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RESEARCH ARTICLE

A REVIEW OF THE HIV/AIDS EPIDEMIC IN KARNATAKA

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ABSTRACT

This study has explored the geographical and demographic patterns of transmissibility of HIV/AIDS in Karnataka of India, using yearly epidemiological time series, made available by monitoring and evaluation unit, Karnataka State AIDS Prevention Society. We identified spatial variations of the transmissibility of HIV by age and sex using various statistical methods. The Games-Howell Post Hoc analysis created four homogeneous subgroups. Northern Karnataka is more severally affected by HIV than southern Karnataka, in this region the commercial sex workers networks is more intense than other part of Karnataka. In addition in northern Karnataka the HIV epidemic tends seems to be more advanced in rural than in urban areas.

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INTRODUCTION

Since the discovery of the first HIV/AIDS case more than three decades ago, enormous progress has been made in understanding, treating, and preventing the infection. Globally, an estimated 35.3 (32.2–38.8) million people were living with HIV in 2012. There were 2.3 (1.9–2.7) million new HIV infections globally, showing a 33% decline in the number of new infections from 3.4 (3.1–3.7) million in 2001. At the same time the number of AIDS deaths is also declining with 1.6 (1.4–1.9) million AIDS deaths in 2012, down from 2.3 (2.1–2.6) million in 2005. India has the third highest number of estimated people living with HIV in the world, after South Africa and Nigeria (UNAIDS, 2013). According to the HIV Estimations 2012, the estimated number of people living with HIV/AIDS in India was 20.89 lakh, with an estimated adult (15-49 age group) HIV prevalence of 0.27% in 2011. The first AIDS case in India was detected in 1986 and since then HIV infection has been reported in all states and union territories (Solomon *et al*., 2004). The spread of HIV in India has been uneven. Although much of India has a low rate of infection, certain places have been more affected than others. HIV epidemics are more severe in the southern half of the country and the far north-east. The highest estimated adult HIV prevalence is found in Manipur (0.78%), followed by Andhra Pradesh (0.76%), Karnataka (0.69%) and Nagaland (0.66%). Karnataka, with 30 districts and a population of 61 million, is one of the four large states in South India facing a relatively advanced HIV epidemic, with the adult HIV prevalence in some districts exceeding 1%. According to national estimates in 2012, Karnataka state had an HIV-prevalence of 0.52% with 0.21 million persons living with HIV (Dodderi *et al*., 2014).

Within Karnataka, HIV prevalence varies substantially across districts, ranging from just over zero in some districts to upwards of 3% in others (KSAPS, 2004). The present article describe the trend and pattern of prevalence of HIV in the general population in Karnataka and different districts of Karnataka for the period 2002 to 2012 by using different statistical tools and further discuss the implications for HIV prevention programmes.

