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Temporal trends and regional inequalities in HIV incidence in Brazil, 2011-2024: a joinpoint regression analysis of sociodemographic patterns in the context of PrEP

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Abstract

Background

Brazil continues to face substantial challenges in HIV control, falling short of optimal targets and underscoring that HIV remains a major public health concern, even 40 years after its identification. Accordingly, this study aimed to assess temporal trends in HIV incidence among adults in Brazil across the pre- and post-implementation periods of pre-exposure prophylaxis within the public health system (2011–2024), stratified by sociodemographic and regional characteristics.

Methods

We conducted a retrospective ecological study using secondary data. Joinpoint and Jamovi software were used to analyze trends in HIV incidence across Brazil's macro-regions and to compare periods before and after pre-exposure prophylaxis implementation.

Results

The study found that the average HIV incidence in the country decreased by 14.3% following pre-exposure prophylaxis implementation. In contrast, the Central-West region exhibited an increase of 3.94% during the 2020–2024 period. Furthermore, the results indicate a disproportionate burden among key populations, such as Brown individuals and men who have sex with men. Additionally, unexpectedly, the study identified an increase in new cases among individuals with higher levels of education, as well as those aged 50–59 years.

Conclusions

The findings indicate that although pre-exposure prophylaxis implementation is associated with an overall reduction in HIV incidence in Brazil, its effects have not been evenly distributed across regions and population groups. Marked inequalities persist, highlighting the need for more targeted and context-specific strategies that address regional disparities and expand access to prevention, testing, and care, particularly among vulnerable and emerging populations in the evolving epidemiological landscape.

Background

It is estimated that approximately 40.8 million people are living with HIV (PLHIV) worldwide, including around 1.1 million in Brazil. The country has experienced a decline in HIV-related mortality; however, it continues to face stable or increasing rates of new infections [1]. HIV infection negatively impacts quality of life and individual productivity, while also contributing to social exclusion due to stigma and discrimination and exacerbating health inequalities [2, 3].

Given its epidemiological significance and the substantial burden placed on health systems, HIV/AIDS has been incorporated into major global development agendas, including the Millennium Development Goals (MDGs) and the Sustainable Development Goals (SDGs) established by United Nations Member States [4, 5]. Despite these efforts, Brazil continues to face considerable challenges, particularly regarding access to treatment, remaining below optimal targets and reinforcing that HIV persists as a major public health issue, even four decades after its identification [6].

Moreover, the HIV epidemic has also been affected by the COVID-19 pandemic, which caused substantial disruptions to HIV-related prevention, testing, and care services across multiple settings, directly influencing case detection and population behavior patterns [7, 8]. These impacts were heterogeneous, reflecting regional disparities and disproportionately affecting key populations, such as men who have sex with men (MSM), transgender individuals, sex workers, people who use drugs, and incarcerated populations [9, 10].

In this context, public health policies have been required to adapt services to emerging health technologies, as well as to ongoing social changes and shifts in population behavior and epidemiological profiles. One of the most important contemporary strategies has been the implementation of pre-exposure prophylaxis (PrEP) within Brazil's public health system (SUS) [11]. However, studies assessing the impact of PrEP on HIV incidence at the national level remain limited, particularly those focusing on sociodemographic and regional disparities.

Therefore, this study aims to analyze temporal trends in HIV incidence among adults in Brazil during the pre- and post-implementation periods of PrEP in the public health system (2011–2024), according to sociodemographic and regional population characteristics.

Methods

Study Design

This study is a retrospective ecological analysis based on secondary data collected from the Notifiable Diseases Information System (SINAN) and the Laboratory Test Control System (SISCEL), both integrated into the Informatics Department of the Brazilian Unified Health System (DATASUS), an agency affiliated with the Brazilian Ministry of Health. The study analyzes newly reported HIV cases between 2011 and 2024.

The selected time frame reflects the implementation of the National Policy for PrEP in Brazil, which began in December 2017. Accordingly, the analysis was divided into two periods: pre-PrEP implementation (2011–2017) and post-PrEP implementation (2018–2024).

