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Research article

An analysis on the trend of AIDS/HIV incidence in Chongqing and Shenzhen, China from 2005–2015 based on Age-Period-Cohort model

Ying Liu[1,†], Weidong Ji[2,†], Yi Yin[3,†], Zhengrong Yang[4], Shu Yang[5], Chao Zhou[6], Yongli Cai[1], Kai Wang[7,*], Zhihang Peng[3,*], Daihai He[8] and Weiming Wang[1,*]

[1] School of Mathematics and Statistics, Huaiyin Normal University, Huaian, 223300, China
[2] Zhongshan School of Medicine, Sun Yat-sen University, Guangzhou 510080, China
[3] Department of Epidemiology and Biostatistics, School of Public Health, Nanjing Medical University, Nanjing 211166, China
[4] Shenzhen Center for Disease Control and Prevention, Shenzhen 518055, China
[5] Chengdu university of traditional Chinese medicine, Chengdu 610075, China
[6] Chongqing Municipal Center for Disease Control and Prevention, Chongqing 400042, China
[7] College of Medical Engineering and Technology, Xinjiang Medical University, Urumqi 830011, China
[8] Department of Applied Mathematics, Hong Kong Polytechnic University, Hong Kong SAR, China
[†] These authors contributed equally.

* **Correspondence:** Email: wangkaimath@sina.com (K. Wang), zhihangpeng@njmu.edu.cn (Z. Peng) and weimingwang2003@163.com (W. Wang).

Abstract: This paper elucidates that the AIDS/HIV incidence rate differences exist among different population and regions, especially among the old and college students. Due to the effect of age, the AIDS incidence peak in males aged 20–35 years and 50 years old both in Chongqing and Shenzhen, and the incidence rate and increasing spread in males was higher than that of females under period effect. In the local population in Chongqing and Shenzhen, the incidence rate of males in over 40, below and in the whole age groups are predicted to increase sharply in the future six years, while in females, the incidence rates among over 40-year-old and the whole age groups were predicted to increase as well. The incidence rate among homosexually transmitted patients reaches the peak in the 20–35, the incidence rate of patients transmitted through heterosexual reaches the peak around 50-year-old. Under the effect of period, AIDS/HIV incidence rate of patients transmitted through sexual routes showed an upward trend both in Chongqing and Shenzhen. The incidence rate of patients aged between 41 and 70 years old presents with an upward trend in the future six years. The results show great differences exist in the AIDS/HIV incidence between males and females, therefore it is necessary to take specific measures respectively.

Keywords: AIDS/HIV; age effect; periodic effect; cohort effect; prediction

1. Background

Human immunodeficiency virus (HIV)/acquired immunodeficiency syndrome (AIDS) remains a major global public health problem. Up to 2018, 77.3 million people have been infected with HIV and 35.4 million people have died of AIDS related diseases [1]. HIV can destroy T lymphocytes of human immune system, making the body unable to resist other virus/bacterial infection, leading to various diseases or death [2]. The main transmission routes of AIDS include blood transmission, sexual contact transmission and mother to child transmission (vertical transmission). Although the number of people infected with HIV decreased by 36% and the number of HIV related deaths decreased by 38% between 2000 and 2017, the number of people living with HIV increased by 14% between 2010 and 2017, indicating that the HIV/AIDS epidemic is still on the rise [1]. Although existing antiretroviral therapy (ART) and methadone maintenance therapy (MMT) have successfully extended life expectancy, no treatment or prevention can prevent the progression of the disease.

HIV spreads rapidly in China. According to reports, as of December 31, 2017, China has accumulated 75.6 million people infected with HIV, and 2.39 million new people infected with HIV. In China, HIV infection through sexual transmission has been increasing steadily, from nearly 40% in 2006 to 97% in 2017, among which the transmission between men who have sex with men(MSM) is an important way [3]. The proportion of infections transmitted by MSM increased significantly from 3.4% in 2007 to 25.5% in 2017. In China, there is a significant difference between the geographical trend and the different routes of transmission of HIV epidemic [4]. According to the epidemic situation of HIV/AIDS, Qian et al. [5] identified six geographical epidemic areas in China, among which Chongqing, Guizhou and Sichuan belong to the same cluster. In recent years, their epidemic has changed from intravenous drug use to sexual transmission. Shenzhen, Beijing, Tianjin, Jiangsu, Zhejiang, Shanghai and Guangdong constitute a cluster. In the past few years, the prevalence has expanded from heterosexual transmission to MSM transmission [5]. Although studies show that the AIDS incidence of males is higher than that of females [6, 7], there are few researches concentrated on its characteristics.

Chongqing and Shenzhen are located in different geographical locations with various AIDS epidemic conditions [5]. Chongqing is the largest municipality, the political and economic center of southwest China, as well as one of the hot spots of AIDS in China. Studies have shown [8] that during the period 2007–2012, the number of new HIV infections in Chongqing increased at an average annual rate of 19.7%, which was much higher than the national average growth rate (3.130%). Shenzhen is a major city in Guangdong Province, which is the first special economic zone in China, attracting 3.72% of the national floating population. It is estimated that there are 100,000 men who have sex with men in Shenzhen [9]. Therefore, in order to further understand the characteristics of the AIDS incidence in different regions of China, we selected Chongqing and Shenzhen as the representative cities, and conducted the following series of studies.