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MATERIALS AND METHODS

This study was carried out by using secondary data of HIV for Karnataka and different districts of Karnataka. The sample population included 83,06,355 patients tested and seropositive of HIV in Karnataka. The data for the study was collected from different KSAPS reports over a period of 10 years from 2002 to 2012. The data present in the electronic format was abstracted from the Microsoft Excel database and imported into R-programme, SPSS and GPIS statistical software's and analysed using different statistical methods. The confidence interval (CI) for the positive cases and p values were calculated using Graph Pad in Stat statistical software. Further, One-Way ANOVA was applied to the variation between all districts of the Karnataka. In particular we used Lorenz curves and the corresponding Gini coefficients to formally analyse the three different type of samples (Integrated Counselling and Testing Centre (ICTC) and Ante Natal Care (ANC)) variability of HIV/AIDS in Karnataka. The Lorenz curve is a graphic representation of the distribution of some commodity, such as income, against the uniform distribution that represents equality, such as proportion. The Gini coefficient is a summary measure for the Lorenz curve; it allows for comparison of concentration levels without graphic displays. If the Lorenz curves of multiple diseases do not cross, then an ordering of the concentration of the disease will be the same as an ordering of the Gini coefficients. In addition, Gini coefficients can be used to assess concentration levels across studies. The Gini coefficient measures twice the percentage of the total area above the diagonal, which is encompassed by the Lorenz curve, and rages from 0 to 1 (Lee, 1997; Brown, 1994; Roxanne *et al*., 2005). A Gini coefficient of 1 indicates concentration of all disease in a single sample tract, whereas a value of 0 indicates identical rates in all sample tracts. For HIV/AIDS, the three different type of samples present a special problem in applying Lorenz curves, which are usually applied to variables that can be broken down into fractions of whole. Detailed methodological information on the use of Lorenz curves and Gini index, including motivation interpretation and computation, is reported by Lee (1997). To plot the Lorenz curve, the observations are first either arrayed individually or grouped in class intervals according to the appropriate independent variate. Then the cumulative percentage of number of HIV positive persons (Y_i) is plotted against the cumulative percentage of number of persons tested for HIV positive (X_i). For comparison a diagonal line is drawn at 45^0 to show the condition of equal distribution. The Gini concentration ratio measures the proportion of the total area under the diagonal that lies in the area between the diagonal and the Lorenz curve. We estimate this area via the unbiased Gini coefficient (Dixon *et al*., 1987; Mills and Zandvakili, 1998; Demarc *et al*., 2010), given by $G = \frac{1}{n-1}\left[\frac{\sum_{i=1}^{n}(2i-n-1)x_i}{\sum_{i=1}^{n}x_i}\right]$ where x_i is the relative percentage of HIV positive persons within a given time, '*i*' is the rank of the time according to the relative percentage of HIV positive persons within a given time, and *n* is the total number of class intervals or time points.

RESULTS AND DISCUSSION

Data was collected and analysed from a total of 83,06,355 patients who had tested during the period ten years from 2002 to 2012. Out of which 3,08,223 found to seropositive for HIV antibodies with seropositve rate 3.71% (0.036-0.037) (Table 1). A year wise analysis shows that in 2002 only 25,858 patients are tested for HIV. Further, the number of patients tested for HIV increased. The HIV seropositive rate for HIV increased from 14.91% (CI 0.144-0.153) in 2002 to 21.22% (CI 0.208-0.216) in 2003 and from the year 2004 there has been a gradual decrease from 20.71% (CI 0.204-0.210) to 1.9% (CI 0.031-0.032) in 2012 (Table 2). Also the year wise seropositve rate is tested by using the Chi-square tests and the results show that there was a significant difference seropositive and seronegative rates.

Table 1. Details of patients tested and HIV positive in Karnataka, India for the period 2002 to 2012

Total Number of Tested patients	Total Number of HIV positive Patients	Percentage of Seropo sitivity ((5% CI)
83,06,355	3,08,223	3.71 (0.036-0.037)

Further, the number of patients tested for HIV was studied separately as male and female. The results of the study reveal that the seropositive rates for male were more that of female for the study period from 2002 to 2012. The seropositve rates for males showed an increase from 16.26% (CI 0.156-0.168) in 2002 to 23.02% (CI 0.225-0.235) in 2003 and from the year 2004 the rates of seropositve has been slowly decreased from 21.42% (CI 0.210-0.219) to 3.34% (CI 0.033-0.034) in 2012 (Table 3). But in case of females the seropositive rates showed an increasing trend from 13.11% (CI 0.125-0.138) in 2002 to 20.86% (CI 0.204-0.213) in 2005 and from 2006 there has been a slow decrease from 14.80% (CI 0.144-0.152) to 2.96% (CI 0.029-0.030) in 2012 (Table 3).

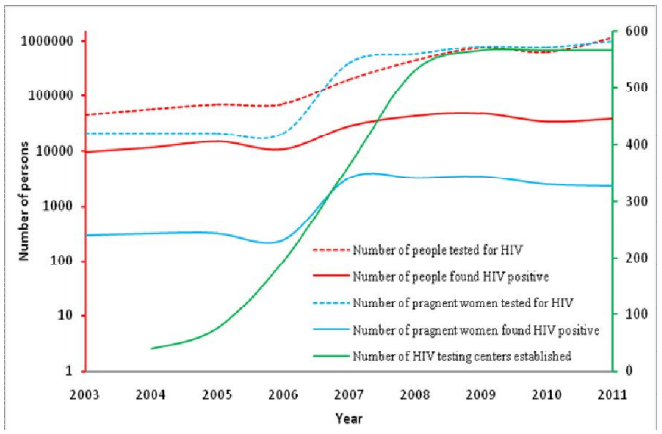

Figure 1. Left hand side scale, Trends in the number of people tested for HIV and diagnosed HIV positive year-wise in Karnataka. Right hand side scale trends in number of testing centres established