Geographical scope and population

The study was conducted using nationwide data from Brazil, the largest country in South America, with a territorial area of 8,509,379.576 km² [12, 13]. The country is administratively divided into five macro-regions (North, Northeast, Southeast, South, and Central-West), comprising 26 states and the Federal District, with a population exceeding 200 million inhabitants [14]. These demographic and geographic characteristics make Brazil a highly relevant setting for epidemiological and public health research.

The study population consisted of adults aged 20–59 years, a group that accounted for 90.8% of new HIV infections during the study period. This age range was selected based on epidemiological evidence indicating a higher concentration of HIV transmission among young and middle-aged adults, particularly those who are sexually active and economically productive [15–17].

Variables

The dependent variable was the number of new HIV infections in Brazil between 2011 and 2024. Independent variables included year, region, sex, age group, race/skin color, educational attainment, and hierarchical HIV exposure category.

Inclusion and exclusion criteria

All newly reported HIV cases among adults aged 20–59 years, notified by health services between 2011 and 2024, were included. Records with inconsistencies or missing information in key study variables were excluded from the analysis.

Due to the secondary nature of the data, incomplete reporting by health professionals is common in notification systems. Therefore, for stratified analyses by sociodemographic characteristics and exposure category, records with missing or “ignored” information in these specific variables were excluded.

Statistical analysis

Data were organized and tabulated by the Brazilian macro-region using Microsoft Excel®. HIV incidence was calculated as the number of new cases divided by the resident population of each region and expressed as rates per 100,000 inhabitants. This standardization was adopted to minimize potential biases related to population size differences across regions. Both case counts and population estimates were restricted to adults aged 20–59 years. No adjustments for underreporting were performed.

Temporal trend analysis of incidence rates by macro-region was conducted using Joinpoint Regression® software (version 4.9.1.0, National Cancer Institute - NCI). This method fits segmented regression models on a logarithmic scale, allowing the identification of inflection points (joinpoints) at which statistically significant changes in trends occur over time [18].

Annual Percent Change (APC) was estimated for each identified segment, and Average Annual Percent Change (AAPC) was calculated for the entire study period. Both measures were presented with 95% confidence intervals (95% CI) and statistical significance testing, adopting a significance level of 5% ($p < 0.05$). The final model was selected based on the Monte Carlo permutation test.

Additionally, a descriptive table was constructed to present the annual evolution of HIV incidence rates in Brazil, expressed as cases per 100,000 inhabitants, from 2011 to 2024. To assess potential changes associated with the implementation of PrEP in the Brazilian Unified Health System, comparisons were performed between two time periods: pre-PrEP (2011–2017) and post-PrEP (2018–2024), using descriptive and comparative analyses.

The Jamovi software (version 2.3.28) was used to support statistical analyses due to its accessibility and reproducibility, enabling descriptive statistics, inferential tests, and modeling procedures, as well as its integration with the R programming language, ensuring transparency and robustness in the analytical process [19].

Finally, the proportional distribution of reported HIV cases among adults was analyzed according to sociodemographic characteristics and hierarchical exposure category, comparing the periods 2011–2017 and 2018–2024. These analyses were conducted in Microsoft Excel®, with results presented as absolute and relative frequencies. Graphical visualization was performed using GraphPad Prism (version 11.0.0), through slope charts, which were used to compare proportional changes in HIV case distribution between the pre- and post-PrEP periods.

Ethical considerations

As this study used aggregated, non-sensitive, and publicly available data without individual-level identifiers, ethical approval from a Research Ethics Committee was not required, in accordance with the guidelines established by Resolution No. 510/2016 [20].

Results

Figure 1 presents the temporal trend analysis of HIV incidence rates in Brazil and its macro-regions from 2011 to 2024, estimated using Joinpoint regression. During this period, the country recorded more than 476,000 new HIV cases. An overall decreasing trend in incidence rates was observed between 2011 and 2020, with a statistically significant annual decline (APC = − 3.16%). However, from 2020 onwards, an inflection point was identified, although not statistically significant, indicating an upward trend through 2024 (APC = 1.83%).

Figure 1. Temporal trends in HIV incidence rates (per 100,000 inhabitants) in Brazil and its macro-regions, 2011–2024, estimated using Joinpoint regression. Brazil, 2026.

