HIV incidence is rapidly increasing with age among young men who have sex with men in China: a multicentre cross-sectional survey

X Mao, 1,2 Z Wang, 3 Q Hu, 1,2 C Huang, 1,2 H Yan, 4 Z Wang, 5 L Lu, 6 M Zhuang, 7 X Chen, 8 J Fu, 9 W Geng, 1,2 Y Jiang, 1,2 H Shang, 1,2 and J Xu 1,2

1Department of Laboratory Medicine, Key Laboratory of AIDS Immunology of National Health and Family Planning Commission, The First Affiliated Hospital, China Medical University, Shenyang, China, 2Collaborative Innovation Center for Diagnosis and Treatment of Infectious Diseases, Hangzhou, China, 3Centre for Health Behaviors Research, The Jockey Club School of Public Health and Primary Care, The Chinese University of Hong Kong, Hong Kong, China, 4Jiangsu Provincial Centers for Disease Control and Prevention, Nanjing, China, 5He’nan Provincial Centers for Disease Control and Prevention, Zhengzhou, China, 6Yunnan Provincial Centers for Disease Control and Prevention, Kunming, China, 7Shanghai Municipal Centers for Disease Control and Prevention, Shanghai, China, 8Hu’nan Provincial Centers for Disease Control and Prevention, Changsha, China and 9Shandong Provincial Centers for Disease Control and Prevention, Jinan, China

Objectives
The HIV epidemic is worsening among men who have sex with men (MSM) in China, especially among those who are younger than 25 years old [younger MSM (YMSM)]. The aim of the study was to compare the prevalences of HIV incidence and recent HIV infection as well as factors associated with recent HIV infection in YMSM and older MSM (OMSM).

Methods
A multicentre cross-sectional survey was conducted among 4496 MSM recruited from seven Chinese cities. YMSM were defined as those aged < 25 years. Data on demographics and sexual behaviours were collected using structural questionnaires. Blood samples were tested for recent HIV infection and other sexually transmitted infections.

Results
Among the participants, 1313 were YMSM and 3183 were OMSM. Compared with OMSM, YMSM had a higher prevalence of recent HIV infection [5.4% (71 of 1313) for YMSM vs. 3.6% (115 of 3175) for OMSM; P = 0.006] and a higher HIV incidence [11.8 per 100 person-years (PY) (95% confidence interval (CI) 9.0–14.5) for YMSM vs. 7.6 per 100 PY (95% CI 6.3–9.0) for OMSM]. The incidence increased with age among YMSM, especially between the ages of 16 and 21 years. In contrast, the incidence declined with age among OMSM. Anal bleeding, recreational drug use, syphilis and herpes simplex virus 2 (HSV-2) infection were independent risk factors for recent HIV infection among YMSM. The prevalence of all these risk factors increased with age between the ages of 16 and 21 years. Anal bleeding (19.8%) and recreational drug use (19.5%) had the highest adjusted population attributable fractions (aPAFs) among YMSM. The highest aPAFs of anal bleeding (27.4%) and syphilis infection (25.5%) were found between the ages of 19 and 21 years.

Conclusions
The HIV incidence in Chinese YMSM was significantly higher than that in OMSM. YMSM aged 16–21 years had an extremely high risk of recent HIV infection.
Introduction

HIV is a serious public health threat among men who have sex with men (MSM) both locally and internationally [1,2]. Young MSM (YMSM), commonly defined as those aged < 25 years, are a key population that requires focused attention for HIV prevention [3]. In the USA, the number of YMSM who were diagnosed as HIV positive increased by 26% from 2008 to 2011 [4]. YMSM accounted for about 30% of newly diagnosed HIV-positive MSM in 2010 [5]. A similar trend was also observed in China. As reported by the China National Centre for STI/HIV Prevention and Control, 14.7% of new HIV cases reported in 2015 were in young people aged 15–24 years [6]. This percentage has been increasing by about 35% every year [6]. A recent meta-analysis showed that the HIV prevalence in YMSM in China has doubled over the last decade (i.e. from 2.9% in 2005–2007 to 6.3% in 2011–2014) [7]. Moreover, it is possible that a high proportion of HIV-positive YMSM may have been recently infected with HIV [9], and some of them may be in the acute infection stage with high viral loads and hence high infectivity [8]. Despite their important role in the HIV epidemic, there are no data on the HIV incidence and the prevalence of recent HIV infection among YMSM in China. Such data will have important implications for planning HIV prevention and are hence greatly needed.

