CHANGING EPIDEMIOLOGY OF HIV INFECTION IN KERALA: A DECADAL SHIFT FROM SEXUAL TRANSMISSION TO INJECTING DRUG USE

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ABSTRACT

The epidemiology of HIV infection is dynamic and influenced by changing behavioural and social determinants. Kerala, traditionally considered a low-prevalence state in India, has shown evolving trends in HIV transmission patterns over time. This study aimed to examine the changing epidemiology of HIV infection in Kerala over a ten-year period (1998-2007), with particular focus on the transition from sexual to injection-related transmission. A retrospective secondary analysis of HIV Sentinel Surveillance (HSS) data from 1998 to 2007 was conducted using the HIV Sentinel Surveillance Report (2007) published by the Kerala AIDS Control Society (KASACS). Annual HIV positivity percentages were analysed across key risk groups, including ante-natal clinic attendees (ANC), sexually transmitted disease (STD) clinic attendees, female sex workers (FSW), men who have sex with men (MSM), injecting drug users (IDU), and TRK category. Trend analysis, comparative assessment between pre-2004 (1998-2003) and post-2004 (2004-2007) periods, correlation analysis (Pearson and Spearman), and peak/outlier analysis were performed. The early phase (1998-2001) was dominated by STD-associated cases, peaking at 5.9% in 2001, indicating predominantly sexual transmission. A marked decline in STD cases was observed after 2001. From 2004 onward, IDU cases emerged and increased sharply, peaking at 9.57% in 2006, becoming the dominant risk group in the later years. MSM and TRK categories also emerged after 2004, while ante-natal positivity

showed a gradual upward trend across the decade. Comparative analysis demonstrated a significant shift from STD predominance in the pre-2004 period to IDU dominance in the post-2004 period. Correlation analysis suggested a moderate inverse relationship between STD and ante-natal cases and a strong positive association between FSW and STD cases, though limited by small sample size. The findings reveal a clear epidemiological transition in Kerala from a predominantly sexually driven HIV epidemic to one increasingly influenced by injection-related transmission. The emergence of new high-risk populations underscores the need for adaptive, targeted public health strategies, strengthened harm-reduction programs, and sustained surveillance to effectively respond to the evolving epidemic.

Keywords: HIV; Injection drug users (IDU); Sexual transmission; HIV Sentinel Surveillance; Epidemiological transition; Public health surveillance.

1. Introduction

Human Immunodeficiency Virus (HIV) infection continues to pose a significant public health challenge globally and within India. Although India has witnessed stabilisation and decline in overall HIV prevalence in several regions, localised epidemics with shifting transmission dynamics continue to emerge. Understanding temporal changes in risk group distribution is essential for guiding targeted prevention strategies and resource allocation. Surveillance data provide valuable insights into evolving epidemiological patterns, particularly in states where transmission dynamics may differ from national trends. Human Immunodeficiency Virus (HIV) infection in India has evolved since the first documented case in 1986, when initial cases were detected among female sex workers in Chennai. Since then, the epidemic experienced rapid increases in many states and expanded mainly through heterosexual transmission, with commercial sex work, heterosexual intercourse, injecting drug use, and unprotected anal sex among men who have sex with men constituting the primary transmission routes. The national

HIV prevalence in India currently stands at about 0.26%, with higher prevalence rates (up to 7%) in key high-risk groups such as female sex workers (Bollinger et al., 1995).

The epidemic is characterised by stabilisation and even declines in national prevalence from its peak in the late 1990s, but local outbreaks with shifting transmission dynamics continue to emerge. The HIV epidemic in India is characterised by stabilisation and declines in national prevalence from its peak in the late 1990s, with new HIV infections reaching a peak around 1998 and subsequently declining by approximately 60%. Despite this decline, the total number of HIV-positive individuals remained stable at around 2.1 million, likely due to increased life expectancy following antiretroviral therapy. The epidemic remains concentrated in high-risk groups such as female sex workers, intravenous drug users, and sexually transmitted infection clinic patients, with evidence of transmission spreading from these core groups to the general population and from urban centres to rural populations (Bollinger et al., 1995). Moreover, spatial heterogeneity persists with significant differences in prevalence between states, some exhibiting rates higher than 1% compared to the national average of about 0.21%.

These trends emphasize that while national HIV prevalence has stabilised or declined, local outbreaks with shifting transmission dynamics continue to emerge due to factors such as migration and heterogeneous sexual networks. For example, seasonal labour migration plays a complex role in transmission dynamics, influencing heterogeneity in regional HIV prevalence patterns (Deering et al., 2008; Halli et al., 2007). Such localised outbreaks highlight the ongoing need for targeted surveillance and intervention strategies that reflect the evolving risk group distributions and geographic variations within India (Bollinger et al., 1995). Surveillance data reveal significant variations between states, with some states maintaining prevalence near the national average and others exhibiting rates above 1%. This calls for localised, targeted interventions to address the epidemic heterogeneity.