Inspired by Wu et al. [10], we collected data from multiple sources. We combined these data to develop an APC model from different perspectives to distinguish the impact of the age structure, historical trends and birth cohort on the incidence of AIDS from an epidemiological perspective. Then we used fitted APC model to predict the future trend of its incidence. Specifically, we assessed AIDS incidence rate under the effect of age and birth cohort in Chongqing and Shenzhen during 2005–2015, and studied the heterogeneity of incidence rate risk in different genders. We characterize the AIDS incidence rate based on three transmission routes (homosexual, heterosexual, drug-injection and others) in specific patients group.

2. Materials and methods

2.1. Data sources

In this study, we collect data of Chongqing and Shenzhen from NCAIDS and CRIMS, and download the data of HIV/AIDS cases (including sex gender, date of birth, confirmed date, route of infection, current address, household registration and other information) reported in Chongqing and Shenzhen from 2005 to 2015. Baseline information is from Statistical Yearbook of Chongqing and Shenzhen. From the statistical yearbook, we collect the detailed age group population of the 2010 permanent population census of the two cities, the total population of the two cities from 2005 to 2015, and a relatively rough age group (0–14 years old, 15–64 years old, and above 65 years old) of the total permanent population of Chongqing.

Because we couldn't get the baseline population data in Chongqing and Shenzhen with an age interval of 1 from 2005 to 2015, we estimated the above data indirectly by querying the population data in the 2005–2015 statistical yearbooks of the two cities.

In order to calculate the exact number of permanent residents with an age interval of 1 year between males and females in Chongqing and Shenzhen over the years,we performed the following processing:

(1) For permanent population of Shenzhen

Firstly, we apply the detailed age group proportion of the 2010 permanent population census to the total population of 2005–2015, so as to calculate the detailed age group population of the total permanent population of 2005–2015. Secondly, we consult the 2005–2015 Shenzhen statistical yearbook, and there is no detailed population of male and female permanent residents between 2005 and 2015, only the number of registered residence of male and female over the years. So we apply the proportion of registered residence male and female in the total population data of 2005–2015 years to estimate the resident population of Shenzhen. We further apply the proportion of detailed age groups of male and female in the 2010 permanent population census to the permanent population data in the calendar year 2005–2015, so as to calculate the detailed age group population of permanent population in both genders.

(2) For permanent population of Chongqing

We calculate the detailed age group population of the total population in 2005-2015: first, we look up *Chongqing statistical yearbook* in 2005–2015, and collect a relatively rough age group (0–14 years old, 15–64 years old, and over 65 years old) of the total resident population. Second, we calculate the total population of the three age groups of the total population (0–14 years old, 15–64 years old, and over 65 years old) in the 2010 census, and then calculate the proportion of the detailed age groups in the three age groups. Thirdly, we apply the proportion of each detailed age group in the three age groups to the relatively rough age group of the permanent population. Thus the detailed age group population of the total resident population from 2005 to 2015 is obtained.

2.2. *Statistical analysis*

As we all know, the epidemiological characteristics of diseases are closely related to age, period and birth cohort. Age effect reflects biological factors. The period effect reflects the factors that directly affect the incidence rate or mortality rate of the disease (such as the implementation of effective treatment or further development of screening work). The cohort effect reflects the influence of different generations of different risk factors [11]. APC model is widely used in cancer incidence rate and mortality research [12, 13, 15, 16, 21], but it is rarely applied in chronic infectious diseases such as hepatitis B, tuberculosis and AIDS. Therefore, the application of APC model in the study of chronic infectious diseases in China may have great significance for disease prevention and monitoring. APC model was a statistical method based on Poisson distribution, which can be used to extract key information from disease data and explore the risk of disease [17].

According to Willekens(1993) [18], APC model was fitted by logistic regression:

$$\mu_{xtk} = e \cdot a_x \cdot b_t \cdot c_k,$$

where μ_{xtk} is the system component, showing the influence of the X age group, the t cycle, and the k cohort(set$\{x, t, k\}$). a_x represents the parameter of age x^{th}, b_t represents the parameter of period t^{th}, c_k refers to the parameter of cohort k^{th}. By placing natural logarithms on both sides, a logarithmic linear regression function can be obtained:

$$y_{xtk} = \ln \mu_{xtk} = \ln e + \ln a_x + \ln b_t + \ln c_k.$$

The regression function can be converted to the following function:

$$y_{xtk} = \beta_1 x_{xtk1} + \beta_2 x_{xtk2} + \beta_3 x_{xtk3} + \beta_4 x_{xtk4},$$

among which x_{xtkj} is a pseudo-variable, if j^{th} beta parameter is related to the age-period-queue category, x_{xtkj} will be equal to 1. Therefore, we improve its function

$$y_{xtk} = \ln \mu_{xtk} = \sum_{j=1}^{N} \beta_j x_{xtk,j},$$

where μ_{xtk} is the system composition, refers to the age group X, the period t, and the influence of the cohort k (set $\{x, t, k\}$), β_j refers to the effect of N unknown parameters (currently three), $x_{xtk,j}$ is the pseudo variable of set $\{x, t, k\}$ and j.

We build the APC model by setting an age interval of one year and a calendar interval of one year. For the AIDS data of Chongqing, we gather the first 15 age groups (0–14) in a set and classified them as under 15 years old, and gather the age groups over 70 years old in a set, that is, classify them as over 70 years old. For the AIDS data of Shenzhen, we gather the first 15 age groups (0–14) in a set and classify them as under 15 years old, and gather the age groups over 60 years old in a set and classify them as over 60 years old.