Risk factors predicting HIV acquisition among MSM in general have been well studied [9]. However, it is unclear whether the same set of risk factors applies to YMSM. Recent studies suggested that the prevalence of some risk factors was different between YMSM and OMSM [10]. For example, compared with OMSM, YMSM had a higher prevalence of recreational drug use [11], unprotected anal intercourse (UAI) with any male partners or with male partners with unknown serostatus [12], and concurrent multiple sex partnerships [12]. They also had a high prevalence of sexually transmitted infections (STIs) and accounted for a significant proportion of newly reported STI cases among MSM in Western countries [13]. According to social marketing approaches, careful segmentation would improve the effectiveness of the interventions [14]. Understanding the factors predicting HIV acquisition and recent infection among YMSM is hence important for developing tailored interventions for this group.

It is suggested that YMSM are experiencing a disjunction between sensation seeking (which increases dramatically from puberty) and the development of self-regulatory competence (which does not fully mature until early adulthood) [15]. As a result, they are more vulnerable to risk taking and their vulnerability may change continuously with age. However, there is a dearth of studies investigating this. Understanding risk profiles of YMSM of different ages is hence important for developing tailored interventions, which would improve the effectiveness of the interventions and optimize the allocation of public health resources.

In order to fill the knowledge and service gaps, a large-scale multicentre cross-sectional survey was conducted among MSM in seven large cities in China. First, differences in sociodemographic variables, risk factors for HIV infection and HIV/STI serostatus between YMSM and OMSM were examined. Secondly, the HIV incidence and the proportion of recent HIV infections in both groups were estimated using an immunoglobulin G-capture HIV-1 subtypes B, AE, and D-enzyme immunoassay (BED-CEIA). Thirdly, factors associated with recent HIV infection in both groups were investigated and the population attributable fractions (PAFs) of the risk factors were calculated. Fourthly, the age-related trends in HIV prevalence, HIV incidence, and risk factors for HIV infection were derived by fitting locally weighted scatterplot smoothing (LOWESS). This study provides researchers and practitioners with information about HIV incidence, recent HIV infection and factors associated with recent HIV infection among YMSM. Such information would facilitate the development of tailored HIV control and prevention strategies for YMSM.

Methods

Study participants and questionnaire interview

A multicentre cross-sectional survey was conducted from June 2012 to June 2013 in seven large cities in China, namely Shenyang, Jinan, Zhengzhou, Shanghai, Nanjing, Changsha, and Kunming. Details regarding subject recruitment, inclusion criteria and the anonymous structured questionnaire have been reported in a previous study [16]. To maintain anonymity, each participant was assigned a unique study identification (ID) number. Their real names were not recorded.

Ethics statement

This study was approved by the Institutional Review Board of the First Affiliated Hospital of China Medical Board of the First Affiliated Hospital of China Medical
University ([2011]-36). This study was performed in accordance with the relevant guidelines and regulations. Written informed consent was obtained from all participants.

Laboratory testing

Blood samples were collected and tested for HIV-1, syphilis and herpes simplex virus 2 (HSV-2) infection. Confirmed HIV-seropositive specimens were further tested by BED-CEIA to determine whether they were recent or established HIV-1 infections [17,18]. Details of the testing procedure have been reported in a previous study [19].

Statistical analysis

In this study, we defined YMSM as those aged < 25 years; such a definition has commonly been used in other studies (e.g. [3]). The χ² test was used to determine the significance of differences in sociodemographic variables, risk factors for HIV infection and HIV/STI serostatus between YMSM and OMSM. The HIV incidence was estimated using the sensitivity/specificity adjustment formula [20]. The window period specific to the Chinese population (168 days) was used to define recent HIV infection [20]. The formula and parameters used in this study were recommended by the National HIV Reference Laboratory, Chinese Centers for Disease Control and Prevention (CDC) [20]. Using recent HIV infection (defined as BED-CEIA positive) as the dependent variable, crude odds ratios for the associations between independent variables and the dependent variable were estimated. Potential confounders (i.e. study site, residence, education level, monthly income and ethnicity) were adjusted for in subsequent multivariate logistic regression analysis involving other independent variables, and adjusted odds ratios (aORs) and respective 95% confidence intervals (CIs) were derived from such analyses. The adjusted population attributable fractions (aPAFs) and 95% CIs of the risk factors for recent HIV infection were estimated based on their aORs using the punaf package available in stata software (Stata Corporation, College Station, TX) [21]. The LOWESS fit was applied to estimate the age-related trends in HIV prevalence, HIV incidence and risk factors. SAS version 9.2 (SAS Institute, Cary, NC) and STATA version 13.0 were used for analysis. A two-tailed P-value < 0.05 was considered statistically significant.