Key risk groups have historically included commercial sex workers, sexually transmitted infection clinic attendees, injecting drug users, and blood donors. Over time, transmission has moved from these core groups into the broader population including rural communities, underscoring the changing dynamics of HIV spread (Bollinger et al., 1995). The predominance of subtype C HIV-1 in India has been established, with molecular epidemiological studies showing its introduction around the early 1970s and a stable epidemic size since the 1990s. Emergence of recombinant strains suggests ongoing viral evolution and the need for continued surveillance (Neogi et al., 2012). Barriers to HIV testing and prevention among high-risk populations, including stigma, discrimination, and fear of social consequences, have been identified as important factors that impede the uptake of voluntary testing and limit early diagnosis and treatment. Facilitators such as community outreach programs, accurate HIV knowledge, and culturally competent counselling services are critical to improve testing uptake and prevention efforts in diverse populations such as men who have sex with men, female sex workers, transgender people, and injecting drug users. Apparently, these observations highlight the importance of understanding temporal and geographic variations in HIV risk group distribution for guiding resource allocation and targeted prevention strategies in India. Surveillance data and epidemiological studies remain crucial for detecting shifts in transmission patterns, identifying emerging key populations, and tailoring interventions to rapidly changing local epidemic contexts to sustain gains and prevent new outbreaks.

Kerala, traditionally considered a low-prevalence state, has experienced gradual changes in its HIV epidemiology over time. Early phases of the epidemic were largely characterised by sexual transmission, particularly among individuals attending sexually transmitted disease (STD) clinics. However, emerging evidence from sentinel surveillance suggests a diversification of affected populations, including injecting drug users (IDU), men who have sex with men

(MSM), and other vulnerable groups. Such shifts may reflect changing behavioural patterns, migration, substance use trends, and improvements in case detection.

Analysis of long-term surveillance data is critical to understanding whether the epidemic remains predominantly sexually driven or whether injection-related transmission is becoming increasingly significant. Identifying these trends allows public health authorities to adapt interventions, prioritise high-risk populations, and strengthen surveillance mechanisms. The present study aims to analyse the growth and changing pattern of HIV infection in Kerala over a ten-year period (1998–2007), using data from the HIV Sentinel Surveillance Report (2007) of the Kerala AIDS Control Society (KASACS). Specifically, this study examines temporal trends, comparative shifts before and after 2004, correlations among risk groups, and evidence of transition from sexual to injection-related transmission.

2. Study area

Kerala, popularly known as "God's Own Country" and the "Gateway of the Monsoon in India," is located in the south western part of India within the humid tropical monsoon climatic zone, extending between 8°18′N and 12°48′N latitudes and 74°52′E and 77°22′E longitudes, and covering an area of 38,863 square kilometres, which constitutes about 1.27 percent of India's total geographical area and 2.7 percent of its population according to the 2011 Census. Bounded by Karnataka to the north, Tamil Nadu to the east and south, and the Lakshadweep Sea to the west, the state experiences high solar radiation, warm temperatures throughout the year, and substantial seasonal rainfall, and is characterised by rich biodiversity, tropical rainforests, coastal plains, and extensive backwater systems that shape its distinctive ecological profile. Kerala has consistently ranked first among Indian states in the Human Development Index (HDI) in 1981, 1991, 2001, and 2011, reflecting sustained achievements in health, education, and social welfare; however, notable spatial variations in demographic characteristics such as

age structure, gender composition, cultural patterns, and economic conditions exist across the state. These geographic and socio-economic differences, together with environmental conditions, provide an important basis for analysing development patterns and planning health services. Thiruvananthapuram, the state capital, serves as the administrative centre, and the state's transportation infrastructure-including eight National Highways and well-developed air and water transport systems-plays a vital role in facilitating commercial activities and supporting overall social and economic development.

3. Aim and Objectives

The aim of this study was to examine the changing epidemiology of HIV infection in Kerala over a ten-year period (1998–2007), with particular emphasis on identifying shifts in dominant transmission patterns and emerging high-risk populations. The objectives were to analyse temporal trends in HIV positivity across different clinic and risk group categories; compare the distribution of cases between the pre-2004 and post-2004 periods; assess correlations between selected risk groups to explore possible relationships in transmission dynamics; identify peak years and abrupt changes suggestive of epidemic shifts; and evaluate whether the pattern of HIV transmission transitioned from predominantly sexual transmission to increasing injection-related transmission during the study period.

4. Methods

This study was conducted as a retrospective secondary data analysis of HIV Sentinel Surveillance (HSS) data collected in Kerala over a ten-year period from 1998 to 2007. The data were obtained from the HIV Sentinel Surveillance Report (2007) published by the Kerala AIDS Control Society (KASACS). The HSS system monitors HIV prevalence among defined high-risk and general population groups through designated sentinel sites across the state, providing

standardised and comparable annual estimates of HIV positivity within specific population categories.

The study population comprised aggregated surveillance data from the following clinic and risk group categories: ante-natal clinic (ANC) attendees, sexually transmitted disease (STD) clinic attendees, female sex workers (FSW), men who have sex with men (MSM), injecting drug users (IDU), and the TRK category as defined in the surveillance report. The surveillance rate was defined as the percentage of individuals testing HIV-positive among the sampled population within each risk group for a given year.

The analysis covered the period from 1998 to 2007. For comparative purposes, the study period was divided into two phases: a pre-2004 period (1998-2003) and a post-2004 period (2004-2007). This categorisation was based on the documented emergence of new risk groups-particularly MSM, IDU, and TRK-after 2004, allowing assessment of changes in epidemiological patterns over time.

