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ORIGINAL RESEARCH

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

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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.

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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 [5], 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, Ji'nan, 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

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 χ^2 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)

		YMSM (n = 1313)		OMSM (n = 3183)		
Variable	***n***	***n***	**%**	***n***	**%**	***P*-value**
Residence						
Local cities	1785	460	35.0	1325	41.6	< 0.001
Non-local cities	2711	853	65.0	1858	58.4	
City						
Kunming	632	221	16.8	411	12.9	< 0.001
Shenyang	664	172	13.1	492	15.5	
Ji'nan	675	229	17.4	446	14.0	
Changsha	689	285	21.7	404	12.7	
Zhengzhou	467	106	8.1	361	11.3	
Nanjing	592	203	15.5	389	12.2	
Shanghai	777	97	7.4	680	21.4	
Education						
Junior school or below	916	171	13.0	745	23.4	< 0.001
High school	1201	352	26.8	849	26.7	
College or above	2379	790	60.2	1589	49.9	
Sexual orientation						
Homosexual	2659	843	64.2	1816	57.1	< 0.001
Other	1837	470	35.8	1367	43.0	
Ethnicity						
Han	4196	1210	92.2	2986	93.8	0.043
Other	300	103	7.8	197	6.2	
Occupation						
Student	565	481	36.6	84	2.6	< 0.001
Nonstudent	3931	832	63.4	3099	97.4	
Monthly income						
No income	769	538	41.0	231	7.3	< 0.001
US$1–600	2858	642	48.9	2216	69.6	
≥ US$600	869	133	10.1	736	23.1	
Main venue for seeking male sexual partners						
Internet	3055	974	74.2	2081	65.4	< 0.001
Noninternet	1441	339	25.8	1102	34.6	
Gender of first sexual partner						
Male	2925	1031	78.5	1894	59.5	< 0.001
Female	1571	282	21.5	1289	40.5	
Age of sexual debut with male partner						
< 18 years	681	312	23.8	369	11.6	< 0.001
18–20 years	1521	725	55.3	796	25.0	
> 20 years	2291	274	20.9	2017	63.4	
Predominant sex position during AI						
Insertive	1395	343	26.8	1052	33.7	< 0.001
Receptive	988	409	31.9	579	18.5	
Versatile	2022	530	41.3	1492	47.8	
Used condom during last AI with male partner						
Yes	3244	926	72.0	2318	74.0	0.154
No	1174	361	28.1	813	26.0	
Number of male sexual partners in past 6 months						
> 2	1785	495	37.8	1290	40.5	0.091
≤ 2	2707	814	62.2	1893	59.5	
Having commercial sex*						
Yes	459	111	8.5	348	10.9	0.013
No	4037	1202	91.6	2835	89.1	
Recreational drug use†						
Yes	1275	385	29.3	890	28.0	0.357
No	3221	928	70.7	2293	72.0	
Anal bleeding in past 6 months						
Yes	695	274	20.9	421	13.2	< 0.001
No	3801	1039	79.1	2762	86.8	
Condom breakage during AI in past 6 months						
Yes	390	124	9.4	266	8.4	0.239
No	4106	1189	90.6	2917	91.6	
Syphilis infection						
Yes	381	91	6.9	290	9.1	0.017
No	4115	1222	93.1	2893	90.9	
HSV-2 infection‡						
Yes	552	98	7.6	454	14.5	< 0.001
No	3863	1187	92.4	2676	85.5	
HIV infection						
Yes	444	121	9.2	323	10.1	0.333
No	4052	1192	90.8	2860	89.9	
Recent or established HIV infection§						
Recent	186	71	58.7	115	36.5	< 0.001
Established	250	50	41.3	200	63.5	
Recent HIV infection§						
Yes	186	71	5.4	115	3.6	0.006
No	4302	1242	94.6	3060	96.4	

AI, 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[†])