Results

Participant profiles

Among all participants (n = 4496), 29.2% (n = 1313) were YMSM. YMSM were more likely than OMSM to be internal migrants (65% vs. 58.4%, respectively; P < 0.001), belong to an ethnic minority (7.8% vs. 6.2%, respectively; P = 0.043), to have been educated to college level or above (60.2% vs. 49.9%, respectively; P < 0.001) and to self-report as a homosexual (64.2% vs. 57.1%, respectively; P < 0.001).

Potential risk factors such as seeking male sex partners mainly on the internet (74.2% vs. 65.4%, respectively; P < 0.001), having a man as one’s first sex partner (78.5% vs. 59.5%, respectively; P < 0.001), first having sex with a man at the age of ≤ 20 years (79.1% vs. 36.6%, respectively; P < 0.001), predominantly adopting the receptive role during anal intercourse (AI) (31.9% vs. 18.5%, respectively; P < 0.001) and experiencing anal bleeding in the past 6 months (20.9% vs. 13.2%, respectively; P < 0.001) were more common among YMSM than OMSM (Table 1).

HIV/STI serostatus of YMSM and OMSM

The proportion of recent HIV infections (5.4% vs. 3.6%, respectively; P < 0.006) and the HIV incidence [11.8 per 100 PY (95% CI 9.0–14.5) vs. 7.6 per 100 PY (95% CI 6.3–9.0)] were significantly higher among YMSM than OMSM. However, the between-group difference in HIV prevalence (9.2% in YMSM vs. 10.1% in OMSM; P = 0.333) was not statistically significant (Table 1). Regarding STI serostatus, YMSM had a significantly lower prevalence of syphilis (6.9% vs. 9.1%, respectively; P = 0.017) and HSV-2 (7.6% vs. 14.5%, respectively; P < 0.001) than OMSM (Table 1).

Risk factors for recent HIV infection

After adjustment for potential confounders, five variables were significantly associated with recent HIV infection among YMSM. They were: (1) predominant sexual position during AI (receptive: aOR 2.7, 95% CI 1.3–5.8; versatile: aOR 2.5, 95% CI 1.2–5.2; reference group: insertive), (2) recreational drug use (aOR 2.1; 95% CI 1.2–3.6), (3) self-reported anal bleeding in the past 6 months (aOR 2.6; 95% CI 1.5–4.6), (4) syphilis infection (aOR 3.9; 95% CI 2.0–7.5) and (5) HSV-2 infection (aOR 2.2; 95% CI 1.1–4.8) (Table 2).

These five variables were also associated with recent HIV infection among OMSM (Table 2).

Adjusted PAFs of risk factors for recent HIV infection

Anal bleeding had the highest aPAF among YMSM (aPAF 19.8%; 95% CI 5.2–32.2%), followed by recreational drug use (aPAF 19.5%; 95% CI 2.7–33.4%), syphilis infection
Table 1 Distribution of demographic variables, HIV-related risk factors and HIV/sexually transmitted infection (STI) serostatus in younger men who have sex with men (YMSM) and older men who have sex with men (OMSM) participating in this survey (n = 4496)

