Gender Disparities and Long-Term Changes of HIV/AIDS Incidence Rate in China and the U.S. From 1994-2019: Age-period-cohort Analysis

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Abstract

Background: HIV/AIDS is a serious sexually transmitted disease with poor prognosis. So statistical data on burden of HIV/AIDS incidence and epidemic characteristics are valuable for policy making and reducing healthcare costs. This study aims to explore gender disparities of HIV/AIDS incidence and relative risks of HIV/AIDS incidence by gender and age groups in China and U.S.

Methods: We extracted data from the 2019 Global Burden of Disease study and compared epidemic characteristic and gender disparities between China and U.S. Then we employed APC model to estimate age-period-cohort effect of HIV/AIDS incidence in both countries.

Results: ASIR in China kept growing between 1994 and 2004 then fell to the level of mid-1990s but in U.S. ASIR increased in the past decade. There existed a huge and continuous expanding gender gap in U.S. while it came to widen in China before 2005 then shrunk during 2005-2019. APC analysis showed the age effect and period effect were consistent to the result of incidence comparison between male and female: gender disparities increased with progress of time in both countries and men had higher incidence of HIV/AIDS when they became old in China. Cohort effect indicated later birth groups bear relatively higher risks of incidence than earlier birth groups.

Conclusions: large gender disparities could worsen the HIV epidemic situation. In the U.S., disparities continuously expanded meanwhile incidence of HIV/AIDS was increasing, while gap was under control in China and incidence curbed. Analyzing by APC model, besides younger age groups exposed to high risks of HIV/AIDS incidence in both countries, elder citizens in China faced higher risks which implies aging of population may lead another wave of HIV/AIDS epidemic. Therefore, both young and old age groups deserve to be noticed by police-makers and narrow gender disparities should put on agenda.

1. Introduction

HIV/AIDS is a serious sexually transmitted disease with poor prognosis, it is no more than a public health issue but a social problem[1]. Four decades after its emergence, HIV remains a leading cause of mortality in STD and continues to threaten millions of people's health worldwide [2, 3]. According to the definition by the Global Burden of Disease Study 2019[4], HIV lead to a variety of opportunistic infections and the disease burden caused by AIDS is not reduced greatly even advanced in medicine. HIV/AIDS is still an incurable disease in present[5], there is no treatment or prophylaxis that can cease disease progression, existing therapeutic regimes such as antiretroviral therapy (ART) and methadone maintenance treatment (MMT) just delay disease progression, therefore, it cause much of health care costs lost.

China is most powerful developing country with the largest population, so the impact of communicable diseases is still tricky. The HIV epidemic in China mainland started from outbreaks in group of people who injected drugs by sharing common syringe needles in the remote southeast area in the late 1980s, from then to the mid-1990s, HIV propagated gradually from Yunnan Province to other Chinese regions along the drug trafficking routes, it also spread from injection drug users to multiple sexual partners[6].

With the development of society, the patterns of transmission had evolved, HIV infections in injecting drug users fell and cases among illegal blood donors had been eliminated, as the law enforcement cracked down on unscrupulous blood harvesters in the mid and late 1990s[7]. Sexual transmission became the main route of HIV spreading in China[8]. According to recent studies[9], the rising part of newly confirmed patients ascribed to the sexual contact transmission had increased from 11% in 2005 to 96% in 2017, the heterosexual contact transmission accounted for 59% while the homosexual contact transmission accounted for 26%.

This shift of epidemiological features were similar to other country like the U.S., which also had substantial changes in the subsets of vulnerable people who were disproportionately represented in HIV/AIDS incident cases[10]. After the first cases of HIV infected patient reported in 1981, routine screening for HIV in medical settings had been introduced in the U.S., new HIV infected patients were diagnosed and then reached to a high level in late-1980s[11, 12].

Similarities in the rapid economic growth, large ethnic diversity, geographic expansion and the institutional transition make the comparison in China and the United States become possible[13]. In term of the epidemiological characteristics of HIV/AIDS, China fall about a decade behind the U.S. in the HIV/AIDS[14]. In other words, the HIV/AIDS epidemic in China is going through what had experienced previously in the U.S. Therefore, by making a comparison between China and the U.S., we could grasp the nature and future of HIV/AIDS and put forward targeted primary or secondary prevention. It can help governments mitigate the burden of disease, reduce healthcare costs and provide constructive guidelines for other countries worldwide to mitigate influences derive from the spreading trend of HIV/AIDS

2. Methods

2.1 Data Sources

Data in this study obtained from global burden of diseases (GBD) 2019 study. The GBD study made a yearly estimation on 195 countries and territories from 1990 to 2019. The study extracted relative risks and exposure estimates from 46,749 randomized controlled trials, cohort studies, household surveys, census data, satellite data, and other sources[15]. In short, the GBD study 2019 is a systematic, scientific effort contributed by the Institute for Health Metrics and Evaluation(IHME) to quantify the comparative magnitude of health loss due to diseases, injuries, and risk factors by age, sex, and geographies for specific points in a series time.

