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Spatial modeling of HIV prevalence among the clients of female sex workers in Tamil Nadu, south India

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***Background & objectives*: The spread of HIV infection is diverse and unpredictable and is often associated with the geographic factors. The objectives of this study were to identify significant predictors of HIV prevalence using spatial modeling and to produce a smoothened map of predicted values of HIV prevalence using the geographic information system (GIS) technology.**

***Methods*: A large cross-sectional survey Integrated Behavioural and Biological Assessment (IBBA) for 1203 clients of female sex workers (FSWs) from three districts (Chennai, Madurai and Salem) of Tamil Nadu, India during October and December 2006, were studied. The survey focused on a number of social, demographic, behavioural and biological indicators and spatial parameters that could be associated with the risk of HIV infection. These were used in a multivariate logistic regression model to predict the probability for positive cases of HIV among the clients of FSWs. To interpolate the prevalence levels across Tamil Nadu and to predict values for areas not covered in the sampling, the study area was divided into 26 clusters or polygons. The predicted HIV probability (prevalence) was aggregated to cluster/polygon level. For interpolation, the inverse distance weighting method (IDW) was used in the GIS methodology.**

***Results*: Literate clients, first sex at the younger age of 20 yr or less, clients not undergone HIV testing and who were sampled at the proximity of major roads and busy stations were at greater risk of being infected with HIV in Tamil Nadu. The smoothened surface obtained using GIS methodology showed the wide regional variation of predicted value of HIV prevalence in Tamil Nadu.**

***Interpretation & conclusions*: This study shows significance of the emerging GIS technology in the field of HIV/AIDS. The significant predictors of HIV infection and the regional variation of predicted values of HIV prevalence could accomplish better understanding and planning for the health officials in future.**

Key words Clients of FSW - HIV - spatial modeling - Tamil Nadu

The State of Tamil Nadu in southern part of India is considered to be a trail-blazer in India in terms of combating the HIV infection[1]. The rapid growing of the epidemic is diverse and the pattern of the spread is still in mute stage. The spread of HIV infection is often associated with geographic factors such as

population mobility, accessibility and proximity to high transmission or urban areas and geographic distribution of populations, which are at greater risk of HIV infection[2]. Geographic information system (GIS) technology is a tracking tool, which enables to analyze the geographic spread of the disease, which identifies the associated risk factors and spatial patterns that might otherwise go concealed. Research on HIV prevalence in India utilizing GIS technology is meager. The benefits of the application of geographic information systems in public and environmental health have been stressed using an example of AIDS data[3].

In a population based survey in Kenya, the spatial indicators (the distance to major roads and the distance to the coast of Lake Victoria) were generated based on the place of residence of the respondents, since they considered these spatial indicators as measures of proximity to trade and migratory routes[2]. They found both the indicators as significant predictors of HIV prevalence in Kenya. In a study in North Carolina, USA, smoothened maps were produced for chlamydial infection, gonorrhoea, syphilis, and HIV infection and clustering of cases was observed in the primary focal areas[4]. In the population based surveys in Cameroon, Kenya and Tanzania, the smoothened surface estimates of HIV prevalence also showed a large sub-regional variation in each of the countries[5].

The present study was undertaken with the objectives to identify significant predictors of HIV using spatial modeling and to produce a smoothened map of predicted values of HIV prevalence of Tamil Nadu, using GIS.

Material & Methods

Study type: A large cross-sectional Integrated Behavioral and Biological Assessment (IBBA) survey for clients of female sex workers (FSWs) in the three districts of Tamil Nadu, south India was carried out by India AIDS initiative, the *Avahan*. The survey collected information from 1203 clients from three districts of Tamil Nadu namely Chennai, Madurai and Salem (406, 401 and 396, respectively) during October and December 2006.

A number of social, demographic, behavioural and biological indicators associated with the risk of HIV infection were studied. The inclusion of variables to multivariate logistic regression model was based on the significant associations of individual factors with the positivity of HIV. The 18 variables included in the model were age, education, occupation, current marital status, most common place of pickup of FSWs, age at first sex, age at first paid sex, number of different sex partners in the last month, number of sex acts with FSWs in the last month, ever had anal sex, consistent condom usage, ever had blood transfusion, symptoms of sexually transmitted infections (STIs) in the last one year, perceived risk of getting HIV/AIDS, ever undergone HIV testing, ever heard of anti-retroviral therapy (ART), media exposure, and presence of reactive syphilis.

The four spatial factors included in the model were whether the clients travelled outside the current place of stay (last year), whether bought sex from the places travelled, the distance from the place from where the clients were sampled to major roads/ national highways (constructed using the Google Maps distance calculator) and whether the client sampled site belonged to busy networking places like bus or railway station.