Similar patterns were observed in the Southeast and South regions, where statistically significant declines in incidence were detected up to 2020 (APC = − 4.54 and − 5.65, respectively), followed by

increasing trends in the subsequent period. In contrast, the Central-West region showed a significant decline in incidence between 2011 and 2020 (APC = − 1.71%), followed by a reversal in trend and a significant increase from 2020 to 2024 (APC = 3.94%), representing the highest annual increase among all regions after 2020.

Table 1 summarizes the results of the Joinpoint regression analysis of HIV incidence rates in Brazil and its macro-regions, highlighting statistically significant changes in trends over the study period.

Table 1
Joinpoint® regression analysis of HIV incidence rates in Brazil and its macro-regions, 2011–2024. Brazil, 2026.

Local	Joinpoint®	Period	APC[1]	Lower	Upper	AAPC[2]	Lower	Upper
Brazil	2020	2011 to 2020	-3,2*	-8,2	-1,4	-1,7*	-2,8	-0,8
		2020 to 2024	1,8	-2,2	9,8			
North	-	2011 to 2024	0,8	-0,7	2,4	-	-	-
Northeast	-	2011 to 2024	-0,4	-1,7	0,8	-	-	-
Southeast	2020	2011 to 2020	-4,5*	-6,8	-3,6	-2,7*	-3,5	-2,0
		2020 to 2024	1,7	-1,8	9,0			
South	2020	2011 to 2020	-5,6*	-9,6	-4,3	-3,5*	-4,7	-2,6
		2020 to 2024	1,4	-3,1	10,7			
Midwest	2020	2011 to 2020	-1,7*	-6,4	-0,5	0,0	-1,2	1,0
		2020 to 2024	3,9*	0,1	12,7			

[1]annual percentage change; [2]average annual percentage change

*Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha level of 0.05

Table 1. Joinpoint® regression analysis of HIV incidence rates in Brazil and its macro-regions, 2011–2024. Brazil, 2026.

Table 2 presents the annual evolution of HIV incidence rates in Brazil, expressed as cases per 100,000 inhabitants, from 2011 to 2024, as well as a comparison between two distinct periods of the time series: before and after the implementation of PrEP in the Brazilian Unified Health System.

Table 2
Annual trends in HIV incidence rates in Brazil (per 100,000 inhabitants) and comparison of mean rates between the pre-PrEP (2011–2017) and post-PrEP (2018–2024) periods. Brazil, 2026.

Year	Incidence (cases/100,000)	Average ± SD (cases/100,000)	Mean difference (CI95%)	t (gl)	p-value
2011	33.35	31.5 ± 1.7	4.5 (2.29–6.71)	4.43 (12.0)	< 0.001
2012	32.85				
2013	32.85				
2014	31.90				
2015	30.89				
2016	29.65				
2017	29.00				
2018	28.91	27.0 ± 2.08			
2019	28.59				
2020	22.71				
2021	26.34				
2022	27.32				
2023	27.88				
2024	27.26				

Table 2. Annual trends in HIV incidence rates in Brazil (per 100,000 inhabitants) and comparison of mean rates between the pre-PrEP (2011–2017) and post-PrEP (2018–2024) periods. Brazil, 2026.

A reduction in the mean incidence rate was observed, decreasing from 31.5 to 27.0 cases per 100,000 inhabitants, representing a 14.3% decline following PrEP implementation. The comparison between the two periods revealed a mean difference of 4.5 cases per 100,000 inhabitants (95% CI: 2.29–6.71), which was statistically significant, as indicated by Student's t-test ($t = 4.43$; $df = 12$; $p < 0.001$).

Table 3 presents the proportional distribution of reported HIV cases among adults according to sociodemographic characteristics and hierarchical exposure category, comparing the periods 2011–2017 and 2018–2024. These data are also illustrated in Fig. 2.

Table 3
Proportional distribution of reported HIV cases among adults according to sociodemographic characteristics in the pre-PrEP (2011–2017) and post-PrEP (2018–2024) periods. Brazil, 2026.