Firstly, we use the APC model of Poisson distribution to describe the data of AIDS incidence in Chongqing and Shenzhen. Secondly, we further analyze the annual incidence rate of the single age group of HIV transmitted in three different routes. We select the most suitable APC model [19] by minimizing the bias and Akaike information criteria (AIC), and conduct 100 bootstrapping data for the whole dataset. Each sample was fitted with APC model to check the sensitivity and fitting performance of the final APC model. Finally, we apply vector autoregression (VAR) to APC model and predict the incidence rate of AIDS for future 6 years.

All analyses, data visualization, and models are programmed in **R** (version 4.0.4). The package "apc" in **R** is used to fit the APC model and to predict future trends.

3. Results

3.1. Descriptive analysis of AIDS incidence rate

Table 1 summarizes the AIDS incidence condition through three different transmission routes in Chongqing and Shenzhen. It can be seen that during 2005–2015, there are totally 42595 confirmed AIDS cases in Chongqing and Shenzhen, including 33500 male patients and 9095 female patients. For the two cities, there are 32477 AIDS patients in Chongqing and 10118 AIDS patients in Shenzhen. The incidence of AIDS through different transmission routes are: 26101 cases of heterosexual transmission, 11332 cases of homosexual transmission, 5162 cases of other transmission routes. In terms of gender, both in Chongqing and Shenzhen, the AIDS number of men is far higher than that of women. In terms of age, among the people suffering from AIDS in Chongqing and Shenzhen, the number of young people aged 21–35 is the highest.

Table 1. Table 1 Data description of AIDS incidence in Chongqing and Shenzhen from 2005 to 2015.

Region	Variable	Heterosexual transmission (N=26101)		Homosexual transmission (N=11332)		Other transmission (N=5162)	
		no.	%(95%CI)	no.	%(95%CI)	no.	%(95%CI)
Gender							
Chongqing	Male	14736	68.43(67.80–69.05)	6761	99.99(99.92–100.00)	3265	78.11(76.83–79.36)
	Female	6799	31.57(30.95–32.20)	1	0.01(0.004–0.08)	915	21.89(20.64–23.17)
Shenzhen	Male	3350	73.37(72.06–74.65)	4570	100.00(—)	818	83.30(80.82–85.58)
	Female	1216	26.63(25.35–27.94)	0	0.00(—)	164	16.70(14.42–19.18)
Age groups							
Chongqing	0–20	481	2.19(2.00–2.39)	753	11.14(10.40–11.91)	223	5.28(4.63–6.00)
	21–35	4926	22.41(21.86–22.97)	4014	59.36(58.18–60.53)	1913	45.33(43.82–46.85)
	36–50	6893	31.36(30.75–31.98)	1539	22.76(21.76–23.78)	1718	40.71(39.22–42.21)
	Over 50	9678	44.03(43.38–44.69)	456	6.74(6.16–7.37)	366	8.67(7.84–9.56)
Shenzhen	0–20	133	2.91(2.44–3.44)	249	5.45(4.81–6.15)	60	6.11(4.69–7.80)
	21–35	2598	56.90(55.45–58.34)	3262	71.38(70.04–72.69)	577	58.76(55.61–61.86)
	36–50	1394	30.53(29.20–31.89)	945	20.68(19.51–21.88)	309	31.47(28.57–34.47)
	Over 50	441	9.66(8.82–10.55)	114	2.49(2.06–2.99)	36	3.67(2.58–5.04)

3.2. APC analysis on incidence of AIDS in Chongqing and Shenzhen

Figures 1 and 2 show the estimated impact of age, period and birth cohort on the incidence of AIDS in Chongqing and Shenzhen, as well as the corresponding prediction trend. We establish APC models for Chongqing and Shenzhen, respectively.

The incidence rate of male AIDS was significantly affected by age effect both in Chongqing and Shenzhen, the peak appear in 20–35-year-old group and 50-year-old group. The incidence rate of females was lower than that of males in the whole age range. The incidence rate of AIDS was significantly affected by age effect among the females aged 20–35 years old and over 46 years old in Chongqing. For Shenzhen, the age effect had a significant impact on the incidence rate of AIDS in females of about 50 years old.

Overall, the incidence rate of males was significantly higher than that of females. During the study period, the incidence rate of male population in Chongqing increased sharply from 2005 to 2015 (20–21 per one hundred thousand people). The incidence rate of females increased slowly in 2005 (1–2 in one hundred thousand cases) to 2015 (6–7 in every one hundred thousand people). The incidence rate of male population in Shenzhen sharply increased in 2006–2015 (16 per one hundred thousand people). The incidence rate of female was relatively stable throughout the whole study period, and maintained a trend of 1–3 people in every one hundred thousand people.

The incidence rate of AIDS in males and females in Chongqing and Shenzhen show a similar pattern on the cohort effect. The incidence rate of AIDS was highest in males born in 1964–1965 and 1980–1990, and decreased sharply in males born after 1985. The incidence rate of females was relatively low with the cohort effect. The incidence rate of AIDS in Chongqing had been small for many times during 1960-1990 years, and then dropped sharply. The incidence rate of AIDS in Shenzhen was not affected by cohort effect during the whole study period.