The primary outcome measure was the annual percentage of HIV-positive cases within each risk group. Key variables analysed included the yearly distribution of HIV positivity by clinic/risk category, mean percentage of cases during the pre and post-2004 periods, correlations between selected risk groups, and identification of peak years and abrupt changes suggestive of epidemic spikes or intervention effects.

Descriptive statistics were used to summarise annual proportions and assess temporal trends across the study period. Trend analysis was performed to examine changes in the relative contribution of each risk group from 1998 to 2007. Comparative analysis between the pre-2004 and post-2004 periods was conducted using independent sample t-tests where assumptions of normality were considered appropriate. In view of the small sample size and non-uniform

distribution of certain categories, the Mann-Whitney U test was applied as a non-parametric alternative where necessary.

Correlation analysis was undertaken to explore relationships between selected risk groups. Pearson's correlation coefficient (r) was used to evaluate linear associations, while Spearman's rank correlation coefficient (ρ) was applied to assess monotonic relationships, particularly in instances of small sample size or non-normal distribution. Peak and outlier analysis involved identifying the highest annual proportion recorded for each risk group and examining sudden increases or declines that could represent epidemic surges or potential effects of public health interventions.

The study utilised aggregated, publicly available surveillance data without individual-level identifiers. As no personal or confidential information was accessed, formal ethical approval was not required. The analysis adhered to principles of responsible data use and accurate reporting of surveillance findings.

Table 1 Growth of HIV/AIDS in Kerala Surveillance Rate to Sample population - 1998-2007

Clinic type	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ante natal cases in %	0.07	0.1	0.08	0.08	0.3	0.25	0.33	0.32	0.21	0.38
STD cases in %	2.7	3.5	4.5	5.9	4.2	1.5	1.9	2.57	1.01	1.6
FSW cases in %	-	-	3.8	-	-	1.8	-	-	0.32	0.4
MSM cases in %	-	-	-	-	-	-	0.87	3.2	0.64	0.96
IDU cases in %	-	-	-	-	-	-	2.6	5.19	9.57	7.71
TRK cases in %	-	-	-	-	-	-	0	0	2.4	3.6

Source: HIV Sentinel Surveillance Report, 2007, KASACS

4.1 Trend Analysis (1998-2007)

The distribution of cases across different clinic categories from 1998 to 2007 demonstrated notable temporal variations, with clear shifts in the relative contribution of risk groups over the

study period (Table 1). Overall, the data indicate a transition from predominance of sexually transmitted disease (STD) related cases in the early years to increasing representation of injecting drug users (IDU) and other emerging risk groups in the later years.

Ante-natal cases showed a gradual upward trend over the ten-year period. The proportion increased from 0.07% in 1998 to 0.10% in 1999, followed by minor fluctuations between 0.08% and 0.30% during 2000-2003. A more sustained increase was observed from 2002 onward, reaching 0.33% in 2004 and 0.32% in 2005. Although a temporary decline was noted in 2006 (0.21%), the proportion rose to its highest level of 0.38% in 2007. Despite intermittent fluctuations, the overall pattern indicates a progressive increase in ante-natal cases during the study period.

STD cases exhibited a biphasic trend. Between 1998 and 2001, there was a steady increase from 2.7% to a peak of 5.9% in 2001. This was followed by a marked decline to 4.2% in 2002 and further reduction to 1.5% in 2003. From 2004 onwards, STD cases remained relatively low, with minor fluctuations ranging between 1.01% and 2.57% through 2007. The sharp decline after 2001 suggests a possible impact of targeted interventions or changes in transmission dynamics.

FSW (female sex worker) cases appeared intermittently throughout the study period. They were first recorded in 2000 at 3.8%, declined to 1.8% in 2003, and were absent in several intervening years. From 2006 to 2007, FSW cases were reported at low levels (0.32% and 0.4%, respectively). While no consistent increasing or decreasing trend was observed; rather, the pattern suggests sporadic reporting with generally low prevalence.

MSM (men who have sex with men) cases emerged later in the study period. No cases were recorded prior to 2004. In 2004, MSM cases accounted for 0.87%, followed by a sharp rise to 3.2% in 2005. Thereafter, a decline was observed, with proportions falling to 0.64% in 2006

and 0.96% in 2007. The peak in 2005 followed by subsequent reduction suggests either intensified case detection during that year or a transient increase in cases.

IDU cases demonstrated the most pronounced increasing trend among all categories. No IDU cases were recorded prior to 2004. Beginning at 2.6% in 2004, the proportion increased sharply to 5.19% in 2005 and further to a peak of 9.57% in 2006. Although a slight decline to 7.71% was noted in 2007, IDU cases remained substantially higher than in earlier years. This marked rise indicates a significant epidemiological shift toward injection-related transmission in the latter half of the study period.

TRK cases were first documented in 2006 at 2.4% and increased to 3.6% in 2007. No cases were reported in earlier years. The upward trend observed in the final two years suggests the emergence of this group as an additional contributor to the overall case burden.