Variable	2011–2017 (%)	2018–2024 (%)
Sex		
Male	68.05	72.63
Female	31.95	27.37
Age range		
20–29 years	27.13	28.31
30–39 years	34.38	31.99
40–49 years	25.05	25.02
50–59 years	13.44	14.69
Skin color		
White	45.53	37.77
Black	9.03	9.67
Yellow	0.82	1.28
Brown	44.38	50.91
Indigenous	0.25	0.37
Educational attainment		
Illiterate	3.09	2.28
Incomplete primary education	37.59	28.30
Completed primary and incomplete secondary education	21.92	22.30
Completed secondary education and incomplete higher education	26.51	34.35
Completed higher education	10.89	12.78
Hierarchical exposure category		
Homosexual	25.29	31.21
Bisexual	6.36	7.11
Heterosexual	64.45	58.27
IDU	3.21	2.19

Variable	2011–2017 (%)	2018–2024 (%)
Sex		
Vertical transmission	0.68	1.22

Table 3. Proportional distribution of reported HIV cases among adults according to sociodemographic characteristics in the pre-PrEP (2011–2017) and post-PrEP (2018–2024) periods. Brazil, 2026.

Figure 2. Changes in the sociodemographic profile of HIV cases before and after PrEP implementation in Brazil.

The findings indicate a process of increasing male predominance in the HIV epidemic in Brazil, with a higher proportion of reported cases among men following PrEP implementation. Men accounted for 68.05% of cases in the first period (2011–2017), corresponding to a ratio of approximately 2.13 men for every woman. In the subsequent period (2018–2024), this disparity intensified, with 72.63% of cases occurring among men, increasing the ratio to approximately 2.65:1.

Regarding age groups, a higher concentration of cases was observed among individuals aged 30–39 years in both periods, although with a decrease of 2.39 percentage points. Conversely, an increase in the proportion of new cases was identified among individuals aged 20–29 years and 50–59 years.

In terms of race/skin color, a notable increase was observed among individuals self-identifying as Brown (pardo), with a rise of 6.5 percentage points, while the proportion of cases among White individuals decreased by 7.76 percentage points, indicating widening racial disparities.

With respect to educational attainment, a substantial increase was observed among individuals with higher levels of education, particularly those with completed secondary education and incomplete higher education (increase of 7.84 percentage points), who became the predominant group affected by HIV after PrEP implementation, highlighting the need for targeted interventions for this population. In contrast, individuals with incomplete primary education, who previously represented the most affected group before PrEP, showed a reduction of 9.29 percentage points following the policy implementation.

Regarding hierarchical exposure category, a decrease in the proportion of cases attributed to heterosexual exposure was observed (from 64.45% to 58.27%), accompanied by a marked increase in the proportion of cases among men who have sex with men (MSM) (from 25.29% to 31.21%). This pattern reflects a shift in the transmission profile, with a greater concentration of cases among key populations historically more vulnerable to HIV infection.

Discussion

The findings of this study demonstrate a declining trend in HIV incidence in Brazil and most macro-regions up to 2020, followed by an inflection or resurgence in rates in the post-2020 period, with varying

magnitudes and levels of statistical significance across regions. This temporal pattern suggests the coexistence of structural advances in HIV control, particularly before 2020, and more recent challenges that appear to have undermined the sustainability of these gains, highlighting the fragility of progress in the absence of sustained and adaptive public health responses.

This shift temporally coincides with the onset of the COVID-19 pandemic, which has been widely documented as a disruptive force across health systems globally. Evidence from Brazil and other middle-income settings indicates that the pandemic severely disrupted HIV epidemiological surveillance and service delivery, generating a “rebound effect” in subsequent years as health services were gradually restored [21, 22]. Importantly, this rebound should be interpreted cautiously, as the observed increase may reflect a combination of delayed diagnoses, accumulated unmet demand for testing, and partial recovery of surveillance capacity, rather than a purely biological increase in transmission.