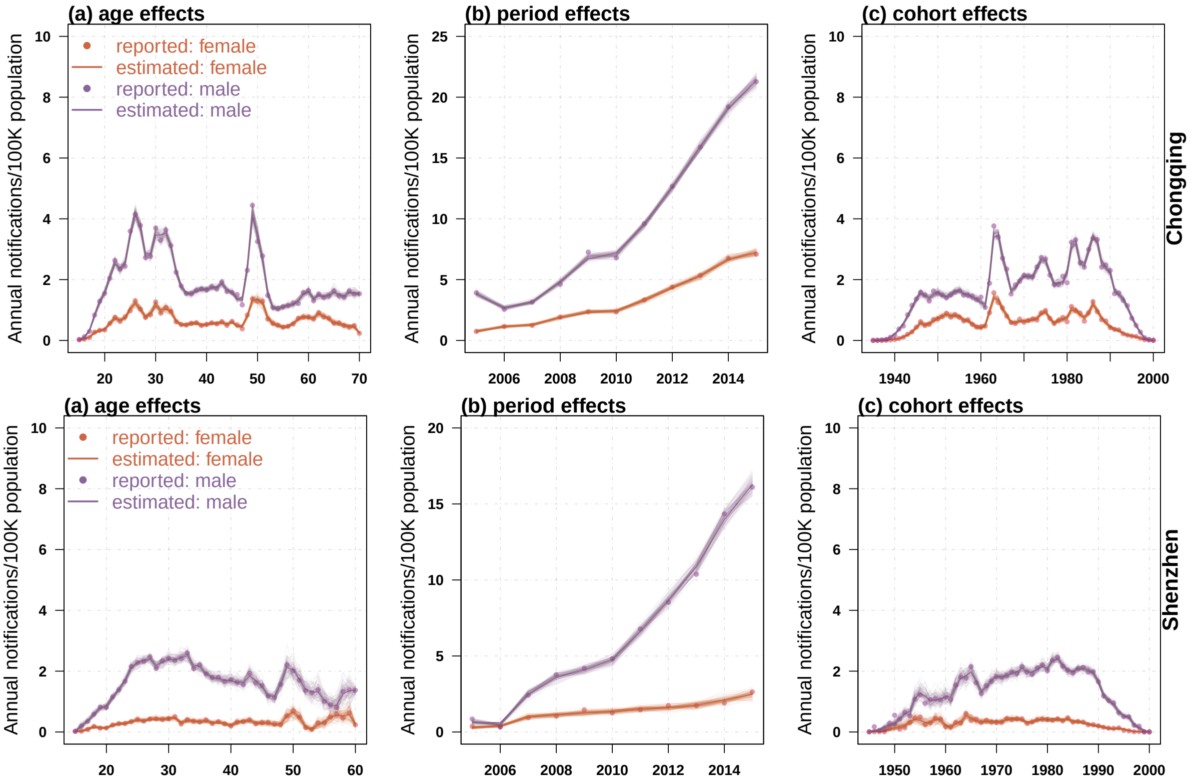

Figure 1. Impact of age(left),period(middle),cohort(right) on the AIDS incidence rate in Chongqing and Shenzhen.

Prediction trends of AIDS incidence in both genders and each age group were shown in Figure 2. There were some similarities between the two cities: (i) The incidence of patients in over 40-year-old age group, under 40-year-old age group, and all age groups have increased from 2005 to 2015, and it is estimated that the incidence will continue to maintain this trend in the next 6 years; (ii) From 2017 to 2022, the morbidity rate of the permanent population of the two cities in the over 40-year-old age group is higher than the incidence rate in the under 40-year-old age group.There were differences of incidence in different age groups between two cities:(i) The AIDS incidence rate of males in the over 40-year-old age group in Chongqing is estimated to increase from about 43 cases per 100,000 in 2015 to about 323 cases per 100,000 in 2021. The AIDS incidence of males the under 40-year-old age group is estimated to increase from about 31 cases per 100,000 in 2015 to about 102 cases per 100,000 in 2021. The incidence rate of females of the over 40-year-old age group in Chongqing is estimated to increase from about 17 cases per 100,000 in 2015 to about 143 cases per 100,000 in 2021. The incidence of females of the under 40-year-old age group is estimated to increase from about 7 cases per 100,000 in 2015 to about 16 cases per 100,000 in 2021; (ii) The incidence rate of males in over 40-year-old age group in Shenzhen is estimated to increase from about 43 cases per 100,000 in 2015 to about 173 cases per 100,000 in 2021. The incidence rate of males of under 40-year-old age group is estimated to increase from about 40 cases per 100,000 in 2015 to about 168 cases per 100,000 in 2021. The incidence rate of females of 40-year-old age group in Shenzhen is estimated to increase from about 2 per 100,000 in 2015 to about 6 per 100,000 in 2021. The incidence rate of females of under 40-year-old age group in Shenzhen is estimated to increase from about 2 cases per 100,000 in 2015 to about 3 cases per 100,000 in 2021.