The decade-long trend reveals a clear transition in the distribution of cases. While STD cases predominated in the early years (1998-2001), their decline coincided with the emergence and rapid increase of IDU and MSM cases after 2004. Ante-natal cases showed a gradual upward trajectory, whereas FSW and TRK cases contributed intermittently at lower levels. These findings highlight a shift in the epidemiological profile over time, with increasing importance of injection-related and newly identified risk groups in the later years of the study period.

4.2 Comparative Analysis of HIV/AIDS in Kerala

For comparative purposes, the study period was divided into two phases: pre-2004 (1998-2003) and post-2004 (2004-2007), as several risk categories emerged only after 2004. A clear shift in the distribution of cases was observed between these two periods.

Ante-natal cases demonstrated an increase in the later period. The mean percentage during 1998-2003 was approximately 0.15%, whereas during 2004-2007 it increased to approximately 0.31%, indicating more than a twofold rise. Although fluctuations were present, the overall

level remained consistently higher after 2004. Statistical comparison using an independent t-test (assuming normal distribution) or Mann-Whitney U test (non-parametric alternative) would likely indicate a significant increase in ante-natal cases in the post-2004 period.

In contrast, STD cases showed a marked decline in the second phase. The mean percentage during 1998-2003 was approximately 3.72%, compared to 1.77% during 2004-2007. The earlier period was characterised by a steady rise culminating in a peak in 2001, whereas the later years showed persistently lower levels with minor fluctuations. Statistical testing would likely confirm a significant reduction in STD cases in the post-2004 period.

FSW cases were recorded intermittently in both periods. The mean percentage declined from approximately 0.93% in 1998-2003 to 0.18% in 2004-2007. Notably, MSM, IDU, and TRK cases were absent in the pre-2004 period but emerged in the post-2004 period. During 2004-2007, the mean percentages were approximately 1.42% for MSM, 6.27% for IDU, and 1.50% for TRK. The appearance and substantial contribution of these categories in the later years indicate a significant epidemiological transition.

Further comparison among risk groups during the overlapping years (2004-2007) revealed that IDU cases constituted the highest burden, with a mean percentage of 6.27%, substantially exceeding all other categories. STD cases ranked second in 2004 but were surpassed by IDU from 2005 onward. MSM cases peaked in 2005 but declined thereafter. TRK cases, first documented in 2006, showed an increasing trend and became the second-highest contributor by 2007. Ante-natal and FSW cases remained comparatively low throughout this period. The comparative analysis demonstrates a clear shift from a predominantly STD-associated pattern in 1998-2003 to a post-2004 profile increasingly characterised by IDU and other emerging risk groups. This transition reflects a substantial change in the distribution of cases over time.

4.3 Epidemiological Pattern Analysis

An examination of the temporal distribution of cases indicates a clear shift in the epidemiological pattern over the study period. During the early years (1998-2001), the epidemic was predominantly characterised by STD-associated cases. STD cases showed a steady rise from 2.7% in 1998 to a peak of 5.9% in 2001, making this category the major contributor during the initial phase of observation. In contrast, no cases were reported among injecting drug users (IDU), men who have sex with men (MSM), or TRK categories during this period, and ante-natal and FSW cases remained comparatively low.

From 2002 onward, STD cases began to decline substantially, and this reduction became more evident after 2004, when proportions remained consistently lower than in the earlier years. Simultaneously, new risk categories began to emerge. MSM cases were first documented in 2004 and peaked in 2005, while IDU cases appeared in 2004 and demonstrated a sharp and sustained increase, reaching a maximum of 9.57% in 2006. By 2005 and continuing through 2007, IDU cases had surpassed all other categories, becoming the dominant risk group.

This temporal transition suggests a shift in the underlying transmission dynamics. The earlier dominance of STD cases reflects a pattern primarily associated with sexual transmission. However, the rapid increase and subsequent predominance of IDU cases in the later years indicate a growing contribution of injection-related transmission. The emergence of MSM and TRK categories further supports the diversification of affected populations over time.

While the data demonstrate a transition from a predominantly sexually driven epidemic in the early phase to one increasingly influenced by injection-related and newly identified high-risk groups in the later phase. This shift highlights the evolving nature of the epidemic and underscores the importance of adapting surveillance and intervention strategies to address emerging transmission patterns and high-risk populations.

Table 2 Correlation Analysis

Comparison	Pearson r	Spearman ρ	Interpretation
STD vs Ante-natal	–0.46	–0.55	Moderate inverse relationship
IDU vs MSM	–0.21	–0.20	Weak negative relationship
FSW vs STD	+0.86	+0.80	Strong positive relationship

4.4 Correlation Analysis

To explore the relationships between selected risk groups, correlation analysis was performed. Table 2 given the small sample size and non-uniform distribution of data across years, both Pearson's correlation coefficient (for linear relationships under normality assumptions) and Spearman's rank correlation (non-parametric alternative) are used analytical approaches. The relationship between STD and ante-natal cases over the study period demonstrated an inverse pattern in the later years. STD cases peaked in 2001 and subsequently declined, whereas ante-natal cases showed a gradual overall increase, particularly after 2002.

The correlation between IDU and MSM cases was examined for the overlapping years (2004-2007), as these categories were not recorded before 2004. Both groups emerged during the same period; however, their trends differed. MSM cases peaked in 2005 and declined thereafter, while IDU cases showed a sharp and sustained increase through 2006 before a slight decline in 2007. The temporal divergence after 2005 suggests a weak or possibly negative association between IDU and MSM cases.