The temporal analysis revealed pronounced regional heterogeneity, with stable or slightly increasing trends in the North and Northeast, contrasting with more consistent reductions observed in the Southeast and South until 2020. These disparities are not merely epidemiological but reflect deeper structural inequities. Regions characterized by greater socioeconomic deprivation, lower primary healthcare coverage, and higher concentrations of key populations are systematically more vulnerable to sustained HIV transmission [23, 24]. Such inequities underscore the persistent misalignment between the geographic distribution of need and the allocation of health system resources.

In this context, the increase in HIV incidence in the North and Northeast regions may be understood as the result of intersecting structural and behavioral drivers, including rapid and unplanned urbanization, persistent barriers to healthcare access, chronic underfunding of health systems, and entrenched stigma and discrimination. Evidence from subnational studies, such as those conducted in Bahia, suggests that urban concentration and social vulnerability interact to amplify the transmission of sexually transmitted infections, including HIV [25]. These findings point to the need for urban health strategies that explicitly address spatial and social determinants of transmission.

Conversely, the sustained decline in HIV incidence and mortality in the Southeast likely reflects a more resilient health system infrastructure, characterized by broader primary care coverage, greater availability of specialized services, and more mature public health policies. The case of São Paulo, historically a pioneer in HIV/AIDS policy, illustrates how early investment, institutional capacity, and financial resources can translate into sustained epidemiological gains [26, 27]. However, these regional successes also risk obscuring national-level inequalities if not interpreted within a broader equity framework.

The role of social determinants is particularly salient in the context of HIV, a condition deeply embedded in social, economic, and political structures [28]. Factors such as living conditions, access to timely and culturally appropriate healthcare, stigma, discrimination, and human rights violations remain central drivers of vulnerability and inequity [29–31]. As such, biomedical interventions alone are unlikely to

achieve sustained reductions in incidence without parallel investments in structural and social interventions.

Consistent with this perspective, historically marginalized populations, including men who have sex with men, people who use drugs, transgender individuals, and women experiencing violence, remain disproportionately affected. The persistence of these disparities reflects not only differential exposure risk but also systemic barriers to prevention, testing, and care, reinforcing stigma and social exclusion as central obstacles to effective HIV control [29–31].

The observed shifts in sociodemographic profiles further complicate the epidemiological landscape. The increasing proportion of cases among men reinforces the ongoing masculinization of the epidemic, a phenomenon strongly associated with transmission dynamics among MSM [15, 16]. Notably, while PrEP implementation has predominantly reached young, urban, and more educated men, the present findings suggest that these same groups are experiencing rising incidence, raising critical questions about adherence, risk compensation, and gaps in prevention coverage.

Brazil's longstanding commitment to universal and free antiretroviral therapy has been instrumental in reducing HIV-related mortality and improving survival outcomes [32]. Nevertheless, the persistence of new infections highlights a fundamental limitation of treatment-centered approaches: while essential, they are insufficient to interrupt transmission in contexts marked by structural vulnerability and unequal access to prevention.

The introduction of PrEP in 2017 represents a pivotal advancement in Brazil's HIV response; however, its population-level impact appears to be uneven and context-dependent. The comparison between pre- and post-PrEP periods suggests that the benefits of PrEP are mediated by coverage, adherence, and effective targeting of key populations. Evidence from other settings indicates that PrEP achieves maximal impact when embedded within comprehensive prevention frameworks that include widespread testing, stigma reduction, and integration with primary and specialized care [15, 17]. The absence of these enabling conditions may partially explain the heterogeneous effects observed in this study.

Importantly, the findings indicate that the expansion of PrEP has not yet translated into reductions in racial disparities in HIV incidence. This underscores the need for explicitly equity-oriented strategies that prioritize underserved populations, expand access through decentralized and community-based models, and address structural barriers to care. Without such efforts, there is a risk that biomedical innovations may inadvertently widen existing inequalities.

At the global level, disparities in access to HIV prevention and treatment remain stark. While high-income countries have achieved near-universal treatment coverage, access in low- and middle-income settings has historically lagged, contributing to a disproportionate burden of HIV in developing regions [33]. Although progress has been made, these global inequities continue to shape national epidemics and constrain the effectiveness of local responses.