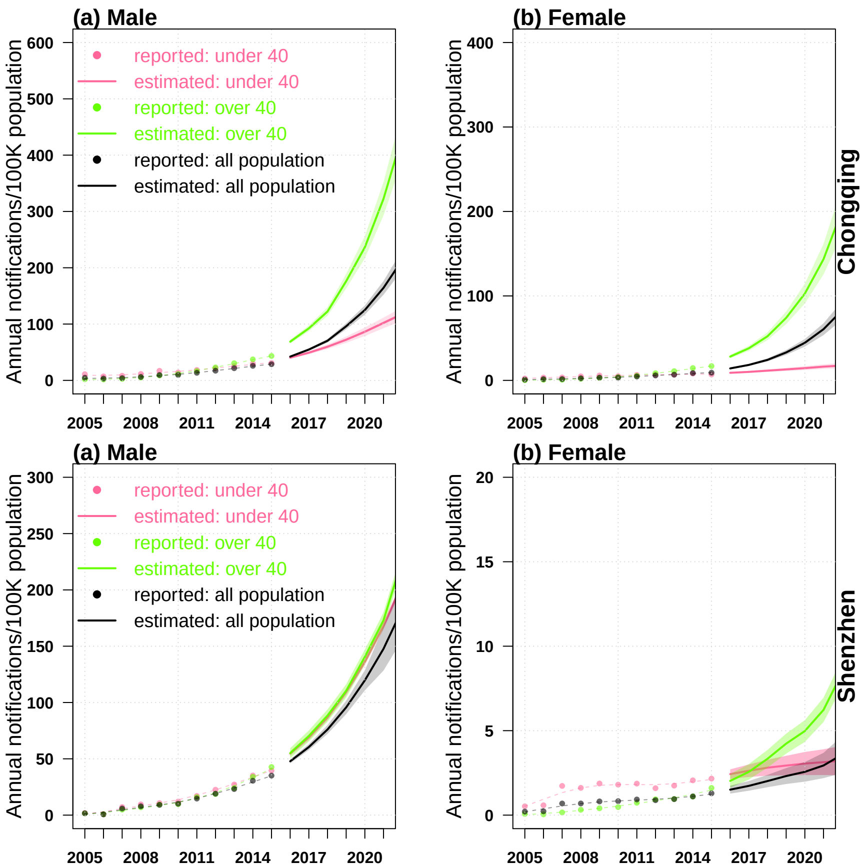

Figure 2. Trend of AIDS incidence in Chongqing and Shenzhen and the prediction results in the future six years.

3.3. APC analysis on AIDS incidence in Chongqing and Shenzhen based on different transmission routes

Figures 3 and 4 depict the impact of age, period, and cohort on the AIDS incidence in Chongqing and Shenzhen based on different transmission routes, as well as the prediction trends. For further study, we establish APC model based on homosexual transmission, heterosexual transmission and other transmission routes (drug-injection, blood transfusion) respectively.

In permanent population in Chongqing and Shenzhen, the number of AIDS patients transmitted through homosexual reached the peak between 20 and 35 years old, and decreased with the increase of age after 35 years old, the same as AIDS incidence, and peaked again around 50 years old. In heterosexual transmission population, the AIDS incidence increased sharply before 30 years old, then fluctuated, and peaked about 50 years old. In Chongqing, the age effect had great impact on AIDS patients age 30 and 50 years old.

With the effect of period, the incidence of homosexual transmission among the permanent residents in Chongqing and Shenzhen showed an upward trend throughout the study period. By 2015, the incidence rate increased to nearly 3 people per one hundred thousand people and nearly 4 per one hundred thousand in Chongqing and Shenzhen, respectively. The incidence rate of heterosexual transmission among the permanent residents in Chongqing and Shenzhen increased sharply to 11 per one hundred thousand and 5 per one hundred thousand during the study period, which was higher than that of homosexual transmission. In Chongqing and Shenzhen, the effect of time on the incidence rate of AIDS patients spreading through other routes was relatively small.

In Chongqing and Shenzhen, the incidence rate of AIDS transmitted by homosexual route reached the peak in patients born in 1985–1990. The incidence rate of AIDS in heterosexual transmission was significantly affected by cohort effect. The incidence rate increased sharply among patients born in 1940–1945 in Chongqing, and then fluctuated sharply. The incidence rate of people who was born in 1985 dropped sharply. In Shenzhen, the incidence rate of population born between 1950 and 1955 increased sharply , and then fluctuated. The incidence rate dropped sharply in the population who was born in 1990. The incidence rate of AIDS patients transmitted through other routes in Chongqing was affected by the cohort effect, reaching the peak in 1975. In Shenzhen, the cohort effect has little effect on the incidence rate of AIDS patients transmitted through other routes.

Figure 4 shows the incidence rate of AIDS in different transmission routes in Chongqing and Shenzhen and the corresponding prediction of trends in the future 6 years. Generally, the incidence of HIV in different age groups transmitted by homosexual and heterosexual sex in both places, the incidence of HIV in the 41–70 year old group transmitted by other routes in Chongqing, and the incidence of HIV in the 41–60 year old group transmitted by other routes in Shenzhen are all on the rise trend in the future 6 years.In Chongqing and Shenzhen, the incidence rate of the 15–40 year old group transmitted by other routes will decrease slowly in the future 6 years. Predicted prevalence of HIV in the future 6 years in different age groups through different transmission routes has some characteristics (Figure 4): (I) In terms of homosexual transmission, the incidence of HIV in the 15–40 years old age group was higher in Chongqing than that in the 41–70 years old age group, and in Shenzhen, the incidence of HIV in the 15–40 years old age group was higher than that in the 41–60 years old age group. (ii) In terms of heterosexual transmission and other routes of transmission, the incidence of HIV in the 41–70 years old age group in Chongqing was significantly higher than that in the 15–40 years old age group, and the incidence of HIV in the 41–60 years old age group in Shenzhen was significantly higher than