We selected the data of both genders in China and the U.S., data such as incidence of HIV, the crude incidence and the age-standardized incidence rate of HIV/AIDS in all age groups from 1994 to 2019 were extracted from the GBD results tool (available at the website <http://ghdx.healthdata.org/gbd-results-tool>).

2.2 Statistical Analysis

2.2.1 Age–Period–Cohort Analysis

We introduced the age-period-cohort model (APC) which is often used in the fields of sociology, population and epidemiology [16, 17]. It can isolate effects of different ages, periods, and cohorts on study outcomes, this model is often used in long-term trend studies such as social changes, disease causes, aging, population process and dynamic researches [18]. The APC model could express as follow:

$$Y = \mu + \alpha age_j + \beta period_j + \gamma cohort_j + \varepsilon_i$$

In this model, Y represents the response variable in APC model, μ represents the intercept item, α , β , γ respectively, represent the coefficients of age, period and cohort of APC model, ε_i in APC model represent the residual. Age effects indicate the different risks of various outcomes during different periods of life; period effects reflect population-wide exposure at a circumscribed point in time; and cohort effects generally represent the disparities in risk across birth cohorts [19, 20]. Collinearity problem caused by the linear relationship between age, period and cohort can be further express as: ***cohort = period - age*** [21, 22].

Therefore, we conducted Intrinsic Estimator (IE) [18] to estimate the coefficient.

2.2.2 Data Arrangement

We chopped the time series from 1994 to 2019 into 5 consecutive intervals, the period from 1990 to 1993 were not a 5 years continuity interval so the data before 1994 were discarded. Successive 5-year age groups from 15–19 to 75–79 years old were divided, individuals younger than 15 years and older than 80 years were excluded. Besides these, 18 consecutive cohorts were allotted, including those born from 1919–1923 to 2004–2009. For the calculation of RR, we chose the mean level in age, period and cohort as reference groups, and then calculated the difference between reference groups and other groups. This process of analysis conducted by Stata 14.0 software (StataCorp, College Station, TX, USA). Wald chi-square tests were used to calculate the significance of the estimable parameters and functions. All statistical tests were 2-sided and the corresponding value of $p < 0.05$ means a vivid significance statistically.

3. Results

3.1. Overall Trends of HIV/AIDS Age-standardized Incidence in China and the U.S.

Figure 1 presented time sequence changes of the age-standardized incidence rate (ASIR) of HIV/AIDS in male and female of China and the U.S. from 1994 to 2019. As we can see, male invariably higher than female in China and U.S. ASIR of both male and female in the U.S. rose first and hit a peak in 1997, after plummeted and went through a smooth period, it turned to gradually went up and attain to a high level in 2019. While in male of China the ASIR of HIV/AIDS from 1.76/100,000 in 1994 to 6.34/100,000 in 2005, which represented an upward trend, then it dropped from 6.19/100,000 in 2006 to 3.30/100,000 in 2019, curve of female remained in a bottom and followed male's trend, from 0.98/100,000 in 1994 to 1.07/100,000 in 2019, the range of changes did not exceed 1.5/100,000.