A client of FSW is defined as any male aged 18 yr or older but not more than sixty years, recruited at solicitation points of FSW, who had also paid for sex to a female within the past month of the survey.

Sampling strategy: As male clients of FSWs are a mobile group and not fixed to any venue at any given time, a time location cluster (TLC) sampling approach was used to capture different types of clients within a sampling district. The sampling universe included different types of solicitation sites such as street-based sites, home-based sites, brothels/brothel areas and lodges, as primary sampling units.

The target sample size was 400. The sample sizes were calculated to detect changes in key behavioural determinants between survey rounds within districts, *i.e.* consistent condom use with all commercial partners in the past one month for clients of FSW. The size of 400 allowed for the detection of an absolute difference of 15 per cent or more from the assumed value of 50 per cent, with 95% confidence interval and 90 per cent power. A design effect of 1.7 was assumed for cluster sampling.

The selection of respondents was done through a two-stage cluster sampling procedure. The TLCs were selected by systematic random sampling (without replacement) by probability proportional to the estimated measure of size of FSW. The number of FSWs in a TLC was considered as a proxy to size of clients. In the selected clusters (TLC), respondents were chosen through simple random sampling methods. A total of 3202 clients of FSWs were identified and approached for participation in the study in three districts of Tamil

Nadu. Of these, 1206 completed both behavioural and biological components. The response rate for Chennai was 42 per cent, Madurai 35 per cent and Salem 36 per cent, and the overall response rate was 36 per cent. Qualitative examination revealed that the main reasons for refusal were largely related to lack of time, as clients were in the midst of work or rushing for important personal activities, could not spare time to participate, or feared of being recognized as having gone to sex workers. In homes and brothels, refusals were also due to the unwillingness of clients to give urine samples before sex with the FSWs[6]. The methodology, laboratory process, weighting procedures, ethical issues, consent process, *etc*. are discussed in detail elsewhere[6,7].

Data analysis: The social, demographic, behavioural and biological indicators together with the spatial indicators were used in a multiple logistic regression model to predict the probability of HIV positive status among the clients of FSWs, SPSS 14 (USA) complex module was used. The model was assessed for confounding, interaction, and multicollinearity. Receiver operating characteristic (ROC) curves were used both to define the optimal cut-off points and to evaluate the ability of the logistic model to distinguish between HIV positivity and negativity[8-10].

For the spatial modeling, the study area was divided into 26 clusters or polygons; Chennai was divided into 10 clusters based on the zonal boundaries, Madurai in seven clusters and Salem in nine clusters based on *Taluk* level boundaries. The predicted HIV prevalence was aggregated to cluster/polygon level. The latitude and longitude values of the centroids of polygon were identified using the Google earth. The inverse distance weighting (IDW) method was used to interpolate the prevalence levels across Tamil Nadu using ArcGIS[11] spatial analyst software to predict values for unmeasured locations. For each predicted value, a minimum of 2 and a maximum of 12 surrounding points (default value) were used. The result was the smoothened surface of Tamil Nadu with predicted values of HIV prevalence, which took into account various spatial, social, demographic, behavioural and biological indicators, included in the model.

Results

Multiple logistic regression analysis indicated that literacy (OR 2.68; 95% CI: 1.10- 6.51), first sex at the younger age 20 yr or less (OR 2.99; 95% CI: 1.13-7.92), ever undergone HIV testing (OR 3.80; 95% CI: 1.21-11.88), clients with reactive syphilis serology (OR 0.15; 95% CI: 0.05-0.45), clients who were sampled in a proximity of distance of less than a kilometre from major roads (OR 3.82; CI: 1.14-12.87) and the clients sampled location happened to be bus or railway station (OR 2.27; CI: 1.01, 5.11) were significant predictors of HIV seropositivity of clients. (Table).

Fig. 1 depicts the smoothened map of HIV predicted prevalence estimates for Tamil Nadu including regions not measured in the survey. The map shows the regional variation of Tamil Nadu with higher HIV prevalence among clients of FSWs sampled around the central part of Tamil Nadu decisively in Salem. Fig. 2 (clipped from Fig. 1) shows the predicted value of HIV prevalence for the surveyed districts in Tamil Nadu. The analysis showed considerable variation even within districts

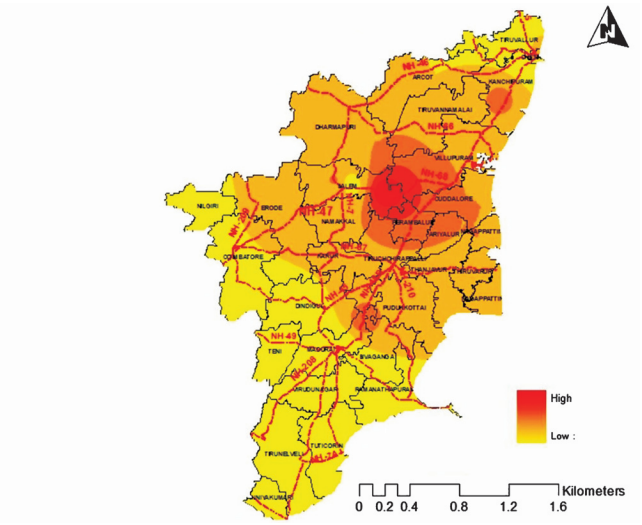

Fig. 1. Spatial mapping of predicted HIV prevalence of clients of FSW, Tamil Nadu, 2006.