| Variable                                      | YMSM (n = 1313) | OMSM (n = 3183) | P-value |
|-----------------------------------------------|-----------------|-----------------|---------|
| Residence                                     |                 |                 |         |
| Local cities                                  | 1785            | 3055            | 0.001   |
| Non-local cities                              | 2171            | 835             | 0.001   |
| City                                          |                 |                 |         |
| Kunming                                       | 632             | 1201            | 0.001   |
| Shenyang                                      | 664             | 1201            | 0.001   |
| Ji’nan                                        | 675             | 1201            | 0.001   |
| Changsha                                      | 689             | 1201            | 0.001   |
| Zhengzhou                                     | 467             | 1201            | 0.001   |
| Nanjing                                       | 592             | 1201            | 0.001   |
| Shanghai                                      | 777             | 1201            | 0.001   |
| Education                                     |                 |                 |         |
| Junior school or below                        | 916             | 1201            | 0.001   |
| High school                                   | 1201            | 1201            | 0.001   |
| College or above                              | 2379            | 1201            | 0.001   |
| Sexual orientation                            |                 |                 |         |
| Homosexual                                    | 2659            | 1201            | 0.001   |
| Other                                         | 1837            | 1201            | 0.001   |
| Ethnicity                                     |                 |                 |         |
| Han                                           | 4196            | 1201            | 0.001   |
| Other                                         | 1837            | 1201            | 0.001   |
| Occupation                                    |                 |                 |         |
| Student                                       | 565             | 1201            | 0.001   |
| Nonstudent                                    | 3931            | 1201            | 0.001   |
| Monthly income                                |                 |                 |         |
| No income                                     | 769             | 1201            | 0.001   |
| US$1–600                                      | 2858            | 1201            | 0.001   |
| > US$600                                      | 869             | 1201            | 0.001   |
| Main venue for seeking male sexual partners    |                 |                 |         |
| Internet                                      | 3055            | 1201            | 0.001   |
| Noninternet                                   | 1441            | 1201            | 0.001   |
| Gender of first sexual partner                |                 |                 |         |
| Male                                          | 2925            | 1201            | 0.001   |
| Female                                        | 1571            | 1201            | 0.001   |
| Age of sexual debut with partner              |                 |                 |         |
| < 18 years                                    | 681             | 1201            | 0.001   |
| 18–20 years                                   | 1521            | 1201            | 0.001   |
| > 20 years                                    | 2291            | 1201            | 0.001   |
| Predominant sex position during AI            |                 |                 |         |
| Insertive                                     | 1395            | 1201            | 0.001   |
| Receptive                                     | 988             | 1201            | 0.001   |
| Versatile                                     | 2022            | 1201            | 0.001   |
| Used condom during last AI with male partner   |                 |                 |         |
| Yes                                           | 3244            | 1201            | 0.001   |
| No                                            | 1174            | 1201            | 0.001   |
| Number of male sexual partners in past 6 months|           |                 |         |
| > 2                                            | 1785            | 1201            | 0.001   |
| ≤ 2                                            | 2707            | 1201            | 0.001   |
| Having commercial sex*                        |                 |                 |         |
| Yes                                           | 459             | 1201            | 0.001   |
| No                                            | 4037            | 1201            | 0.001   |
| Recreational drug use*                        |                 |                 |         |
| Yes                                           | 1275            | 1201            | 0.001   |
| No                                            | 3221            | 1201            | 0.001   |
| Anal bleeding in past 6 months                |                 |                 |         |
| Yes                                           | 695             | 1201            | 0.001   |
| No                                            | 3801            | 1201            | 0.001   |

Table 1 (Continued)

| Variable                                      | YMSM (n = 1313) | OMSM (n = 3183) | P-value |
|-----------------------------------------------|-----------------|-----------------|---------|
| Condom breakage during AI in past 6 months    |                 |                 |         |
| Yes                                           | 390             | 1201            | 0.001   |
| No                                            | 4106            | 1201            | 0.001   |
| Syphilis infection                            |                 |                 |         |
| Yes                                           | 381             | 1201            | 0.001   |
| No                                            | 4115            | 1201            | 0.001   |
| HSV-2 infection‡                              |                 |                 | 0.001   |
| Yes                                           | 552             | 1201            | 0.001   |
| No                                            | 3863            | 1201            | 0.001   |
| HIV infection                                 |                 |                 |         |
| Yes                                           | 444             | 1201            | 0.001   |
| No                                            | 4052            | 1201            | 0.001   |
| Recent or established HIV infection§          |                 |                 |         |
| Recent                                        | 186             | 1201            | 0.001   |
| Established                                   | 250             | 1201            | 0.001   |
| Recent HIV infection§                         |                 |                 |         |
| Yes                                           | 186             | 1201            | 0.001   |

Al, anal intercourse; HSV-2, herpes simplex virus 2.
*Buying or selling sex services, including anal intercourse or oral intercourse.
†Recreational drugs were psychoactive drug that alter one’s mental state in a way that modifies emotions, perceptions, and feelings for recreational purposes, such as methamphetamine, cocaine, ketamine, bath salts and rush poppers.
‡There were 81 participants for whom we could not perform the assay for HSV-2 antibody because of a lack of sufficient blood specimens.
§There were eight HIV antibody-positive participants for whom we could not perform the immunoglobulin G-capture HIV-1 subtypes B, AE, and D-enzyme immunoassay (BED-CEIA) because of a lack of sufficient blood specimens.