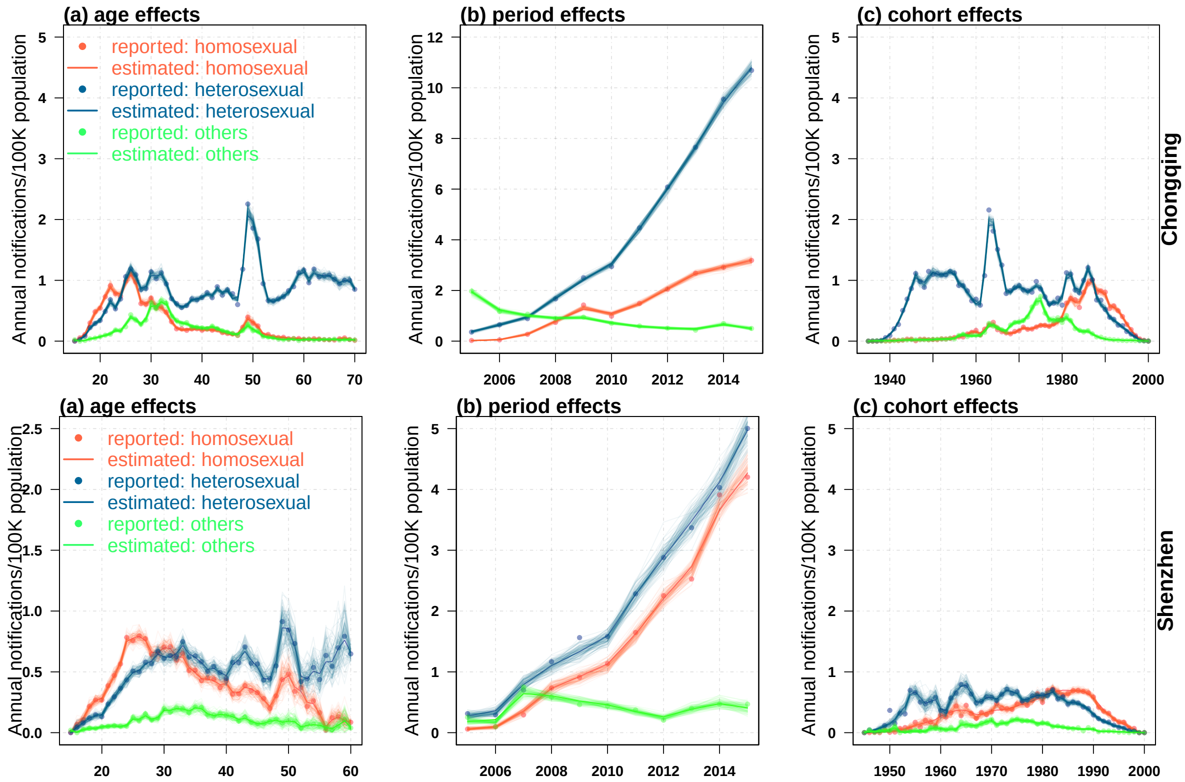

Figure 3. The effect of age (left), period ((middle), and cohort (right) on the estimation of AIDS incidence based on different transmission routes.

that in the 15–40 years old age group. Table 2 and Table 3 show the actual (2005–2015) and predicted (2016–2021) rates of HIV by different transmission routes in Chongqing and Shenzhen. Combined with Figure 4, we found heterogeneity in the predicted rates of HIV between the two cities in different age group : (I) In Chongqing, the incidence is about 3–4 times higher in the 15–40 years old age group with homosexual transmission than in the 41–70 years old age group, about 3–7 times higher in the 41–70 years old age group with heterosexual transmission, and about 2–4 times higher in the 41–70 years old age group with other transmission (Table 2). (ii) In Shenzhen, the incidence of homosexual transmission in the 15–40 age group was not significantly different from that in the 41–60 years old age group. The incidence of heterosexual transmission in the 41–60 years old age group is about 2–3 times higher than in the 15–40 years old age group. The incidence in the 41–60 years old age group transmitted by other means is about 2–3 times higher than in the 15–40 age group (Table 3).

4. Discussion

We applied a relatively novel method to model the trends in AIDS confirmations across two areas among population in Chongqing and Shenzhen, China. Compared to a compartmental model within a Markov process, which needed presumptions on key parameters and mass computation capacity , APC models were able to estimate and forecast directly in a short time. Although the APC model is often applied to studies of morbidity or mortality in oncologenetic diseases [20–24], it can be applied to