	YMSM (n = 1263)				OMSM (n = 2975)			
Variable	Recent HIV infection % (n/total)	Crude model cOR (95% CI)	Adjusted model aOR (95% CI)[§]	aPAF[‡] % (95% CI)	Recent HIV infection % (n/total)	Crude model cOR (95% CI)	Adjusted model aOR (95% CI)[§]	aPAF[‡]% (95% CI)
Occupation								
Nonstudent	6.2 (49/788)	1.4 (0.8 to 2.3)	NA	NA	3.8 (111/2896)	Ref		
Student	4.6 (22/475)	Ref			5.1 (4/79)	1.3 (0.5 to 3.7)	NA	NA
Sexual orientation								
Homosexual	6.1 (49/805)	1.3 (0.8 to 2.2)	NA	NA	4.6 (77/1683)	1.6 (1.1 to 2.4)*	1.6 (1.0 to 2.4) *	NA
Other	4.8 (22/436)	Ref			2.9 (38/1292)	Ref	Ref	
Main venue for seeking male sexual partners								
Internet	5.9 (55/940)	1.2 (0.7 to 2.1)	NA	NA	3.9 (75/1939)	1.0 (0.7 to 1.5)	NA	NA
Noninternet	5.0 (16/307)	Ref			3.9 (40/1036)	Ref		
Gender of first sexual partner								
Male	5.6 (56/995)	1.0 (0.6 to 1.8)	NA	NA	3.8 (67/1776)	Ref		
Female	5.6 (15/268)	Ref			4.0 (48/1199)	1.1 (0.7 to 1.6)	NA	NA
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		
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			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
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
Insertive	3.0 (10/337)	Ref	Ref		3.1 (31/987)	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			3.7 (80/2178)	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)
≤ 2	4.7 (37/789)	Ref			3.2 (56/1778)	Ref	Ref	Ref
Having commercial sex[¶]								
Yes	6.9 (7/102)	1.3 (0.6 to 2.8)	NA	NA	3.3 (11/336)	Ref		
No	5.5 (64/1161)	Ref			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)
No	4.8 (43/897)	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 32.2)	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)
No	4.7 (47/1001)	Ref	Ref	Ref	3.5 (90/2590)	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			6.3 (16/256)	1.8 (1.0 to 3.0)*	1.9 (1.0 to 3.3)*	6.1 (−1 to 12.7)
Syphilis infection								
Yes	18.0 (14/78)	4.3 (2.3 to 8.2)***	3.9 (2.0 to 7.5)***	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)
No	4.8 (57/1185)	Ref	Ref	Ref	3.5 (96/2723)	Ref	Ref	Ref

Table 2 (*Continued*)

Variable	YMSM (n = 1263) Recent HIV infection % (n/total)	Crude model cOR (95% CI)	Adjusted model aOR (95% CI)§	aPAF‡ % (95% CI)	OMSM (n = 2975) Recent HIV infection % (n/total)	Crude model cOR (95% CI)	Adjusted model aOR (95% CI)§	aPAF‡% (95% CI)
HSV-2 infection‡‡								
Yes	10.7 (9/84)	2.3 (1.1 to 4.8)*	2.2 (1.1 to 4.8)*	7.1 (−1.9 to 15.2)	6.8 (27/397)	2.1 (1.3 to 3.3)***	2.1 (1.4 to 3.4)***	12.2 (2.9 to 20.6)
No	5.0 (57/1152)	Ref	Ref	Ref	3.4 (85/2528)	Ref	Ref	Ref

AI, anal intercourse; aOR, adjusted odds ratio; CI, confidence interval; cOR, crude odds ratio; HSV-2, herpes simplex virus 2; NA, not applicable; aPAF, adjusted population attributable fraction; Ref, reference.

*P < 0.05; **P < 0.01; ***P < 0.001.