District wise distribution of HIV positive cases

The district wise of HIV positive cases is show in Figure 2 and it demonstrates that six districts viz. Bagalkot, Bijapur, Bellary, Dharwad, Gadag and Koppal are having more percentage of HIV positive cases than others in Karnataka. Further it is observed that for almost all the districts the rate of positivity went on decreasing for the study period.

Table 2. Year wise seropositive rates of HIV in Karnataka for the period 2002-2012

Year	Tested	Positive	% HIV	95% CI
2002	25858	3855	14.91	(0.144-0.153)
2003	45904	9741	21.22	(0.208-0.216)
2004	57705	11949	20.71	(0.204-0.210)
2005	70422	15108	21.45	(0.212-0.217)
2006	70783	10954	15.48	(0.152-0.157)
2007	136592	23261	17.03	(0.168-0.172)
2008	591804	32213	5.44	(0.054-0.055)
2009	598969	98291	16.41	(0.163-0.165)
2010	745723	48472	6.50	(0.064-0.065)
2011	626993	34869	5.56	(0.055-0.056)
2012	651890	20574	3.16	(0.031-0.032)

Table 3. Year wise seropositive rates of HIV in male and female in Karnataka

Year	Male				Female			
	Tested	Positive	% positivity	95% CI	Tested	Positive	% positivity	95% CI
2002	15245	2464	16.16	(0.156-0.168)	10613	1391	13.11	(0.125-0.138)
2003	26644	6133	23.02	(0.225-0.235)	19260	3608	18.73	(0.182-0.193)
2004	34360	7360	21.42	(0.210-0.219	23345	4589	19.66	(0.192-0.202)
2005	41800	9137	21.86	(0.215-0.223)	28622	5971	20.86	(0.204-0.213)
2006	38656	6199	16.04	(0.157-0.164)	32127	4755	14.80	(0.144-0.152)
2007	72577	13022	17.94	(0.177-0.182)	64015	10239	15.99	(0.157-0.163)
2008	208358	23460	11.26	(0.111-0.113)	193567	19084	9.86	(0.097-0.100)
2009	322465	24771	7.68	(0.076-0.078)	276504	20264	7.33	(0.072-0.074)
2010	346546	33013	9.53	(0.094-0.096)	230912	30254	13.10	(0.130-0.132)
2011	518020	43987	8.49	(0.084-0.086)	337322	42847	12.70	(0.126-0.128)
October 2012	330689	11061	3.34	(0.033-0.034)	321201	9513	2.96	(0.029-0.030)

Table 4. Results of One-Way ANOVA

Variable : Positivity					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3265.724	29	112.611	4.308	.000
Within Groups	3137.036	120	26.142		
Total	6402.760	149			

Table 5. The homogeneous subsets formed using Games-Howell Post Hoc tests are displayed along Means for groups and with p-values

Factors	Subset for alpha = 0.05			
	1	2	3	4
Chickkaballapur	2.5860			
Kodagu	2.9300			
Bangalore Rural	3.1240			
Uttara Kannada		3.5960		
Ramanagar		3.8380		
Hassan			4.1040	
Shimoga			4.2300	
Kolar			4.2760	
Chamarajanagar			4.3580	
Bidar			4.4140	
Chikmagalur			4.7740	
Tumkur			5.0660	
Mandya			5.4500	
Dakshina Kannada			5.7500	
Chitradurga			5.9680	
Bangalore			6.5520	
Udupi			6.6260	
Haveri			6.9700	
Mysore			7.8260	
Davanagere			7.9100	
Gulbarga				9.1960
Yadgir				10.4080
Belgaum				10.9840
Gadag				11.5860
Bellary				12.2760
Dharwad				14.1960
Raichur				14.3020
Bijapur				15.7380
Koppal				16.4280
Bagalkot				21.1360
Sig.	.095	.065	.055	.078

