, our assessment was done retrospectively, relying on available data. Although we have tried to control for all effects that we believe could affect the measurement of the effect of Avahan, our model might not have fully controlled for all potential confounders, including selective programme placement, which could affect our findings. Third, we estimated the effect of Avahan on the general population, but the trends in HIV prevalence come from data from sentinel surveillance antenatal-clinic sites, which were the only available data over time but were not necessarily fully representative of the adult population. Although we have tried to control for this by adjusting our estimates by use of the NFHS HIV prevalence estimates, we might not have fully controlled for the bias introduced by the sentinel surveillance antenatal-clinic data. Furthermore, the NFHS estimates are only available for 2005–06, and so in our analysis we have applied the same adjustment factor for 2003–08, thereby making the assumption that the relation between antenatal-clinic prevalence and population-level prevalence of HIV was constant for men and women during this period. Also, high-risk groups are probably underestimated in the population-based NFHS sample and that might contribute to an underestimation of overall adult HIV prevalence in the six states. We investigated this possibility further by using alternative estimates of overall adult HIV prevalence in 2006 that tried to adjust for the under-represented high-risk groups49 to estimate the HIV infections averted by Avahan, and noted that this estimate was 113 387 (95% CI 26 602–235 634). The estimates of infections averted based on the two methods are consistent.

These limitations draw attention to the need for large-scale health intervention programmes, such as Avahan, to invest early in the study-design stage to enable data gathering that would allow for prospective assessments of the effect at the population level. Investments in robust prospective assessments are crucial to increase the knowledge-base of what does and does not work in large-scale programmes, especially in low-income and middle-income countries.

Although large reductions in HIV prevalence at the population level, with Avahan interventions focused on high-risk groups, would take a long time,6 the 2.4–12.7% relative reduction in HIV prevalence that was attributable to Avahan intervention in different states in our analysis seems plausible. The foundation laid by the Avahan intervention effort could give progressively higher effect with time, in which case its actual effect, taking into account the long-term benefits, could have been underestimated in our analysis. This analysis extends to 2008, which is the latest year for which data were available from the antenatal-clinic sentinel surveillance sites. It is possible that over the past 3 years the effect of Avahan has changed because the programme has been in effect now for a longer time.

The estimated reduction in HIV prevalence per dollar spent, adjusted for the number of individuals with HIV, varied between states. Of the large southern states, this coefficient was smallest for Tamil Nadu. Since this state was the first in India to launch HIV-prevention efforts,6 and already had fairly low HIV prevalence when Avahan was implemented, the smaller coefficient associated with reduction in HIV prevalence could be accounted for by greater difficulty in reducing HIV prevalence when the prevalence is already low. The small coefficient associated with HIV decline in the northeastern states, where the HIV transmission is largely attributable to injecting drug users, could be related to the challenges in efforts to implement HIV prevention in a difficult hilly geographic terrain, or the higher complexity of HIV transmission in these states. Understanding why some states or districts have achieved greater reductions at lower costs is crucial for the next phase of the programme and should be studied in detail.

The findings of this study have substantial implications for the National AIDS Control Programme of India. There has been some scepticism about the effect
of Avahan. Initial calculations suggest that with 100 178 HIV infections averted with $258 million spent up to 2008 by Avahan, the cost per HIV infection averted is in a similar range to that with the publicly funded HIV prevention effort in Andhra Pradesh in 2005–06, if, in addition to grant payouts to implementing partners, all indirect planning and administration costs are included.6

In conclusion, the results of our analysis suggest a strong association between the large-scale Avahan HIV prevention programme in India and reductions in HIV prevalence at the population level, which is the ultimate goal of the programme.11 Further detailed studies of Avahan, which are in progress, would be useful in helping to understand the pathways through which this effect manifests12 and which methods of intervention delivery have been effective. The findings of this study provide support for investment in well planned and managed HIV-prevention programmes in other countries too. This support has particular significance because funding for HIV treatment has increased heavily over the past 5 years while funding for prevention has stagnated, resulting in a larger portion of the global HIV/AIDS funding being spent on treatment than on prevention.6,7 Substantial reduction in HIV transmission with antiretroviral treatment has been suggested.52 However, inadequate behavioural prevention and other methods of prevention of HIV will lead to an increase in the requirement for antiretroviral treatment, which would not be sustainable in the long term. Therefore, demonstration of the population-level beneficial effect of preventive efforts, such as the Avahan initiative in India, has global significance for HIV control strategies.

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