†A total of 258 MSM participants were not included in the analysis in bivariate and multivariate logistic regression models, of whom 250 had HIV infection established by BED-CEIA detection and eight HIV antibody-positive participants were not tested by immunoglobulin G-capture HIV-1 subtypes B, AE, and D-enzyme immunoassay (BED-CEIA) because of a lack of sufficient blood samples.

‡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, Ji'nan, Shenyang and Kunming), residence (local/migrant), education (junior school or below, high school, or college or above), monthly income (no income, US\$1–600 or ≥ US\$600) and ethnicity (Han or other).

¶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, bath salts and rush poppers.

‡‡There were 81 participants for whom we were unable to perform the assay for HSV-2 antibody because of a lack of sufficient blood specimens.

decreasing. The peak of the prevalence of anal bleeding was observed at the age of 21 years. This prevalence then decreased until the age of 45 years. The prevalences of syphilis and HSV-2 infection both increased with age (Fig. 2).

We also found that the aPAF of risk factors for recent HIV infection varied greatly by age group. The aPAF of recreational drug use increased with age among YMSM. Its peak was observed between the ages of 25 and 27 years (26.7%; 95% CI 2.3–45). The highest aPAF of anal bleeding was observed between the ages of 19 and 21 years (27.4%; 95% CI −0.3–47.4). This value declined sharply thereafter. The highest aPAF of syphilis infection was also observed between the ages of 19 and 21 years (25.5%; 95% CI 2.8–42.9), while that of HSV-2 infection was observed between the ages of 28 and 30 years (18.4%; 95% CI −4.9–36.5) (Fig. 3).

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 the ages of 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 (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

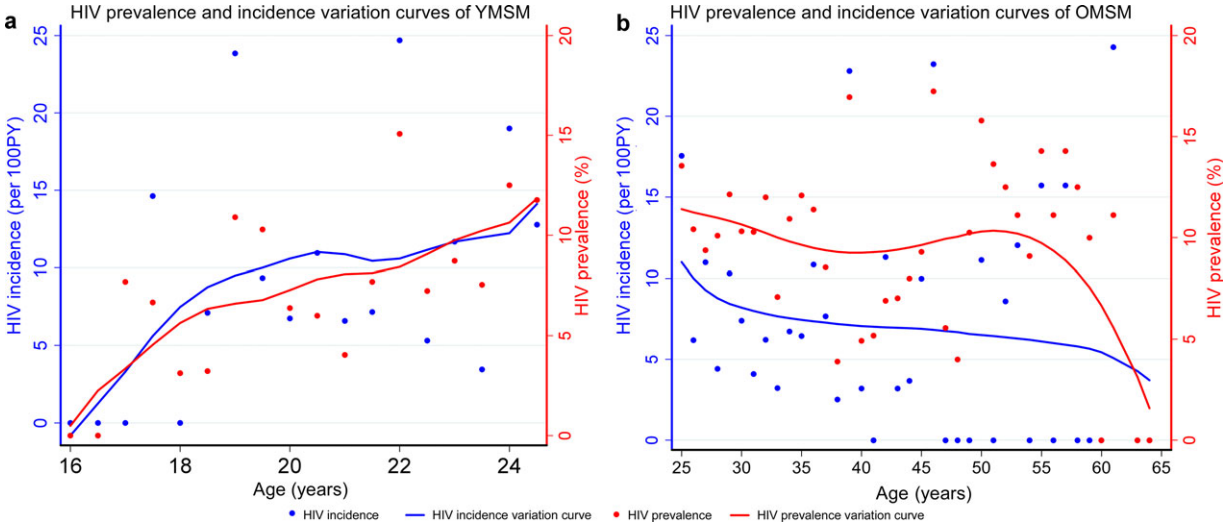


Fig. 1 HIV prevalence and incidence variation curves for (a) younger men who have sex with men (YMSM) and (b) older men who have sex with men (OMSM) participating in this survey. The two age-dependent variation curves represent HIV incidence and prevalence changing with age in YMSM and OMSM. PY, person-years.