(aPAF 13.8%; 95% CI 4.1–22.4%) and HSV-2 infection (aPAF 7.1%; 95% CI 1.9–15.2%).

Among OMSM, recreational drug use had the highest aPAF (aPAF 19.4%; 95% CI 7.3–30.0%), followed by HSV-2 infection (aPAF 12.2%; 95% CI 2.9–20.6%), anal bleeding in the past 6 months (aPAF 9.4%; 95% CI 0.3–17.7%) and syphilis infection (aPAF 8.9%; 95% CI 1.5–15.8%).

Age-related trends in HIV prevalence, HIV incidence and risk factors

Among YMSM, both the HIV prevalence and the HIV incidence increased gradually with age. Sharp increases were observed between the ages of 16 and 21 years. However, among OMSM, although there was a slight increase in the HIV prevalence between the ages of 40 and 55 years, both the HIV prevalence and HIV incidence decreased with age (Fig. 1).

The prevalence of recreational drug use increased sharply between the ages of 16 and 18 years. This prevalence reached its peak at the age of 25 years and then started...
### Table 2

Crude and adjusted measures of the odds ratio (OR) and adjusted population attributable fraction (PAF) of recent HIV infection risk factors in younger men who have sex with men (YMSM) and older men who have sex with men (OMSM) (n = 4238)†