Table 6. Gini Index for HIV positivity tested in general Integrated Counselling and Testing Centre and Ante Natal Care (ANC) centers

S.No.	District	General Gini Index	ANC Gini Index
1	Bagalkot	0.17	0.28
2	Bangalore	0.21	0.19
3	Bangalore Rural	0.24	0.06
4	Belgaum	0.25	0.31
5	Bellary	0.32	0.27
6	Bidar	0.18	0.09
7	Bijapur	0.35	0.35
8	Chamarajanagar	0.22	0.06
9	Chickkaballapur	0.09	0.06
10	Chikmagalur	0.27	0.26
11	Chitradurga	0.18	0.17
12	Dakshina Kannada	0.29	0.34
13	Davanagere	0.27	0.23
14	Dharwad	0.33	0.28
15	Gadag	0.23	0.25
16	Gulbarga	0.32	0.29
17	Hassan	0.19	0.30
18	Haveri	0.23	0.21
19	Kodagu	0.24	0.27
20	Kolar	0.18	0.19
21	Koppal	0.37	0.21
22	Mandya	0.20	0.25
23	Mysore	0.25	0.22
24	Raichur	0.31	0.21
25	Ramanagar	0.25	0.32
26	Shimoga	0.22	0.18
27	Tumkur	0.21	0.28
28	Udupi	0.22	0.27
29	Uttara Kannada	0.28	0.25
30	Yadgir	0.35	0.22