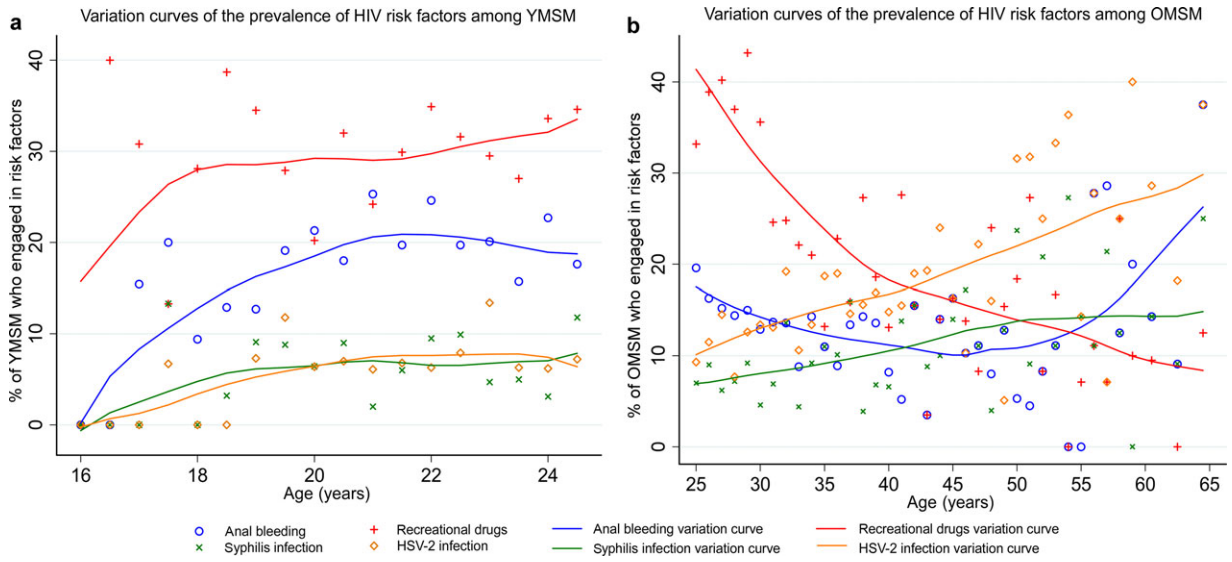
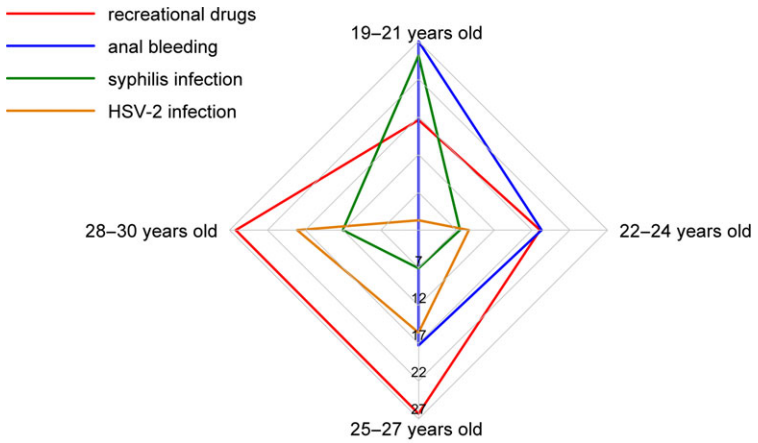


Fig. 2 Variation curves for the prevalence of HIV risk factors in (a) younger men who have sex with men (YMSM) and (b) older men who have sex with men (OMSM) participating in this survey. The four age-dependent variation curves represent the prevalence of four risk factors related to recent HIV infection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



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	16.9%	18.4%	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%

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.

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

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 (approximate 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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Conflicts of interest: The authors declare no conflicts of interest.

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