| Variable | YMSM (n = 1263) | OMSM (n = 2975) |
|----------|-----------------|-----------------|
|          | Recent HIV infection | Crude model OR (95% CI) | Adjusted model aOR (95% CI) | aPAF\(^{\text{‡}}\) % (95% CI) | Recent HIV infection | Crude model OR (95% CI) | Adjusted model aOR (95% CI) | aPAF\(^{\text{‡}}\) % (95% CI) |
| Occupation |                  |                  |                  |                  |                      |                  |                  |                  |
| Nonstudent | 6.2 (49/788) | 1.4 (0.8 to 2.3) | NA | NA | 3.8 (111/2896) | Ref | 5.1 (479) | 1.3 (0.5 to 3.7) | NA | NA |
| Student | 4.6 (22/475) | Ref | NA | NA | 4.6 (77/1683) | 1.6 (1.1 to 2.4)* | 1.6 (1.0 to 2.4)* | NA | NA |
| Sexual orientation |                  |                  |                  |                  |                      |                  |                  |                  |
| Homosexual | 6.1 (49/805) | 1.3 (0.8 to 2.2) | NA | NA | 2.3 (38/1292) | Ref | Ref | Ref | Ref |
| Other | 4.8 (22/436) | Ref | NA | NA | 3.9 (75/1939) | 1.0 (0.7 to 1.5) | NA | NA |
| Main venue for seeking male sexual partners |                  |                  |                  |                  |                      |                  |                  |                  |
| Internet | 5.9 (55/940) | 1.2 (0.7 to 2.1) | NA | NA | 3.9 (40/1036) | Ref | Ref | Ref |
| Noninternet | 5.0 (16/307) | Ref | NA | NA | 3.8 (47/1776) | Ref | 4.0 (48/1199) | 1.1 (0.7 to 1.6) | NA | NA |
| Gender of first sexual partner |                  |                  |                  |                  |                      |                  |                  |                  |
| Male | 5.6 (56/995) | 1.0 (0.6 to 1.8) | NA | NA | 4.6 (34/747) | 1.3 (0.8 to 1.9) | NA | NA |
| Female | 5.6 (15/268) | Ref | NA | NA | 3.7 (80/2176) | Ref | 5.5 (49/892) | Ref | Ref |
| Age of sexual debut with male partner |                  |                  |                  |                  |                      |                  |                  |                  |
| < 18 years | 5.0 (15/303) | 0.8 (0.4 to 1.7) | NA | NA | 3.4 (12/353) | Ref | Ref | Ref |
| 18-20 years | 5.8 (40/696) | 0.9 (0.5 to 1.7) | NA | NA | 3.6 (27/746) | 1.1 (0.5 to 2.1) | NA | NA |
| > 20 years | 6.1 (16/262) | Ref | NA | NA | 4.1 (76/1875) | 1.2 (0.7 to 2.2) | NA | NA |
| Predominant sex position during AI |                  |                  |                  |                  |                      |                  |                  |                  |
| Receptive | 6.9 (27/390) | 2.4 (1.2 to 5.1)* | 2.7 (1.3 to 5.8)** | NA | 4.7 (25/534) | 1.5 (0.9 to 2.6) | 1.7 (1.0 to 3.0) | NA | NA |
| Versatile | 6.1 (31/507) | 2.1 (1.0 to 4.4)* | 2.5 (1.2 to 5.2)** | NA | 4.2 (58/1397) | 1.3 (0.9 to 2.1) | 1.7 (1.1 to 2.7)* | NA | NA |
| Insertive | 3.0 (10/337) | Ref | Ref | Ref | 3.1 (31/987) | Ref | Ref | Ref |
| Used condom at last AI with male partner |                  |                  |                  |                  |                      |                  |                  |                  |
| No | 5.5 (19/346) | 1.0 (0.6 to 1.7) | NA | NA | 4.6 (34/747) | 1.3 (0.8 to 1.9) | NA | NA |
| Yes | 5.5 (49/892) | Ref | NA | NA | 3.7 (80/2176) | Ref | 5.5 (49/892) | Ref | Ref |
| Number of male sexual partners in the past 6 months |                  |                  |                  |                  |                      |                  |                  |                  |
| > 2 | 7.0 (33/472) | 1.5 (0.9 to 2.5) | NA | NA | 4.9 (59/1197) | 1.6 (1.1 to 2.3)** | 1.6 (1.1 to 2.4)** | 18.8 (2.4 to 32.5) | Ref | Ref |
| ≤ 2 | 4.7 (37/789) | Ref | NA | NA | 3.2 (56/1778) | Ref | Ref | Ref |
| Having commercial sex |                  |                  |                  |                  |                      |                  |                  |                  |
| Yes | 6.9 (3/710) | 1.3 (0.6 to 2.8) | NA | NA | 3.3 (11/336) | Ref | Ref | Ref |
| No | 5.5 (64/1161) | Ref | NA | NA | 3.9 (104/2639) | 1.2 (0.6 to 2.3) | NA | NA |
| Recreational drug use†† |                  |                  |                  |                  |                      |                  |                  |                  |
| Yes | 7.7 (28/366) | 1.7 (1.0 to 2.7)* | 2.1 (1.2 to 3.6)** | 19.5 (2.7 to 33.4) | 5.1 (42/817) | 1.6 (1.1 to 2.3)* | 2.2 (1.5 to 3.4)** | 19.4 (7.3 to 30.0) | Ref | Ref |
| No | 4.8 (48/939) | Ref | Ref | Ref | 3.4 (73/2158) | Ref | Ref | Ref |
| Anal bleeding in the past 6 months |                  |                  |                  |                  |                      |                  |                  |                  |
| Yes | 9.2 (24/262) | 2.1 (1.2 to 3.4)** | 2.6 (1.5 to 4.6)** | 19.8 (5.2 to 322) | 6.5 (25/385) | 1.9 (1.2 to 3.1)** | 1.8 (1.1 to 3.0)* | 9.4 (0.3 to 17.7) | Ref | Ref |
| No | 4.7 (47/1001) | Ref | Ref | Ref | 3.5 (90/250) | Ref | Ref | Ref |
| Condom breakage during AI in the past 6 months |                  |                  |                  |                  |                      |                  |                  |                  |
| No | 5.7 (65/1145) | 1.1 (0.5 to 2.7) | NA | NA | 3.6 (99/2719) | Ref | Ref | Ref |
| Yes | 5.1 (6/118) | Ref | NA | NA | 6.3 (16/258) | 1.8 (1.0 to 3.0)* | 1.9 (1.0 to 3.3)* | 6.1 (1.0 to 12.7) | Ref | Ref |
| Syphilis infection |                  |                  |                  |                  |                      |                  |                  |                  |
| Yes | 18.0 (5/78) | 4.3 (2.3 to 8.2)** | 3.9 (2.0 to 7.9)** | 13.8 (4.1 to 22.4) | 7.5 (19/252) | 2.2 (1.3 to 3.7)** | 2.3 (1.4 to 3.9)** | 8.9 (1.5 to 15.8) | Ref | Ref |
| No | 4.8 (57/1185) | Ref | Ref | Ref | 3.5 (96/2723) | Ref | Ref | Ref |