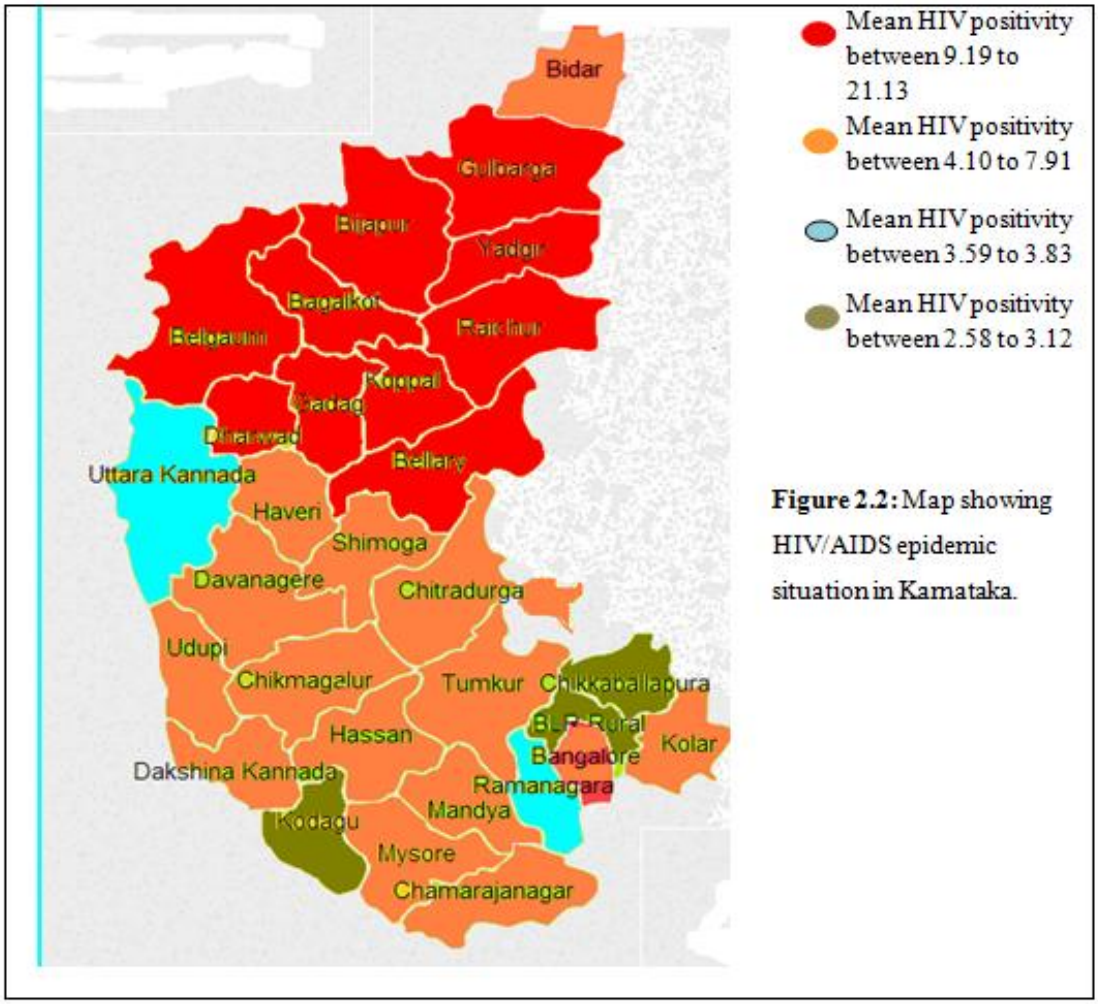

Figure 2.2: Map showing HIV/AIDS epidemic situation in Karnataka.

Table 7. Projection rate of HIV positive by using different growth curves

Year	Rate of HIV Positive	
	Exponential Growth Curve	Polynomial Growth Curve
2012	0.036193	0.073
2013	0.028757	0.056
2014	0.022848	0.039
2015	0.018154	0.022
2016	0.014424	0.005

Table 8. Accuracy of forecast error for different growth curves