3.2 Gender Disparities Between Male and Female in Both Countries

Gender gaps between male and female can be seen clearly in Figure 1, it expanded gradually before 2006 in China, raising from 0.78/100,000 in 1994 to 4.07/100,000 in 2006, but had shrunk from 3.99/100,000 in 2007 to 2.23/100,000 in 2019. A huge gap exists in U.S. and expanded from 8.38/100,000 in 1994 to 17.08/100,000 in 2019. Albeit gap decreased a little from 1997 to 2001, this promising trend did not keep hold. It still maintained an exaggerated gap and had no sign of narrowing. We classified 13 age groups into three stage of life: young age(15-34), middle age(35-59) and old age(60-79). In Figure 2, gender difference in HIV/AIDS incidence increased gradually with age and was readily apparent in China. Ratio in young age was modest in three stage further demonstrated that young people are most vulnerable to infection whatever male and female. At the same time, with the change of time, almost all age groups showed an increase in the sex ratio. However, Figure 2 can't indicate gender disparities in which country was much severer, it only reflected trends of gender disparities with time change or with age change, this can be attributed to incidence rate of HIV/ADIS in U.S. was considerably higher than China. Rate ratio cover the gender disparities in some degree, for example, the incidence rate was 26/100,000 in male and 21/100,000 in female in U.S. while 2/100,000 in male and 0.6/100,000 in female in China, the former rate ratio was 1.24 but latter was 3.33.

The RR of a particular age, period, or birth cohort was calculated based on these coefficients of age, period, and cohort effects estimated by using the age-period-cohort model (Table A1 and Table A2).

3.3.1. Age effect

Relative risks (RRs) of HIV/AIDS incidence in China and the U.S. were depicted in Figure3,4,5. Age effect could be seen in Figure 3. In groups younger than 50 years old, we found the fluctuations of RRs, which rose from 15-19 age group in a quick speed and reached peak in 25-29 age group then had a steep slide in middle-aged groups (30-34 to 45-49 age groups), were resemblant in both countries and genders. In the peak of young age, risks of HIV/AIDS in the U.S. were 1.5 and 1.4 times larger than China for male and female respectively. Although risks of both male and female in the U.S. had a steep glide and hit a rock-

bottom position in 75-79 age group, trend of old groups in China was in opposite. Curve of RRs exhibited an uninterrupted escalating trend from 45-49 to 75-79 age groups in male of China. For female, down trend among 60-64 to 65-69 age groups mitigated previous uptrend, risks of both gender in China surpassed the first peak and reached to a new high in 75-79 age group. In this group, risks were 9.5 and 8.4 times larger than male and female in the U.S. respectively. This finding indicate that younger groups exposed to high risks of HIV/AIDS incidence, but for China, groups over 70 years old climbed in an exaggerate speed and bear higher risks than younger groups ultimately.

3.3.2. Period effect

We observed RRs of HIV/AIDS incidence in the U.S. moderately fluctuated at low level with advancing time in Figure 4. However, it showed an increasing trend in past decade and RRs of incidence increased by 1.6 times in men and 1.2 times in women. Risks in China plotted an oscillating trend. Curves did not display a sign of decline until it reached the summit in 2004, at this point risks were 1.87 times and 1.9 times larger than male and female in the U.S., from then on, upward momentum of risks was curbed and RRs of incidence glided down to the level of 1994 finally in China.

3.3.3. Birth cohort effect

Birth cohort effect on HIV/AIDS incidence presented in Figure 5. RRs of incidence almost same in male and female. Compare to the U.S., RRs of incidence had more complex fluctuations in China.

Curves showed an upside-down V trend which indicated that RRs of incidence rose up first then drop down from 1919-1923 to 1979-1983 birth groups, risks began augment from 1989-1993 birth groups then acquired its highest value in 2004-2009 birth group. In the U.S. risks of incidence hiked remarkably to the first peak then experienced a transitory dip from 1919-1923 to 1934-1938 birth cohort, after a succession of steady growth, a new height appeared in 1984-1989 cohort group. From 1989-1993 to 2004-2009 birth groups, RRs increased by 227.6% in male and 329.0% in female in China; in the U.S., it increased by 238.2% in male and 290.1% in female. In term of birth cohort, later birth groups exposed relatively higher risks of HIV/AIDS incidence than earlier birth groups.

4. Discussion

In the present study, we conducted a comparison about gender disparities of HIV infection among young, middle and old age groups and performed an APC model to estimate the age, period, and birth cohort effects of incidence in China and the U.S. The result of comparison kept parallel to age and period effect: gender disparities increased with progress of time in both countries and men had higher incidence of HIV/AIDS when they became old in China. Cohort effect denoted latter birth groups bear higher risks of infection than earlier birth groups.