Comparative evidence highlights that sustained reductions in HIV incidence are achievable, as demonstrated in high-income settings such as the United States and Western Europe, where combined prevention strategies have been scaled up effectively [34, 35]. Similarly, in Southern Africa, large-scale implementation of antiretroviral therapy and community-based interventions has yielded significant declines, albeit with persistent intra-country disparities [36]. These experiences underscore that success depends not only on the availability of effective tools but also on the strength and equity of their implementation.

Brazil's alignment with the "Test and Treat" strategy represents an important step; however, in a country marked by profound regional and social inequalities, this approach must be complemented by interventions targeting structural and behavioral determinants, particularly among key populations [37]. Failure to do so may limit the long-term effectiveness of national HIV control efforts.

Persistent challenges, including unequal service distribution, fragmentation of prevention strategies, and weak integration between surveillance, primary care, and specialized services, continue to hinder progress [38]. Addressing these gaps will require not only technical adjustments but also systemic reforms aimed at strengthening health system integration and governance.

From a policy perspective, the findings reinforce the importance of decentralizing and integrating HIV services, particularly through the expansion of PrEP delivery within primary healthcare settings. The involvement of general practitioners and nurses, alongside the adoption of integrated care models, has been shown to improve access, uptake, and continuity of care [39–41]. Innovations such as telemedicine further offer opportunities to expand reach, particularly in underserved areas, although their implementation must be carefully managed to avoid exacerbating digital inequalities [42].

Ultimately, achieving sustained and equitable reductions in HIV incidence in Brazil will require a comprehensive approach that integrates biomedical, behavioral, and structural interventions, grounded in a strong equity framework and responsive to regional and population-specific needs.

This study has limitations inherent to its ecological design and reliance on secondary data, including potential underreporting, reporting delays, inconsistencies in data quality, and regional variation in information systems. Nonetheless, the findings provide important insights into the evolving dynamics of the HIV epidemic in Brazil and highlight critical priorities for policy and research. Strengthening surveillance systems, expanding equitable access to PrEP, and aligning national strategies with global development goals will be essential to advancing HIV control in the coming years.

Conclusion

This study examined temporal trends in HIV incidence in Brazil and across its macro-regions, demonstrating that the national average incidence declined following the implementation of PrEP. However, epidemiological patterns were not homogeneous across regions, revealing important territorial

disparities. In addition, shifts in the sociodemographic profile were observed, with a greater concentration of cases among men, younger adults, Black populations, and priority exposure categories.

From a public health policy perspective, these findings underscore the need to strengthen equity-oriented approaches, including the expansion of PrEP access, decentralization of prevention strategies, and their integration into primary healthcare, particularly in more vulnerable regions. Such measures are critical to achieving the targets established under the Sustainable Development Goals by 2030.

Furthermore, strengthening epidemiological surveillance systems is essential, including improving data quality and ensuring continuous monitoring of regional trends. Finally, further longitudinal studies and qualitative approaches are warranted to deepen the understanding of these findings and the barriers to accessing prevention and care strategies, thereby contributing to more effective and context-sensitive public health responses.

Abbreviations

AAPC
Average Annual Percent Change
APC
Annual Percent Change
CI
Confidence Interval
COVID
19–Coronavirus Disease 2019
DATASUS
Department of Informatics of the Brazilian Unified Health System
HIV
Human Immunodeficiency Virus
MDGs
Millennium Development Goals
MSM
Men Who Have Sex with Men
NCI
National Cancer Institute
PLHIV
People Living with HIV
PrEP
Pre–Exposure Prophylaxis
SDGs
Sustainable Development Goals
SINAN

Notifiable Diseases Information System
SISCEL
Laboratory Test Control System
STIs
Sexually Transmitted Infections
SUS
Brazilian Unified Health System

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

K.T.S.C. conceived and designed the study, performed data extraction, statistical analysis, and drafted the manuscript. R.A.R.S. supervised the study and critically revised the manuscript for important intellectual content. I.A.R.C. and S.M.C.S.D. provided methodological guidance and critically revised the statistical methods section during the revision process. All authors reviewed the manuscript.

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Data Availability

Data were deposited into the Notifiable Diseases Information System (SINAN) and the Laboratory Test Control System (SISCEL) and are available at the following URL: http://www2.aids.gov.br/cgi/deftohtm.exe?tabnet/br.def.