Measures	Exponential Growth Curve	Polynomial Growth Curve
Mean Absolute Deviation	0.0035	0.0009
Mean Square Error	0.0001	0.000008
Tracking signs	-9.00	-9.00

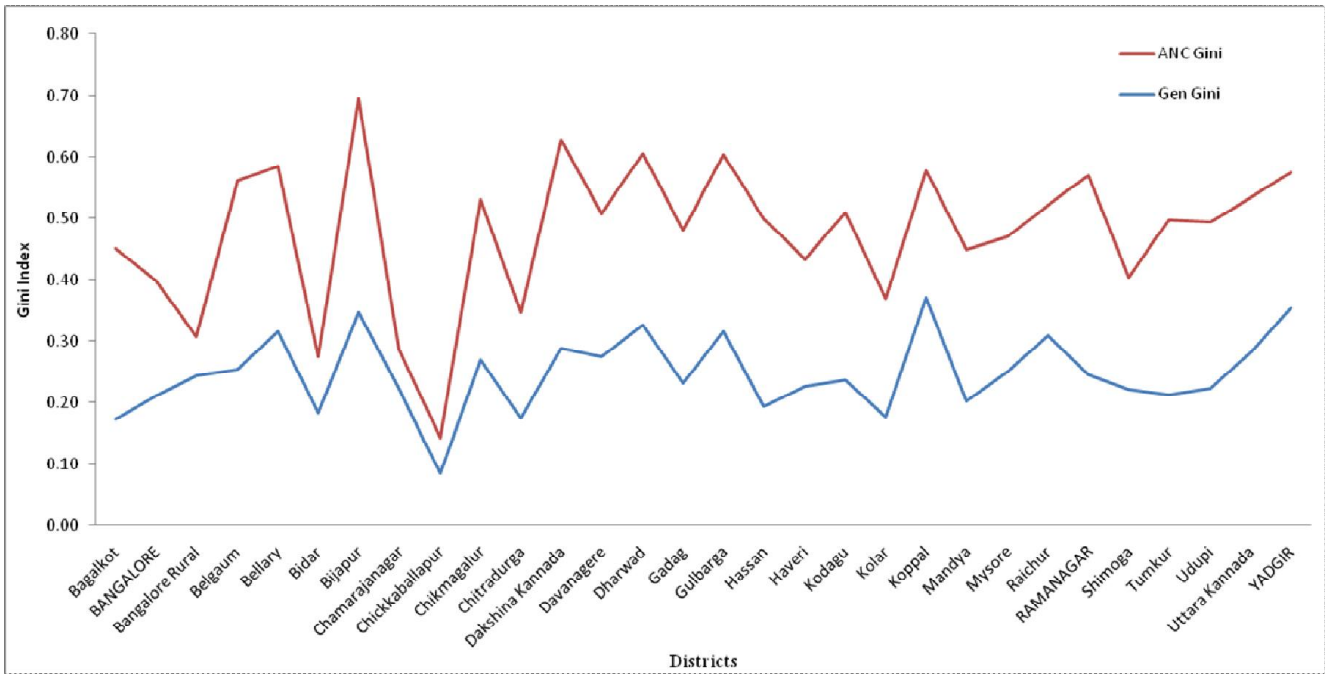

Figure 3. Graph showing the comparison of Gini Index for HIV positivity tested in general Integrated Counselling and Testing Centre and *Ante Natal* Care (ANC) centers