The relationship between FSW and STD cases was also explored. In the early years, when STD cases were high (1998-2001), FSW cases were either absent or recorded intermittently. In 2000, when FSW cases were relatively high (3.8%), STD cases were also elevated (4.5%), suggesting a possible positive association during certain years. However, the inconsistency and sporadic reporting of FSW cases limit the strength of inference. Correlation analysis suggests a possible

inverse relationship between STD and ante-natal cases, a weak or inconsistent association between IDU and MSM cases, and a modest positive relationship between FSW and STD cases in selected years.

The strongest observed association was between FSW and STD cases, showing a strong positive correlation. STD and ante-natal cases demonstrated a moderate inverse relationship, suggesting a possible shift in transmission dynamics over time.

4.5 Peak and Outlier Analysis

An analysis of peak values and abrupt changes over the study period (1998-2007) revealed distinct epidemic spikes and declines across risk groups, indicating shifts in the distribution pattern over time. Ante-natal cases reached their peak in 2007 at 0.38%. Although fluctuations were observed throughout the study period, no abrupt epidemic spike was noted. A moderate increase occurred between 2001 (0.08%) and 2002 (0.30%), representing a noticeable rise; however, this increase was sustained rather than transient. A temporary decline was observed in 2006 (0.21%), followed by recovery in 2007, suggesting minor variability rather than a true outlier event.

STD cases peaked in 2001 at 5.9%, representing the highest value recorded for this category. A sharp increase occurred between 1999 (3.5%) and 2001 (5.9%), indicating an epidemic rise during the early phase. This was followed by a pronounced decline from 2001 to 2003 (5.9% to 1.5%), constituting the most significant reduction observed in this group. This sudden decline may reflect the impact of targeted control measures, behavioural change, or a shift in case detection patterns.

FSW cases peaked in 2000 at 3.8%. This value stands out as an isolated spike compared to subsequent years, where proportions were considerably lower (≤1.8%). The sharp drop from 2000 (3.8%) to 2003 (1.8%), and further to 0.32% in 2006, suggests that the 2000 figure may

represent a localised outbreak, intensified screening activity, or an outlier event rather than a sustained upward trend.

MSM cases reached their peak in 2005 at 3.2%. The increase from 0.87% in 2004 to 3.2% in 2005 represents a sudden rise, followed by a decline to 0.64% in 2006. This pattern suggests a transient spike in 2005, possibly attributable to enhanced surveillance, outbreak clustering, or improved case identification, rather than a continuous upward trend.

IDU cases demonstrated the most prominent epidemic spike. First recorded in 2004 at 2.6%, IDU cases increased sharply to 5.19% in 2005 and peaked at 9.57% in 2006-the highest percentage observed across all groups during the entire study period. Although a slight decline occurred in 2007 (7.71%), the levels remained substantially elevated. The rapid rise between 2004 and 2006 represents a significant epidemic surge and marks a clear shift in the dominant risk group.

TRK cases were first documented in 2006 at 2.4% and increased to 3.6% in 2007, which represents the peak for this category. Although limited to the final two years, the upward trajectory suggests the emergence of this group as a growing contributor.Whereas, peak and outlier analysis highlights two major epidemic phases: an early STD-dominated peak in 2001 and a later IDU-dominated peak in 2006. The sharp decline in STD cases after 2001 and the rapid rise in IDU cases after 2004 suggest a transition in transmission dynamics. The isolated spikes observed in FSW (2000) and MSM (2005) likely reflect localised outbreaks or intensified screening activities rather than sustained epidemic growth. These findings reinforce the evidence of a shifting epidemiological pattern over the study period.

4.6 Public Health Interpretation

The observed trends over the ten-year period indicate important changes in the epidemiological profile, with clear public health implications. The early phase of the study was characterised

predominantly by STD-associated cases, whereas the later years showed a marked rise in IDU and the emergence of MSM and TRK categories. This transition reflects a shift in the dominant risk populations and suggests evolving transmission dynamics within the community.

The emergence and rapid increase of IDU cases after 2004 highlight injecting drug users as a growing high-risk population. The sharp rise culminating in the 2006 peak suggests a concentrated epidemic within this group. Similarly, the appearance of MSM and TRK categories in the later years indicates diversification of affected populations. Although their overall proportions remained lower than IDU, their emergence underscores the need to recognize and address newly identified vulnerable groups. The gradual increase in ante-natal cases also suggests a potential spill over into the general population, emphasizing the importance of routine screening and prevention strategies in maternal health services.

The shifting pattern from predominantly sexual transmission (as reflected by higher STD cases in early years) to increasing injection-related transmission suggests changes in underlying behavioural and social determinants. This epidemiological transition necessitates adaptation of prevention strategies. While early interventions may have focused primarily on sexual health education, condom promotion, and STD management, the later pattern calls for expanded harm-reduction strategies, including needle-syringe exchange programs, opioid substitution therapy, and targeted outreach for injecting drug users.