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Figures

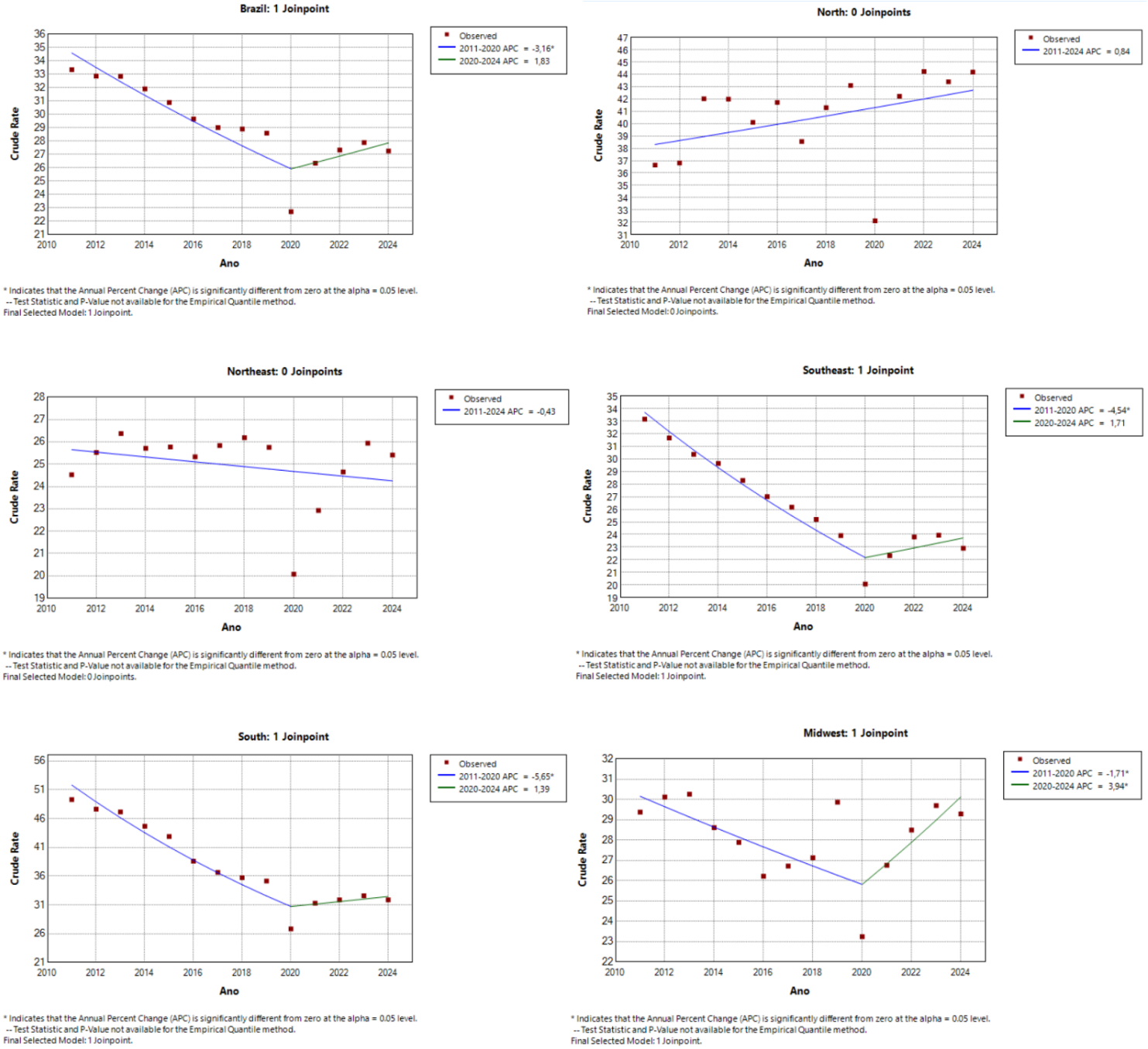


Figure 1

Temporal trends in HIV incidence rates (per 100,000 inhabitants) in Brazil and its macro-regions, 2011-2024, estimated using Joinpoint regression. Brazil, 2026.