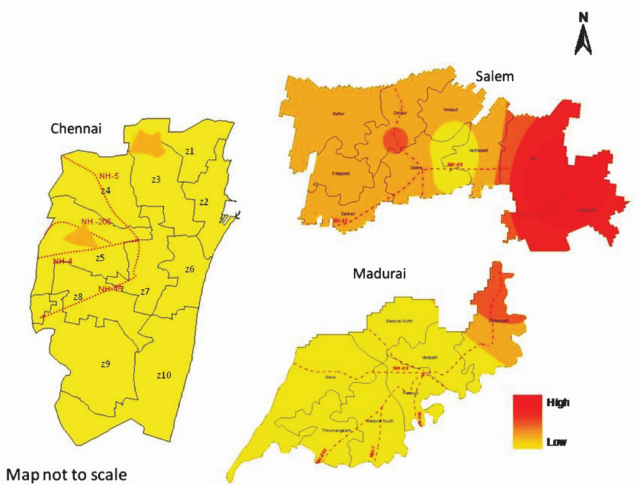

Fig. 2. Geographic distribution of predicted value of HIV prevalence of clients of FSWs by the districts surveyed, Tamil Nadu, 2006.

Table. Factors associated with the HIV infection in clients of FSWs, Tamil Nadu, 2006

Characteristics	N	Adjusted OR (95% CI)	*P* value
Socio-demographic characteristics			
Age (yr)			
18-29	594	1	
≥30	574	0.79 (0.28, 2.19)	0.647
Literacy			
Illiterate	235	1	
Literate	933	2.68 (1.10, 6.51)	0.030
Occupation			
Bus/Truck drivers/helpers /transport workers	118	1	
Unemployed/student	110	0.27 (0.01, 5.13)	0.385
Agri labour/ Non-agri/casual labour/cultivator	541	1.97 (0.44, 8.77)	0.375
Skilled / semi-skilled labour	283	0.53 (0.08, 3.68)	0.520
Petty or large businessman / shop owner/others	116	0.50 (0.06, 4.53)	0.536
Current marital status			
Currently married	597	1	
Not married	493	1.64 (0.58, 4.61)	0.350
Divorced /widowed/separated	78	1.70 (0.50, 5.79)	0.399
Sexual behaviour			
Most common place of pick of FSWs			
Non public places	325	1	
Public places	843	1.68 (0.71, 3.97)	0.237
Age at first sex (yr)			
≥21	402	1	
18-20	766	2.99 (1.13, 7.92)	0.027
Age at which started to have paid sex (yr)			
>22	658	1	
≤22	510	1.35 (0.61, 2.98)	0.455
No. of different FSW partners (last month)			
1	453	1	
≥2	715	0.78 (0.31, 2.00)	0.611
No. of sex acts with FSW (last month)			
1-3	680	1	
≥4	488	1.02 (0.39, 2.64)	0.969
Ever had anal sex			
No	1066	1	
Yes	102	0.91 (0.26, 3.25)	0.890

Contd....

Characteristics	N	Adjusted OR (95% CI)	*P* value
Consistent condom use with FSWs			
Yes	386	1	
No	782	1.17 (0.45, 2.99)	0.750
Ever given blood transfusion			
No	1085	1	
Yes	83	1.39 (0.36, 5.29)	0.631
Having any STI symptom past one year			
No	1103	1	
Yes	65	0.42 (0.10, 1.73)	0.228
HIV perception			
Feel at risk to be infected with HIV/AIDS			
Yes	283	1	
No	885	1.39 (0.55, 3.54)	0.487
Ever taken HIV testing			
Yes	94	1	
No	1074	3.80 (1.21, 11.88)	0.022
Ever heard of ART			
Yes	61	1	
No	1107	2.74 (0.60, 12.46)	0.192
Heard/seen /read any advertisement/messages on condoms/STIs			
Yes	1059	1	
No	109	0.63 (0.20, 1.78)	0.430
Biological parameters			
Syphilis			
Negative	1122	1	
Positive	46	0.15 (0.05, 0.45)	0.001
Spatial factors			
Traveled outside the current place of residence last year			
No	478	1	
Yes	690	1.03 (0.35, 3.00)	0.955
Bought sex from FSWs at places traveled (past year)			
No	718	1	
Yes	450	1.77 (0.53, 5.89)	0.349
Distance from the site to major roads (km) (National Highways)			
Farthest quartile (5+)	268	1	
Third quartile (2 - <5)	344	0.91 (0.20, 4.08)	0.910
Second quartile (1- <2)	268	2.57 (0.72, 9.23)	0.148
Nearest quartile (<1)	288	3.82 (1.14,12.87)	0.030

Contd....