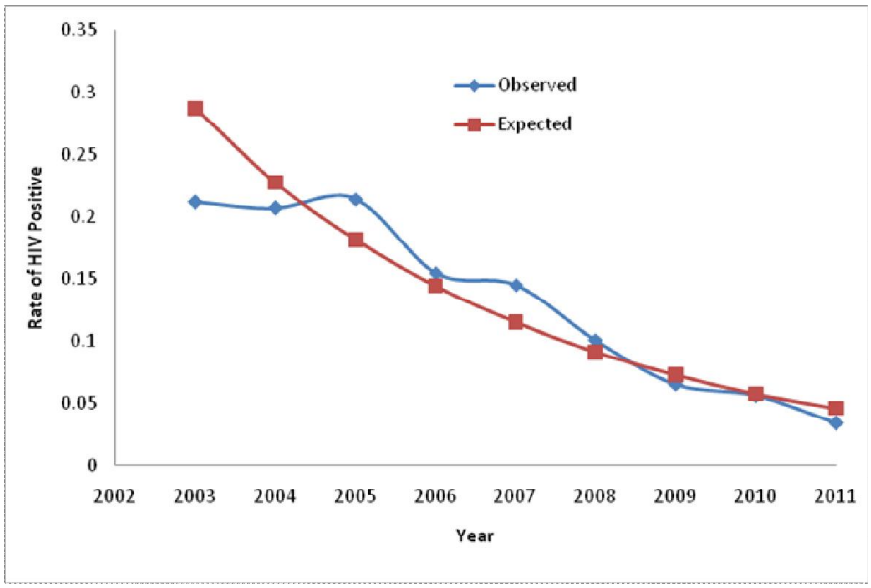

Figure 4. Fitting of Second degree polynomial growth curve

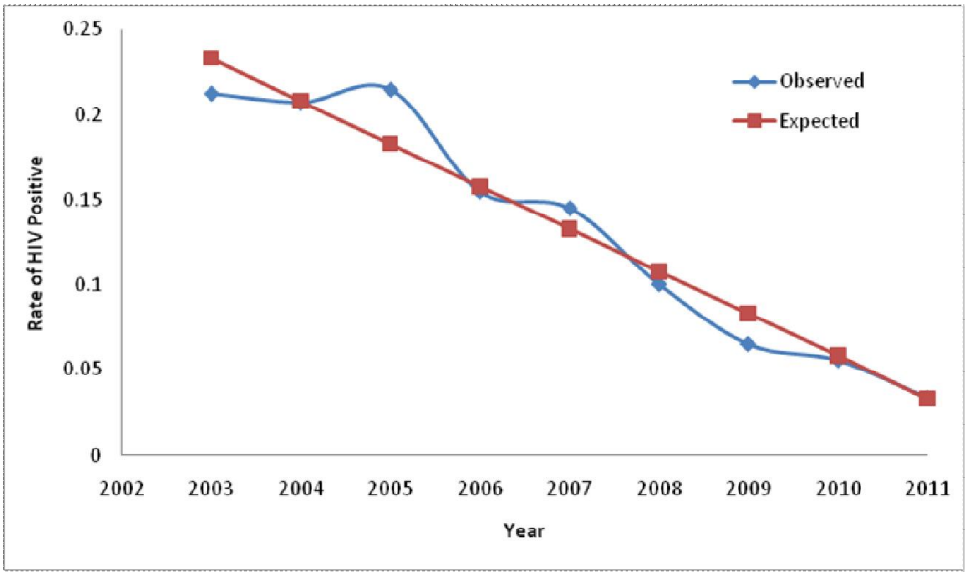

Figure 5. Fitting of Second degree polynomial growth curve

In order to carry the preceding analysis deeper and derive more meaningful conclusion further we were going to study the rates of seropositive district wise. The one-way ANOVA was applied to verify whether the rate of the seropositive of HIV was unequally distributed between the districts. Prior to examine whether group means differ; we need test the assumptions underlying the one-way ANOVA. The assumption of independence was met, since the testing centers in twelve of our groups of Taluk's being independent of each other, the assumptions of normality was met for this set of data, but the assumption of homogeneity of variance was not met (p value <0.05 for Levene Statistic for test for homogeneity of variance). If a statistical procedure is little affected by violating an assumption, the procedure is said to be robust with respect to that assumption. The One-way ANOVA is robust with respect to violations of the assumptions, except in the case of unequal variances with unequal sample sizes. That is, the ANOVA can be used when variances are only approximately equal if the number of subjects in each group is equal and since we have equal sample sizes for all the groups we can assume that variances are approximately equal and proceed with one-way ANOVA. The results of the study conclude that there was significant variation between the districts of the Karnataka (See, Table 4). It does not indicate that which attachment groups are significantly different from others. One way to further examine group differences is to use post-hoc or a posterior multiple comparison tests, such as the Student-Newman-Keuls or Tukey HSD test if the assumption of homogeneity of variance was met. In our example, we have used Games-Howell Post Hoc test to test for differences between all possible pairs of means that control alpha inflation as the assumption of homogeneity of variance was not met. In our example, we have used Games-Howell Post Hoc test to test for differences between all possible pairs of means that control alpha inflation. The Table 5, shows the homogeneous subsets generated in SPSS using Games-Howell Post Hoc test, by which we formed four homogeneous subgroups. First subgroup of homogeneous subsets generated in SPSS consists the districts which has very low HIV seropositivity rate i.e., Chickkaballapur, Kodagu and Bangalore Rural districts. Second group in homogenous subset consists Uttara Kannada and Ramanagar districts which have slightly high HIV positivity rate and third group which has moderate HIV positivity rate consists almost half of the districts. Fourth homogeneous group consists of Gulbarga, Yadgir, Belgaum, Gadag, Bellary, Dharwad, Raichur, Bijapur, Koppal and Bagalkot districts which have highest HIV positivity rate. In third and fourth homogenous group most of the districts are from northern Karnataka. This means northern Karnataka is more severally affected by HIV than southern Karnataka, because of the large concentrated of commercial sex worker networks in northern Karnataka. In addition in northern Karnataka the HIV epidemic tends seems to be more advanced in rural than in urban areas in India.

Table 6 and Figure 3, throws light on the Gini coefficients computed for all district of Karnataka for for HIV positivity tested in general Integrated Counselling and Testing Centre and Ante Natal Care (ANC) centers. A value close to 0 indicates a smaller number of concentrations of HIV positive persons compared with that of at-risk population over a period of time, and a value close to 1 indicates more number of concentrations of HIV positive persons compared with that of at-risk population over a period of time. Bijapur district shows the highest difference and Chickkaballapur district shows lowest difference in the Gini Index for HIV positivity tested in general ICTC and ANC centers.

Estimation and Projection of HIV Rate of Positivity

In the late 1980's many researchers were interested in HIV/AIDS epidemic and developed mathematical and statistical models to describe the trend, impact and predictions of new cases of which some are complex to understand or to interpret and are very difficult to implement upto. One of the widely used models at that early stage of the epidemic was back-calculation model by (Brookmeyer and Gail, 1988; Cox and Davidson, 1989) which was used mainly on HIV cases in the developed countries. Very few researchers have employed time series univariate model to predict new HIV cases (eg. Finland data, Loytonen (1999). In this chapter Exponential curve and Second degree polynomial curve will be applied to