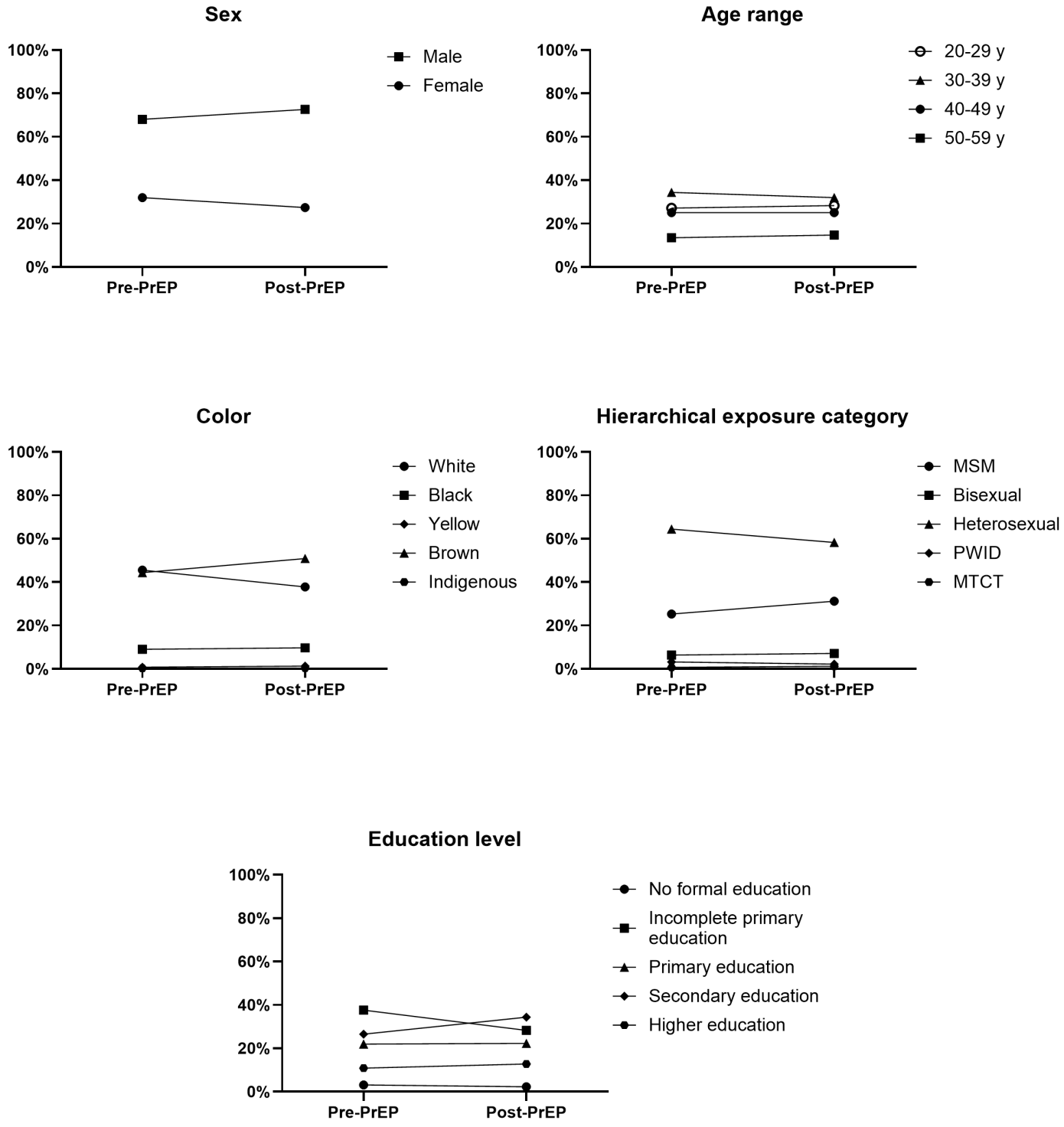


Figure 2

Changes in the sociodemographic profile of HIV cases before and after PrEP implementation in Brazil.