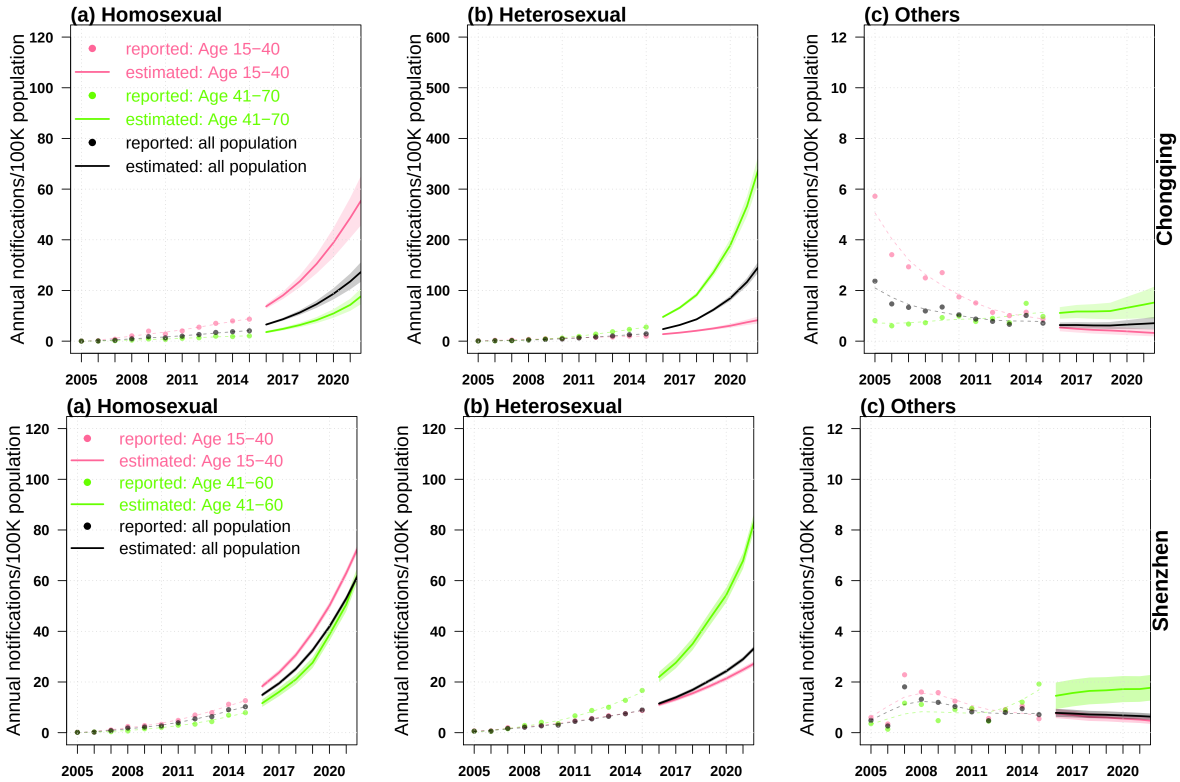

Figure 4. The incidence rate of AIDS based on different routes and the prediction trends in the future 6 years in Chongqing and Shenzhen.

Table 2. Incidence of HIV based on different transmission routes in Chongqing from 2005 to 2021

Yaer	Heterosexual transmission (age group)		Homosexual transmission (age group)		Other transmission (age group)	
	15–40	41–70	15–40	41–70	15–40	41–70
Annual incidence						
2005	0.07	0.02	0.93	0.29	5.72	0.81
2006	0.16	0.03	1.68	0.58	3.41	0.60
2007	0.75	0.16	2.24	0.93	2.93	0.67
2008	2.09	0.40	3.57	2.46	2.50	0.73
2009	3.96	0.83	4.87	4.19	2.70	0.93
2010	2.79	0.63	5.00	6.07	1.74	0.99
2011	4.04	1.10	7.06	9.38	1.51	0.78
2012	5.51	1.33	7.58	13.92	1.13	0.90
2013	7.03	1.96	8.17	18.55	1.00	0.72
2014	7.97	1.82	9.93	23.19	1.14	1.49
2015	8.68	2.07	9.60	27.73	0.87	0.98
Predicted incidence						
2016	13.71	3.58	13.78	47.74	0.54	1.11
2017	18.07	4.83	16.75	66.03	0.49	1.17
2018	23.59	6.36	20.53	91.26	0.44	1.17
2019	30.49	8.29	25.05	135.52	0.42	1.19
2020	38.84	10.91	30.35	188.87	0.39	1.32
2021	48.63	14.31	37.25	266.19	0.35	1.44

Table 3. Incidence of HIV based on different transmission routes in Shenzhen from 2005 to 2021

Yaer	Heterosexual transmission (age group)		Homosexual transmission (age group)		Other transmission (age group)	
	15–40	41–60	15–40	41–60	15–40	41–60
Annual incidence						
2005	0.19	0.14	0.70	0.57	0.60	0.36
2006	0.23	0.27	0.72	0.54	0.34	0.14
2007	1.07	0.39	1.99	1.55	2.28	1.17
2008	2.45	0.68	2.35	2.85	1.61	1.11
2009	2.81	1.54	2.84	4.10	1.58	0.47
2010	3.28	2.05	3.34	3.59	1.24	0.91
2011	4.85	2.93	4.71	6.66	0.93	0.96
2012	6.96	3.36	5.61	8.77	0.56	0.46
2013	7.91	4.37	6.71	10.02	0.91	0.90
2014	11.22	6.90	7.53	12.77	1.05	1.21
2015	12.64	7.89	8.72	16.66	0.55	1.92
Predicted incidence						
2016	18.34	11.64	11.03	21.97	0.75	1.46
2017	23.74	16.06	13.14	27.60	0.69	1.57
2018	30.64	20.99	15.55	35.02	0.62	1.65
2019	39.57	27.62	18.34	44.76	0.60	1.67
2020	50.07	38.66	21.37	54.28	0.55	1.72
2021	62.95	50.56	24.83	67.80	0.52	1.72

some chronic infectious diseases, such as AIDS, hepatitis B and tuberculosis due to whose long-term infectious processes [25, 26].

We used the APC model to analyze the incidence trends of AIDS between different genders in Chongqing and Shenzhen, and to explore the characteristics of the incidence of AIDS among groups infected through different transmission routes. The basic information revealed by the findings (including the age structure, temporal trends and birth cohort characteristics of AIDS incidence in different regions and groups) could provide public health authorities with insights into target age groups and historical trends.

Age is one of the important factors affecting the incidence of AIDS. Our results show that the incidence of AIDS is significantly affected by age in both Chongqing and Shenzhen, males between 20- and 35-year-olds presented the obvious peak. The effect of age on AIDS incidence in males was higher than that in females [27, 28]. Significant age-specific peak appeared in the patients transmitted by sex between 20 and 35 years old, suggesting that sexual contact was the main source of HIV infection among young people in both regions, which is consistent with other studies. Some of these young people are students. According to the data of CDC, in the past few years, the number of newly diagnosed college students has increased by 30% to 50% every year [29]. Research show that MSM has become the main way of AIDS transmission among college students [30]. Although the awareness of basic AIDS knowledge among college students is good, it is not comprehensive enough, and the condom use rate is not high when having sex [31].Therefore, as some college students have sex earlier, it is necessary to strengthen the intervention at the early stage of high school and low grade, focus on male students, and improve the ratio of active counseling and testing [32]. The other part of society is the young people who frequented entertainment places such as bars and KTV, who tends to have multiple sexual partners as being sexually active period, which contributes to the spread of AIDS [33].