the yearly rate of HIV positivity in India. Curve fitting is the process of constructing a curve, or mathematical function, that has the best fit to a series of data points, possibly subject to constraints. Curve fitting can involve either interpolation, where an exact fit to the data is required, or smoothing, in which a "smooth" function is constructed that approximately fits the data. A related topic is regression analysis, which focuses more on questions of statistical inference such as how much uncertainty is present in a curve that is fit to data observed with random errors. Fitted curves can be used as an aid for data visualization, to infer values of a function where no data are available, and to summarize the relationships among two or more variables. Extrapolation refers to the use of a fitted curve beyond the range of the observed data, and is subject to a degree of uncertainty since it may reflect the method used to construct the curve as much as it reflects the observed data. Exponential growth occurs when the growth rate of the value of a mathematical function is proportional to the function's current value. Exponential decay occurs in the same way when the growth rate is negative. In the case of a discrete domain of definition with equal intervals, it is also called geometric growth or geometric decay (the function values form a geometric progression). The formula for exponential growth of a variable *x* at the (positive or negative) growth rate *r*, as time *t* goes on in discrete intervals (i.e., at integer times 0, 1, 2,...), is

$$x_t = x_0(1 + r)$$

where x_0 is the value of *x* at time 0. For example, with a growth rate of $r = 5\% = 0.05$, going from *any* integer value of time to the next integer causes *x* at the second time to be 1.05 times (i.e., 5% larger than) what it was at the previous time. Polynomial curves fitting points generated with a sine function. Polynomial curves have several undesirable features, including a nonintuitive variation of fitting curve with varying coefficients, and numerical instability for high orders.

Starting with a first degree polynomial equation:

$$y = ax + b$$

This is a line with slope *a*. A line will connect any two points, so a first degree polynomial equation is an exact fit through any two points with distinct x coordinates. If the order of the equation is increased to a second degree polynomial, we get the following results:

$$y = ax^2 + bx + c$$

This will exactly fit a simple curve to three points. Further, the forecast accuracy of the above growth curves are calculated by using some statistical tools.

Mean Absolute Deviation

The Mean Absolute Deviation (MAD) of a set of data is the average distance between each data value and the mean. It is measure of accuracy in a fitted time series value in statistics, specifically in growth curves. It is defined as,

$$MAD = \frac{1}{n}\sum_{i=1}^{n} IO_t - E_tI$$

where,
O_t – The observed rate of HIV positive at time t.
E_t – The Estimated rate of HIV positive at time t.

Mean Squre Error (MSE)

In statistics the mean square error of a curve fitting procedure is the expected value of the squared difference between the fitted values of rate of HIV positive E_t and the observed value of rate of HIV positive O_t. It is defined as,

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(O_t - E_t)^2$$

Tracking signal (TS)

In statistics and management science, a tracking signal monitors any forecasts that have been made in comparison with actuals, and warns when there are unexpected departures of the outcomes from the forecasts. The tracking signal is a simple indicator that forecast bias is present in the forecast model. It is most often used when the validity of the forecasting model might be in doubt. It is given by,

$$\text{Tracking signal} = \frac{(O_t - E_t)}{MAD}$$

We analysis the rate of HIV positive cases in India by using exponential growth curve method and second degree polynomial curve for the period 2002 to 2011. The analysis of the study reveals that both the curves are fitted well to the rate of HIV positive (Fig. 4 and 5). With the help of these two growth curves rate HIV positivity is estimated and also predicted for the next five years from 2012- 2016 (Table 7). Table 8 summaries the accuracy of different growth curves for India. Table 7 reveals that the values of all the three methods of accuracy are smaller in case of polynomial growth curve as compared to exponential growth curve for India. This concludes that the polynomial growth curve is fitted well to the rate of HIV positive as compared to the exponential growth curve.

Conclusion

This study has explored the geographical and demographic patterns of transmissibility of HIV/AIDS in Karnataka of India, using yearly epidemiological time series, made available by monitoring and evaluation unit, Karnataka state AIDS control society in its report HIV/AIDS in Karnataka (2004). We identified spatial variations of the transmissibility of HIV by age and sex using various statistical methods. Limitations of this study include the study of differences in incidence rates of urban and rural areas as the study is based on the secondary data.

There are still many unanswered questions that will require research. Chief among them is operational research that is directed towards a better understanding of how to design and implement effective control programmes for higher risk communities. Network analysis could also be used to provide a better understanding of the specifics of transmission patterns and to control outbreaks more efficiently.

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