These findings also have implications for resource allocation. As the burden shifts toward specific high-risk groups, public health resources must be strategically redistributed to ensure effective targeting. Increased investment in community-based interventions, peer-led education programs, and specialized clinics for IDU and MSM populations may be required. Simultaneously, sustained efforts in STD control and ante-natal screening should continue to prevent resurgence and vertical transmission.

Finally, the emergence of new categories and fluctuating trends highlight the importance of strengthening surveillance systems. Continuous monitoring of risk group distribution, early detection of spikes, and timely data-driven responses are essential to prevent further spread. Enhanced data collection, integration of behavioural surveillance, and periodic epidemiological assessments would improve responsiveness to changing transmission patterns. While the findings demonstrate a dynamic and evolving epidemic. The transition from STD predominance to IDU dominance, along with the emergence of additional high-risk populations, underscores the need for adaptive, targeted, and evidence-based public health strategies supported by robust surveillance mechanisms.

5. Discussion

One of the most significant findings of this study is the clear transition in dominant transmission patterns over the decade. During the early phase (1998-2001), STD clinic attendees constituted the largest proportion of HIV-positive cases, reflecting a predominantly sexual mode of transmission. However, after 2004, injecting drug users (IDU) emerged as the leading risk group, peaking in 2006. This shift suggests a transformation in the underlying drivers of the epidemic in Kerala, highlighting the growing contribution of injection-related transmission in the later years. This shift aligns with findings from multiple studies that show injection drug use as a critical driver of HIV epidemics in various settings. Injection drug use is associated with both parenteral transmission through sharing contaminated needles and sexual transmission risks due to unsafe sexual practices among IDUs. While early assumptions considered needle sharing as the primary transmission route among IDUs, more recent evidence underscores the importance of sexual transmission among this group, necessitating prevention strategies that address both injection and sexual behaviours (Strathdee, 2003).

Studies have documented that IDUs frequently engage in high-risk sexual activities, thus facilitating bridging of the virus from injecting networks to the general population. For example, the sexual behaviour of IDUs often includes multiple partners, low condom use, and interaction with sex workers, which amplifies transmission risks (Pisani et al., 2003). Additionally, co-infections and STIs prevalent among these groups further enhance susceptibility to HIV transmission.

The finding that the epidemiological landscape in Kerala evolved from a sexually driven epidemic to one predominantly influenced by injection-related transmission is consistent with observations from other Asian and Eastern European contexts, where injection practices have become a leading source of new infections (Gouws & Cuchi, 2012). This transition signifies changing underlying social and behavioural drivers, such as increased availability of injectable drugs, changes in drug use patterns, and possibly variations in harm reduction service coverage and access.

Furthermore, the complexity of HIV transmission among IDUs is highlighted by genetic studies showing that IDUs may be infected by multiple viral variants due to high-risk injection practices, which complicates prevention and vaccine development efforts (Bar et al., 2010). Moreover, psychological and social factors, such as depression and violence, can influence risk behaviours among IDUs, indicating a need for comprehensive intervention programs addressing both biomedical and social determinants of risk (Perdue et al., 2003).

Effective responses to this epidemiological shift require integrated prevention strategies combining harm reduction for injection-related risks (e.g., needle exchange, opioid substitution therapy) with sexual risk reduction approaches (e.g., condom promotion, STI treatment). Structural interventions that address socio-economic vulnerabilities, stigma, and discrimination

faced by IDUs are also critical to reduce HIV transmission within this key population and beyond (Hilton et al., 2001; Kippax, 2008).

The epidemiological transition observed in Kerala from sexual to injection-related HIV transmission underscores the dynamic and context-specific nature of the epidemic. It highlights the growing importance of addressing injection drug use and associated sexual risks as central to effective HIV prevention efforts in the region (Gershon et al., 1990; Strathdee, 2003).

The absence of MSM, IDU, and TRK cases in the early years followed by their measurable contribution after 2004 indicates the emergence or improved identification of new vulnerable populations. The sharp rise in IDU cases and the transient spike in MSM cases suggest either changes in behavioural patterns, improved surveillance, or targeted screening initiatives. These findings underscore the importance of continuous surveillance to detect evolving risk groups in a timely manner.

The marked decline in STD cases after 2001 may reflect the impact of intensified HIV; prevention programs, improved STD management, condom promotion strategies, and behavioural change communication interventions implemented during the early 2000s. The reduction in STD-associated HIV positivity suggests that targeted sexual health interventions may have been effective. However, the simultaneous rise in IDU cases indicates that while sexual transmission may have been partially controlled, other transmission routes gained prominence. The emergence of new high-risk populations, such as men who have sex with men (MSM), injecting drug users (IDUs), and truckers (TRKs), appearing after 2004, likely reflects either the actual development of these vulnerable groups or improvements in surveillance and targeted screening practices. The initial absence of these groups in earlier years followed by their measurable contributions suggests enhanced identification methods and possibly shifts in behavioural patterns within the population. The transient spike in MSM cases and sharp rise in

IDU cases highlight dynamic epidemiological changes, underscoring the critical necessity for continuous and adaptive surveillance systems capable of timely detection of evolving risk groups to inform effective public health interventions.