Characteristics	N	Adjusted OR (95% CI)	*P* value
Whether the site belongs to busy networking places like bus/ railway station			
No	810	1	
Yes	364	2.27 (1.01, 5.11)	0.047

ART, anti-retroviral therapy; STI, sexually transmitted infection

surveyed as shown by the subsetted figure. Eastern part of Salem, northern part of Madurai and Chennai showed a higher predicted value of HIV prevalence.

Discussion

In the present study literate clients and those involved with sexual activities at the younger ages were found to be at greater risk of acquiring HIV infection. Among the clients who came forward to participate in the survey, 72 per cent had their first sex at the age of 21 yr or less and among them 55 per cent had their first paid sex by 21 (data not shown). In an urban Malawi study, one of the sexual behaviours that was associated with HIV risk was early age of sexual debut (before 15 yr) among men/women[12]. Early age of sexual activity (median age 19 yr for males) was found to be a risk factor for acquiring HIV infection and other sexually transmitted infections (STIs) in a rural Zimbave study[13]. Sex education to youngsters on the evil of early sexual activities would directly play a substantial role in reducing risk of HIV infection to a greater extent.

Only one fifth of the participants who had tested positive for HIV in the current study had reported as had undergone HIV testing earlier. This finding suggests that 4 out of 5 HIV positive clients were unaware of their HIV serostatus. This is a major concern and has considerable implications on HIV transmission in general population. In a study done in India among adults in a high HIV prevalence district[14], two thirds of the HIV positive participants reported that they had not undergone HIV testing earlier. Campaign of universal HIV testing in health care settings and adopting precautionary measures during sexual activities among HIV infected clients can reduce the spread of HIV infection to a greater extent.

The spatial co-ordinates were based on the place where the clients were sampled. On the other hand when the client's place of residence was examined, it was observed that for 29 per cent of the clients, both the place of residence and the place at which they were sampled were the same. Seventy one per cent of the clients belonged to the neighbourhood location or district of radius less than 50 km and a negligible percentage of the clients belonged to other States (longer distance) (data not shown). This showed that there was not much difference in distance between the place of survey and place of residence of clients in Tamil Nadu. They were highly mobile at the time of survey identified near busy road and rail networks. Clients of FSWs in Tamil Nadu were not only the HIV carriers to the neighbourhood wherein they were sampled but also to the places where they reside and the neighbourhood. In a study in a Sub-Saharan African setting an increased mobility of individuals through education and work turned out as significant determinants of the risk of contracting HIV/AIDS[15]. In another study an increased level of education and some specific occupational categories and a disproportionate number of male migrants searching for job were significant predictors of sex workers' contacts[16]. The above findings were substantiated circuitously by the present study, since the literate clients and clients sampled at the proximity of major roads and busy station turned out to be significant predictors of HIV positivity. Focused targeted intervention among the clients in the main roads/national highways and bus/ railway station would decrease the HIV transmission to a greater extent.

The smoothened surface map showed regional variation in the prevalence of HIV in Tamil Nadu. The pattern with the high prevalence of HIV infection was observed in the central part. The central region of Tamil Nadu with a few patches of very high risk of HIV infection and the regions, which show a medium risk of prevalence of HIV, are also at greater risk of spreading the HIV infection.

Smoothened maps were produced to estimate the inter-urban differential of HIV prevalence among pregnant women in a city of Brazil[17]. They observed areas with higher HIV prevalence in pregnant women circled in the center of the city. The primary advantage of

using such maps was also discussed. The 'smoothened surface estimate' showed the regions at a greater risk of HIV infection in Tamil Nadu as intact and the clipped surface as sub district level. This can help to improve the understanding and better planning, prevention and control measures for health officials.

Incidence is a better measure for this kind of predictions than prevalence, although in the case of HIV, it is difficult to get incidence hence prevalence was used. The spatial co-ordinates for the "clients sampled location" were obtained using the address details on Google Earth, which was time consuming. Hand held GPS would have given the exact location readily. If the data were found to be highly confidential then techniques like geo-masking (shifting the co-ordinates of all the data to a fixed distance) can be used for geo-referencing the data. This would augment to build complex spatial models.

If more number of districts (probably at sub *Taluk* level) with wide coverage over the State was surveyed, then the centriod points would have been much finer and the HIV high prevalence pockets would have been pinpointed precisely for remedial measures.

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