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Table 2 (Continued)

| Variable            | Recent HIV infection n/total | Crude model aOR (95% CI) | Adjusted model aOR (95% CI) |
|---------------------|-----------------------------|--------------------------|-----------------------------|
| HSV-2 infection     | Yes                         | 2.3 (1.1 to 4.9)         | 2.2 (1.1 to 4.9)            |
|                     | No                          | 5.0 (3.71 to 6.72)       | 2.2 (1.1 to 4.9)            |

The aPAFs were calculated based on aORs of the risk factors associated with recent HIV infection in multivariate logistic regression models. The models were adjusted for study site (Shanghai, Nanjing, Changsha, Zhengzhou, Jinan, Shenyang and Kunming), residence (local/migrant), education (junior school or below, high school, or college or above), monthly income (no income, US$1 to US$600 or US$600), and ethnicity (Han or other).‡ The aPAF of HSV-2 infection was calculated based on aORs of HSV-2 infection established by EIA detection and eight MSM participants were not tested because of a lack of sufficient blood samples.¶ Buying or selling sex services, including anal intercourse or oral intercourse.†† Recreational drugs: psychoactive drugs to alter one’s mental state in a way that modifies emotions, perceptions, and feelings for recreational purposes, such as methamphetamine, cocaine, ketamine, and amyl nitrate.‡‡ The aPAF of HSV-2 infection was calculated based on aORs of HSV-2 antibody established by EIA detection and eight MSM participants were not tested because of a lack of sufficient blood specimens.

Discussion

Our survey showed that the HIV incidence among YMSM was significantly higher than that among OMSM, although there was no significant difference between their HIV prevalences. Although risk factors for recent HIV infection were similar among YMSM and OMSM, the aPAFs of these risk factors were quite different. We found that anal bleeding and recreational drug use played major roles in HIV acquisition among YMSM.

To our knowledge, this is the first study showing that HIV incidence increased gradually with age among YMSM but declined with age among OMSM. Previous studies suggested that YMSM were more sexually active than OMSM [22]. Based on our findings, we further deduced that YMSM would be more sexually active during adolescence to young adulthood. During this period, they are most vulnerable to sexual risk taking, and hence had an increased risk of HIV infection [22]. Among YMSM, the HIV incidence increased rapidly (i.e. from 0 per 100 PY to approximately 12 per 100 PY) between 16 and 21 years. Some social and emotional factors might contribute to such a change. Firstly, during this period, YMSM might migrate from less developed areas to big cities to study or work. Their social networks would hence be expanded [23]. This might increase their possibility of having sexual contact with men and/or using recreational drugs [23]. In our study, 80.5% of sexual debuts of YMSM happened in this period. Secondly, previous research found that the socio-emotional control systems in the brains of adolescents may not be able to cope with emotional arousal or inhibit impulsive behaviours, especially in the presence of peers. This may explain why there is an increase in risk-taking behaviours, especially in the presence of peers.
behaviours (i.e. drug or alcohol use and unprotected sexual behaviours) [24]. Therefore, effective prevention targeted to YMSM of a younger age (aged ≤ 21 years) should be prioritized in order to control the HIV epidemic [15].

Risk factors associated with recent HIV infection were the same among YMSM and OMSM [25–29]. However, we found some unique characteristics with respect to these risk factors among YMSM. Firstly, one-third of YMSM had used recreational drugs and most users started using such drugs when they were very young (16–18 years old). The prevalence of recreational drug use gradually increased with age among YMSM, with the peak value being observed at the age of 25 years. YMSM might use recreational drugs in conjunction with their sexual debut for different purposes, such as socializing, facilitating AI, reducing pain during AI, and enhancing sexual pleasure [30–33]. Secondly, compared with OMSM, the prevalence of anal bleeding among YMSM was higher, especially among those aged 20–22 years. One possible explanation was that many of the YMSM in this study adopted a receptive role in AI but they did not have adequate knowledge of and experience in using water-based lubricants and condoms [34]. Thirdly, although the prevalence of syphilis and HSV-2 infection among YMSM was lower than in their older counterparts, they were still strongly associated with recent HIV infection. Furthermore, the sharpest increases in the prevalence of some risk factors (i.e. recreational drug use and anal bleeding) were observed among YMSM between the ages of 16 and 21 years, which were coincident with trends for HIV incidence. Therefore, YMSM should be targeted and educated as promptly as possible.