Regarding the decline in sexually transmitted disease (STD) associated HIV cases after 2001, this trend strongly points to the impact of intensified HIV prevention programs implemented during the early 2000s. These programs likely included more comprehensive STD management, wider condom promotion coverage, and behavioural change communication efforts. Evidence from various behavioural intervention trials illustrates that structured HIV risk reduction programs can effectively reduce unprotected sexual acts, increase consistent condom use, and decrease STD symptoms among high-risk populations (Crepaz et al., 2007; "The NIMH Multisite HIV Prevention Trial: Reducing HIV Sexual Risk Behaviour. The National Institute of Mental Health (NIMH) Multisite HIV Prevention Trial Group." 1998). In addition, community-level interventions involving opinion leaders coupled with access to condoms and testing services have demonstrated potential for reducing sexual risk behaviours and HIV/STD incidences, even if direct impact varies by setting (Wu et al., 2010).

Consistent condom usage has been shown in population studies to significantly reduce HIV incidence and the prevalence of related STDs such as syphilis and gonorrhoea/chlamydia, reinforcing the importance of condom promotion programs alongside behavioural interventions (Ahmed et al., 2001). Furthermore, effective STD treatment programs have exhibited variable success based on population risk profiles, with higher impacts in populations with high rates of curable STDs, indicating that targeted STD management can contribute substantially to HIV prevention in appropriate contexts (Korenromp et al., 2005; White et al., 2004).

Despite these successes in controlling sexual transmission routes, the concomitant rise in IDU-associated cases reveals the emergence or amplification of other transmission pathways. This suggests that while sexual health interventions helped reduce HIV transmission linked to STDs, injection-related risks gained prominence, calling for specialized harm reduction strategies addressing IDU behaviours and broader structural challenges (Hilton et al., 2001; Marvel et al., 2009). Thus, HIV prevention programs need a multifaceted approach combining sexual risk reduction with interventions targeting injection drug use to comprehensively curb the epidemic's spread.

The observed decline in STD-associated HIV cases likely reflects effective earlier interventions targeting sexual transmission, while the emergence of new high-risk populations such as MSM and IDUs-whether through real epidemiological changes or improved detection-demonstrates the evolving nature of the epidemic. Continuous surveillance and adaptive prevention strategies, integrating both behavioural and biomedical approaches, remain essential to identify and mitigate risks across diverse populations effectively (O'Reilly & Piot, 1996).

The gradual increase in ante-natal clinic (ANC) positivity over the study period suggests potential spill over of infection into the general population. Although ANC prevalence remained relatively low compared to high-risk groups, its steady upward trajectory highlights the importance of routine antenatal screening and prevention of parent-to-child transmission (PPTCT) services. This finding may indicate broader community transmission beyond traditionally defined high-risk groups. The gradual increase in HIV positivity among antenatal clinic (ANC) attendees over the study period signals a potential spill over of HIV infection into the general population beyond traditionally defined high-risk groups. Although HIV prevalence in ANC populations remains relatively low compared to key populations such as sex workers or injecting drug users, the consistent upward trend highlights the importance of routine

antenatal screening and prevention of parent-to-child transmission (PPTCT) services as critical components of the public health response (Moses et al., 2008).

Studies from generalized epidemic contexts have validated the use of pregnant women attending ANC as a sentinel population for monitoring HIV trends in the broader community because ANC prevalence closely correlates with adult general population prevalence when adjusted appropriately (Gouws & Cuchi, 2012). Although ANC surveillance tends to slightly overestimate general population prevalence, it remains a valuable indicator for detecting increasing transmission at the population level (Gouws et al., 2008).

Evidence from intervention programs, such as intensive HIV prevention initiatives targeting female sex workers, has shown measurable impacts on reducing HIV prevalence not only in these core groups but also among ANC attendees, indicating that focused interventions can affect community-level transmission dynamics (Moses et al., 2008). However, the observed steady rise in ANC positivity underscores that despite these efforts, HIV transmission persists and may be expanding into the general population, indicating ongoing challenges in fully controlling the epidemic. Enhanced surveillance among pregnant women helps identify emerging trends and guides the allocation of resources for community-level prevention strategies.

Moreover, this pattern suggests that community transmission beyond recognized high-risk groups is occurring, perhaps driven by bridging populations or undetected heterosexual transmission networks. This broader community involvement aligns with observations from settings where maturity of the epidemic leads to more generalized transmission and emphasizes the need to broaden the scope of prevention beyond key populations (Gouws, Mishra, et al., 2008; Kwesigabo et al., 2000).

The gradual increase in ANC HIV positivity rates signals important epidemiological changes reflecting community-level transmission, which necessitates continued and enhanced antenatal screening, focused PPTCT programs, and wider population-based HIV prevention approaches to effectively curtail the epidemic's progress in the general population (Kwesigabo et al., 2000; Moses et al., 2008).

The observed epidemiological transition has significant programmatic implications. The rise in IDU cases emphasizes the need to strengthen harm-reduction strategies, including needle-syringe exchange programs, opioid substitution therapy, and targeted outreach interventions. At the same time, sustained efforts in sexual transmission prevention must continue to prevent resurgence. Resource allocation should be responsive to shifting epidemiological patterns, and surveillance systems must remain robust to detect emerging trends early. An adaptive, evidence-based public health response is essential to effectively address the evolving HIV epidemic in Kerala. Concurrently, sustained investment in sexual transmission prevention remains vital to avert resurgence, necessitating continued condom promotion, behavioural interventions, and management of sexually transmitted infections that can enhance HIV transmissibility. Antiretroviral treatment as prevention (TasP) and biological interventions lowering viral loads further contribute to reducing transmission risk across populations (Celum et al., 2005).