Gender disparities in both countries can be explained by followed reasons. Firstly, Changes of the demographic characters aggravated this issue. According to a Chinese census[23], the sex ratios of male to female at birth rose since 1990. The same concern existed in the U.S. as well. More HIV infections among males eventually lead a larger gender gap in HIV/AIDS incidence. Secondly, sexual transmission, especially men who have sex with men(MSM) in the U.S., played as a leading cause of gender disparities[24, 25]. It means men were at a higher risk of HIV exposure. For China, sexual liberation acted as a key factor in the rapid dispersion of HIV. Male-male sex had been legalized in China since 1997[6] since then homosexual was not as unacceptable as before. It undoubtedly fastens the transmission of HIV in male. Thirdly, men made up the majority in the large mobile populations which were proved as a high risk group of HIV infections in China[26]. Finally, treatment of HIV/AIDS had been shown to prevent HIV transmission[27-29] and certainly had affected its distribution and evolution. Previous studies suggested some HIV/AIDS treatments such as ART benefited woman more[30], which means women were respond to some HIV/AIDS therapies or interventions positively and it in turn protected them from HIV infections[31]. To sum up, as the gender gap widens with time change, female seems safer than male, but if more men become infected with HIV, women will eventually be threatened.

For the age effect, younger age groups are easier to addicted to high-risk sexual behaviors or drug use and assume high risks of HIV infection proved a known fact around the world[32]. A more serious fact is much more risks of HIV/AIDS in Chinese senior citizens, which may imply that ageing and without social assistance drive the elders under the threaten of HIV/AIDS. Chinese residency system reform in 1980 compelled millions of elder migrants left their native places[33]. Education and expertise scarce compelled middle- or elder-groups away from home to earn a living. Lack of family support might generate influences on opportunistic infections among the older generation[34]. Compared to non-migrants living with families, elder migrants were far away from home and may seek sexual services. Unprotected sexual intercourse was common in these groups due to short of education and out of pocket[35]. Hence sexually risky behaviors caused an exacerbation of the HIV/AIDS epidemic in older groups. Besides, sexual demands of the elders are often neglected by their partners as well as by the society[36], for the sake of dispelling loneliness, they chat on internet via various kind of mobile applications and date with unfamiliar persons under the background of information era[37]. Being short of self-protection consciousness among older adults eventually increases the risk of HIV/AIDS acquisition. If these issues get no attention from government, acute aging problems in China[38] may intensify the current situation in HIV/AIDS incidence and lead to a new wave of increasing.

Period effect presented RRs held steadily in a low level in the United State when birth cohort and age effects were both controlled, but it turned to increase in past decade. The U.S. healthcare system is the largest and most advanced in the world[39], a series of therapies in treating HIV like the introduction of the first nucleoside analogue reverse transcriptase inhibitor in 1987[40], the expanding of AIDS surveillance definition in 1993[41] and protease inhibitors in 1995[42], were proved effective at a population level. Under this circumstance, a decline trend was exhibited in RRs of HIV/AIDS in both gender during 1999 to 2009. Nevertheless, advanced therapies on patients after HIV infection just restricted it spreading but can't eliminate the virus completely[43], uncontrollable high risk behaviors

under its culture background[44] may cause HIV resurgence. At the same time, the advent of some aggressive treatment regimens accompanied with side-effects too[45]. Suffering severe side-effect profiles made potential patients hesitate to receive therapies or not and eventually resulted more new infections continued to occur.

As for China, our study showed that the trend of period effect was consistent to its ASIR. According to former studies[46, 47], time before 2005 were described as the “rapid expansion phase”. Upward trend of ASIR in China could ascribe to the reform and opening-up policy. Prior to the reform and opening-up policy, traditional Chinese held that premarital or extramarital sex were shameful, so their attitudes on sex only limited to marital sex and the purpose only for reproductions[48]. It was undeniable that the introduction of “Open Door Policy” brought traditional Chinese people wide acceptance of pre- and extramarital sex[49, 50]. Considering other factors such as living with hemophilia[26], drug addiction, illegal plasma donors[51], homosexual and heterosexual contact[6], all these caused an escalation in RRs previous to 2004. For the purpose of repressing the upsurging trend of HIV/AIDS. In 2003, Chinese government announced its “Four Frees and One Care” policy[52]. In 2005, a web-based HIV reporting system integrated the HIV and AIDS surveillance system were established[53]. In 2006, the National Center for AIDS/STD Control and Prevention (NCAIDS) at the Chinese Center for Disease Control and Prevention (China CDC) launched its national, web-based HIV/AIDS information system, the Comprehensive Response Information Management System (CRIMS)[53]. Together with delivering health promotion strategies in social network, strengthening sexual health services and partner services[54, 55], these measures not only provided researchers a comprehensively understand about the epidemic features of HIV, but made a breakthrough contribution on curbing HIV.