In Table 1 and Figure 3, we also found that age effect had a significant impact on MSM patients aged 20–30 years old in Shenzhen. A survey shows that more and more MSM tend to use mobile phone software to make friends, which further increases the occurrence of multiple sexual partners and drug/drug abuse [34]. The incidence rate of AIDS through three different transmission routes was significantly affected by age effect at about 50 years old in Chongqing and Shenzhen. A survey shows [35, 36] that the proportion and number of middle-aged and elderly people suffering from AIDS are getting higher and higher. Research shows that 75 percent of males between 50 and 70 years old still have sex activities, until 80 years old which relative decline. As this normal demand is often ignored by society, therefore behaviors such as prostitution, homosexuality and other unsafe sexual increase the risk of AIDS.

The period effect show that the incidence rate of AIDS in males was higher than that in females, and the increasing spread of male AIDS incidence was significantly higher than that of female, which is consistent with the results of other regions [37, 38]. Overall, the incidence rate of AIDS in Chongqing and Shenzhen increased from 2005 to 2015, which was consistent with Nie et al. [39]. According to Qiao [40], the incidence rate of HIV/AIDS in China had been increasing from 2004 to 2016. Due to various reasons, there is a significant regional difference in the geographical distribution of HIV/AIDS epidemic. The incidence rate of AIDS transmitted by sex among the permanent residents in Chongqing and Shenzhen also shows an upward trend throughout the study period, which is consistent with other studies [41–43]. We found that the incidence of heterosexual transmission was significantly higher than that of homosexual transmission (Figure 3). The present study also shows that the incidence rate of AIDS transmitted by homosexual transmission and heterosexual transmission was increasing during the study period, and the incidence rate of heterosexual transmission was significantly higher than that of homosexual transmission. Huang et al. [44] also showed that heterosexual behavior had become the mainstream in China, accounting for more than 60% of new infections. Yan et al. [45] through the study of the changes of HIV epidemic in Southeast China, the proportion of homosexual males had increased greatly in recent years.

The cohort effect reflects the changes of early life environment, and assumes that the chances of people in the same birth queue to contact disease risk factors are the same, and exposure to some adverse environmental factors in the early life may have adverse effects on future life [46]. The incidence rate of incidence of AIDS in males and females in Chongqing and Shenzhen showed a similar pattern on the cohort effect. The incidence rate of AIDS in males born in 1964–1965 and 1980–1990 was the highest, while the incidence rate of females was less influenced by cohort. In Chongqing and Shenzhen, the incidence rate of AIDS transmitted by homosexual transmission reached its peak in the group born between 1985 and 1990. The incidence rate of AIDS transmitted by heterosexual transmission increased sharply in the population born between 1940 and 1945 in Chongqing. There was a sharp fluctuation afterwards. The incidence of the disease dropped sharply in the population born around 1985, and the incidence rate increased sharply in the people born between1950 and 1955 in Shenzhen, and then fluctuated while the incidence rate of the people born in 1990 was dramatically reduced. This show that HIV diagnosis among heterosexuals and homosexuals presents a very different distribution of birth cohorts: heterosexuals were more concentrated in the 1950–1985 cohort in Chongqing and Shenzhen. For homosexual people, they are very inclined at young age.

The results show that the incidence rate of all age groups in Chongqing and Shenzhen is expected to increase in the future 6 years. The incidence rate of males is significantly higher than that of females, and the incidence rate of patients over 40 years old is higher than that of under 40 years old. In chongqing and Shenzhen, the incidence of sexually transmitted AIDS in all age groups is predicted to increase in the future 6 years. In Chongqing, the incidence rate of AIDS patients aged 41–70 years old who are transmitted by other routes is on the rise in the future 6 years. In Shenzhen, the incidence rate of AIDS patients aged 41–60 who are transmitted by other routes is on the rise as well. Therefore, we hope that public health authorities in Chongqing and Shenzhen could focus on this rising population to better control the AIDS epidemic.

In this study, the characteristics and future trends of AIDS in different regions, different genders and different transmission routes were studied. For the control of AIDS epidemic, we suggest that relevant departments pay more attention to the following groups: in Chongqing and Shenzhen, young people aged 20–35 years old(especially college students and frequent entertainers), MSM, people aged around 50 years old(especially males). Prevention of HIV through sexual transmission is still the focus of the current work in Chongqing and Shenzhen. Setting up cooperation mechanisms combined by the health, public security, industry and commerce and other multi-sectoral departments is essential. And it is important to increase the availability of condoms, enhance the self-protection awareness of the target population, active detection awareness, and provide accessible, standardized STD diagnosis and treatment services, so as to reduce second-generation transmission.

5. Conclusions

Our research results show that AIDS has a significant impact on young people in different regions, especially college students and middle-aged and elderly people, and mainly through sexual transmission, which will continue to rise in the future. Due to unprotected sexual behavior between young people, multiple sexual partners, contacting with many people, young people's excessive pressure, staying up late, drinking, smoking, improper work and rest and other unhealthy living habits, as well as the lack of sexual health and AIDS prevention education in schools, the burden of AIDS in Chongqing and Shenzhen may still increase in the next few years, Therefore, we hope to attract the attention of public health departments to better control the AIDS epidemic. The results also show the difference in incidence rate of AIDS between men and women. Therefore, measures should be taken to control AIDS in both genders.

Author contributions

All authors conceived the study, carried out the analysis, discussed the results, drafted the first manuscript, critically read and revised the manuscript, and gave final approval for publication. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare no conflict of interest.

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