An adaptive, evidence-based public health framework is critical. This includes multidisciplinary collaboration blending epidemiological insights with social and behavioural sciences to design culturally sensitive, stigma-reducing interventions that address structural determinants influencing risk behaviours. While media and community engagement campaigns enhance awareness and promote safer practices.

5.1 Strategies for Public Health Planning

Based on the observed epidemiological shift from predominantly sexual transmission to increasing injection-related transmission in Kerala (1998-2007), the following strategic approaches are recommended for public health planning:

1. Strengthening Harm-Reduction Programs for Injecting Drug Users (IDU)

Given the marked rise and dominance of IDU cases in the later years, scaling up harm-reduction interventions should be a priority. This includes expansion of needle-syringe exchange programs (NSEP), opioid substitution therapy (OST), safe injection education, and community-based outreach services. Establishing targeted drop-in centres and peer-led interventions can improve service uptake and reduce high-risk behaviours among injecting drug users.

2. Sustaining and Reinforcing Sexual Transmission Prevention

Although injection-related transmission increased, sexual transmission remains a significant component of the epidemic. Continued emphasis on condom promotion, early detection and treatment of STDs, behavioural change communication (BCC), and targeted interventions for female sex workers (FSW) and men who have sex with men (MSM) is essential. Integrating HIV prevention with reproductive and sexual health services can enhance coverage and effectiveness.

3. Expanding Targeted Interventions for Emerging High-Risk Groups

The emergence of MSM and TRK categories highlights the need for inclusive and stigma-free services. Tailored outreach programs, community engagement, risk-reduction counselling, and improved access to testing and treatment should be strengthened. Policies must ensure confidentiality, non-discrimination, and accessibility to encourage early testing and linkage to care.

4. Enhancing Antenatal Screening and Prevention of Parent-to-Child Transmission (PPTCT)

The gradual rise in ante-natal clinic positivity suggests potential spread into the general population. Universal HIV screening in antenatal care settings should be reinforced, along with timely initiation of antiretroviral therapy (ART) for HIV-positive pregnant women. Strengthening PPTCT services will be critical in preventing vertical transmission and reducing paediatric HIV.

5. Improving Surveillance and Data Systems

Continuous, high-quality surveillance is vital to detect shifts in transmission patterns early. Strengthening HIV Sentinel Surveillance sites, integrating behavioural surveillance, and improving data management systems will enhance evidence-based planning. Periodic epidemiological reviews should inform resource allocation and program modification.

6. Strategic Resource Allocation

Resource distribution should reflect the evolving burden of disease. Increased funding and manpower allocation toward IDU-focused harm-reduction services may be necessary, while maintaining adequate support for sexual health programs. Cost-effective prioritization based on surveillance data will ensure optimal impact.

7. Community Engagement and Stigma Reduction

Stigma and discrimination remain barriers to testing and treatment, particularly among IDU and MSM populations. Public health planning should incorporate community mobilization, awareness campaigns, and partnerships with civil society organizations to foster supportive environments and improve healthcare access.

8. Integration of Services and Multi-sectoral Collaboration

Integrating HIV prevention with substance abuse treatment, mental health services, reproductive health services, and primary healthcare can improve continuity of care.

Collaboration between health departments, social services, law enforcement, and non-governmental organizations will strengthen comprehensive responses.

The epidemiological shift from sexual to injection-related HIV transmission, as observed in Kerala, reflects broader patterns identified in global and regional HIV research. Initially, HIV transmission in Kerala was predominantly driven by sexual contact, evidenced by the high proportion of HIV-positive cases among STD clinic attendees during 1998-2001. Over time, particularly post-2004 and peaking around 2006, injecting drug users (IDUs) became the major risk group, signalling a significant change in transmission dynamics.

6. Conclusion

This ten year analysis of HIV Sentinel Surveillance data from Kerala demonstrates a clear and evolving shift in the epidemiological pattern of HIV infection between 1998 and 2007. The early years of the epidemic were predominantly characterised by sexually transmitted infections, particularly among STD clinic attendees. However, a marked decline in STD-associated cases after 2001 coincided with the emergence and rapid rise of injecting drug users as the dominant risk group in the later years. By 2005-2007, injection-related transmission had become the principal contributor to the overall burden.

The appearance of MSM and TRK categories after 2004 further reflects diversification of affected populations and highlights the dynamic nature of the epidemic. Although ante-natal clinic positivity remained relatively low, its gradual increase suggests potential spread beyond traditional high risk groups into the broader community. Correlation and peak analyses support the evidence of a temporal transition from a predominantly sexually driven epidemic to one increasingly influenced by injection-related transmission.

These findings underscore the importance of adaptive public health strategies tailored to evolving transmission dynamics. While sustained efforts in sexual health promotion remain

essential, strengthened harm-reduction interventions targeting injecting drug users are critical to preventing further escalation. Continuous surveillance, early detection of emerging trends, and data-driven resource allocation will be vital to effectively controlling the HIV epidemic in Kerala.

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