Cohort effects in China and the U.S. should be explained carefully because of the resemblance in their trends: the cohort effect revealed that people among latter birth groups had a relatively higher risks than earlier birth groups. Changing of background can be regarded as a predominant reason, latter birth cohort groups in their adolescence and young adulthood, a considerable biologic, physiologic even mental changes took place[56], in addition to younger generations enjoyed much greater freedoms today in thought, speech, and choices, including sexual behaviors, thus they were easier to get hooked on some risk factors of HIV/AIDS such as high-risk sexual behaviors or taking drugs[8]. It's predictable that risk of incidence will drop down quickly when they farewell to their young age. Therefore, latter birth cohort groups bear higher risk of HIV/AIDS incidence compare to earlier birth cohort groups.

5. Limitations

In regard of constraints in our study, initially, the data included in the study was extracted from the latest data in GBD 2019, it was undeniable that certain deviations in the completeness and accuracy of HIV/AIDS incidence rate were inevitable. Although the GBD 2019 adapted numerous adjustments and corrections to the source, collation, and evaluation of the HIV/AIDS incidence rate data to enhance data accuracy and comparability, refraining from data inaccuracy thoroughly seemed impossible. Besides, the shortcomings exist in APC model may cause its accuracy to be affected, so other sophisticated models should be

applied in future studies to explore the nature of HIV/AIDS precisely, this will be a further step for our human to quest for drug to cure rampant HIV. Finally, giving that enormous population and complex demographic characteristics in both countries, more adequate data are needed to provide robust evidences of location or ethnic effect on HIV/AIDS incidence. Considering all above limitations, we will further concentrate on the model upgrading and data updating to obtain more accurate analysis results.

6. Conclusions

The ASIR of HIV/AIDS showed an oscillating trend which increased to peak between 1994 and 2004 then fell to the level of mid-1990s. Despite ASIR in China was much lower than the U.S., the virus had not yet been eliminated. In U.S., previous interventions and therapies worked but it still fell short thus HIV incidence came to ascended over the past decade. Large gender disparities could worsen the HIV epidemic situation. In the U.S., disparities continuously expanded meanwhile incidence of HIV/AIDS was increasing, while gap was under control in China and incidence curbed. Analyzing by APC model, not only younger age groups and latter birth groups exposed to high risks of HIV/AIDS incidence, elder citizens in China also faced higher risks than U.S which implies aging of population may lead another wave of HIV/AIDS epidemic. Therefore, both young and old age groups deserve to be noticed by police-makers and narrow gender disparities should put on agenda.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analyzed during the current study are available in the GBD results tool repository, <http://ghdx.healthdata.org/gbd-results-tool>.

Competing interests

Not applicable.

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Authors' contributions

Yudiyang Ma designed the study, implemented the study protocol, collected and analyzed data and wrote the first manuscript. Yiran Cui directed statistical analyses of the data and revised the paper. Qian Hu analyzed and interpreted the data. Chuanhua Yu also revised the manuscript. All authors contributed to the discussion, reviewed and edited the manuscript, and approved the final manuscript.

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Figures

Figure 1

Age-standardized incidence rate for China and the U.S.,1994 to 2019

Figure 1

Age-standardized incidence rate for China and the U.S.,1994 to 2019

Figure 2

HIV/AIDS incidence rate ratios of males compared with females of young, middle and old age groups in China(A,B,C) and the U.S.(D,E,F), from 1994 to 2019.

Figure 2

HIV/AIDS incidence rate ratios of males compared with females of young, middle and old age groups in China(A,B,C) and the U.S.(D,E,F), from 1994 to 2019.

Figure 3

Age effect on HIV/AIDS incidence rate for male and female in China(A) and the U.S.(B), from 1994 to 2019

Figure 3

Age effect on HIV/AIDS incidence rate for male and female in China(A) and the U.S.(B), from 1994 to 2019

Figure 4

Period effect on HIV/AIDS incidence rate for male and female in China(A) and the U.S.(B), from 1994 to 2019

Figure 4

Period effect on HIV/AIDS incidence rate for male and female in China(A) and the U.S.(B), from 1994 to 2019

Figure 5

Cohort effect on HIV/AIDS incidence rate for male and female in China(A) and the U.S. (B), from 1994 to 2019

Figure 5

Cohort effect on HIV/AIDS incidence rate for male and female in China(A) and the U.S. (B), from 1994 to 2019

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