By calculating the aPAFs of risk factors, it was possible to quantify how many of the cases of HIV infection could be avoided if the corresponding risk factors were eliminated. Two risk factors, i.e. anal bleeding and recreational drug use, had the highest aPAFs among YMSM and therefore should be the primary targets in future interventions. In addition, we found that the aPAF of each risk factor varied by age. Therefore, it is vital to find the specific age group with the highest aPAF for each risk factor in order to design accurate interventions and to ensure optimized allocation of public health resources. Firstly, we found that peak aPAF values of two risk factors (i.e. anal bleeding and syphilis infection) occurred at younger age, suggesting that early interventions preventing anal bleeding and syphilis are needed and are likely to have a significant impact in preventing HIV infection. Secondly, although the aPAF of recreational drug use in the youngest age group was not the highest, it increased with age. Measures preventing recreational drug use should be implemented among YMSM at an earlier age, which would have long-term benefits for their health.

It is crucial to improve HIV prevention measures targeting YMSM. Such prevention should start as early as possible to control the worsening HIV epidemic. However, in China, YMSM are still a hidden population, and most of the school-based sex education programmes do not provide adequate information to these YMSM [6]. Innovative HIV prevention interventions should be developed. For example, mobile phone-based interventions might be
very well accepted by YMSM. Previous studies showed that mobile phones served as a good platform to deliver HIV prevention information, as well as to inform YMSM about locations where they could acquire lubricants and condoms [35,36]. Another innovative approach could be to integrate screening for HIV infection and STIs into

Fig. 2 Variation curves for the prevalence of HIV risk factors in (a) younger men who have sex with men (YMSM) and (b) older men who have sex with men (OMSM) participating in this survey. The four age-dependent variation curves represent the prevalence of four risk factors related to recent HIV infection changing with age in YMSM and OMSM. HSV-2, herpes simplex virus 2.

Fig. 3 The adjusted population attributable fractions (aPAFs) of risk factors for recent HIV infection in different age groups in men who have sex with men (MSM). The four quadrangles represent four risk factors for HIV recent infection and the four dimensions on the radar map represent four age classes. The aPAFs of risk factors for recent HIV infection were not stable in the different age classes and the detailed aPAFs are shown in the table. The MSM were divided into different age classes based on 3-year intervals; the aPAFs of these four risk factors for recent HIV infection could not be calculated below 19 years old and over 30 years old, because the proportions of recently HIV-infected individuals with the aforementioned risk factors in specific age classes were too small.

| Risk factors     | aPAFs of risk factors in each age class |
|------------------|-----------------------------------------|
|                  | 19-21 years old | 22-24 years old | 25-27 years old | 28-30 years old |
| Recreational drugs | 16.6%      | 16.4%      | 26.7%      | 26.6%      |
| Anal bleeding     | 27.4%      | 18.6%      | 17.6%      | 2.2%       |
| Syphilis infection| 25.5%      | 7.7%       | 7.3%       | 12.3%      |
| HSV-2 infection   | 3.5%       | 8.9%       | 15.9%      | 18.4%      |
school-based primary health examination projects as this could significantly expand coverage and access to care among YMSM [37].

Our study had some limitations. First, as the HIV incidence was estimated using the BED-CEIA test based on a cross-sectional survey, there might be some selection bias with respect to the participants and misclassification of recent HIV infection if participants were at the stage of AIDS with low CD4 cell counts or receiving antiretroviral therapy (approximately 5% of confirmed HIV-seropositive cases). In this study, we used a specificity adjustment formula to minimize the BED-CEIA correlated bias and applied the parameters recommended by the China CDC [20]. Secondly, the sum of aPAFs of all risk factors related to recent HIV infection exceeded 100%; although the effects of other confounders had been corrected for using aORs, the interaction between risk factors still potentially could have affected the aPAFs [38]. We estimated the aPAFs of risk factors based on a hypothetical scenario, i.e. a certain risk factor could be removed entirely without considering that the proportion of other related risk factors would be changed after the elimination of that risk factor.

In conclusion, YMSM in China had a higher HIV incidence than OMSM. Unlike OMSM, whose HIV incidence decreased with age, the HIV incidence in YMSM gradually increased with age. YMSM aged 16–21 years were of extremely high risk of recent HIV infection. Innovative intervention measures targeting this group should be considered to control the HIV epidemic.

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