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Keywords:	HIV testing, gay app, testing approach, MSM

The relationship between use of gay app and HIV testing among men who have sex with men in Shenzhen, China

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Abstract

Objectives To investigate the relationship between use of gay app and HIV testing among MSM. We hypothesized that use of gay app had significant impact on the HIV testing related behaviors of MSM.

Design Three-year serial cross-sectional study

Setting Newly well-developed city in China

Participants 4935 eligible MSM were recruited through offline sampling methods from 2015 to 2017 in Shenzhen, China.

Primary and secondary outcomes The primary outcome of this study is to compare the HIV testing rate and choice of testing approaches between app users and non-app users. The secondary outcome is the risk factors associated with HIV testing among MSM.

Results There were 58.2% of the participants had been tested for HIV within lifetime and 43.7% had been tested within the past one year. App-using MSM had significant higher prevalence of HIV testing than non-app-using MSM. App-using MSM were more likely to receive HIV testing at the center for disease control and prevention, community-based organization, and take home self-testing; however, they were less likely to test at gay venues. MSM with older age, higher education level, self-identified as homosexuality, and recruited through clinic-based sampling had higher odds of HIV testing in the past year. Other predictors beyond app use included engaging in group sex, access to HIV-related service, high level of HIV-related knowledge and risk perception. However, MSM who were money

boys, practiced receptive sexual role, and being HIV seropositive had lower odds of HIV testing.

Conclusions Gay app has significantly increased the HIV testing uptake among MSM who are hard-to-reach by traditional outreach. It is necessary to expand HIV testing among non-app-using MSM. Continued efforts, innovative strategies and increased resource are highly needed to realize the first "90" target.

Key Words HIV testing, gay app, MSM, testing approach

Strengths and limitations of this study

- This large study represents one of the few studies that compare the HIV testing and pattern of testing approaches between app-using MSM and non-app-using MSM from a developing country setting, which has significant implication for future HIV testing expanding strategies.
- Different from most previous studies based online survey, this study uses a combined offline recruitment method, which could provide complementary evidence on this topic.
- This is a cross-sectional study which makes it difficult to establish a causal relationship.
- The findings may not be generalizable to MSM from other areas or settings.

Introduction

HIV testing is an essential component of HIV prevention strategy that linked to treatment and care, lack of knowledge on the HIV serostatus would disable or postpone initiation of antiviral treatment. Also, screening for HIV among asymptomatic HIV carrier may directly reduce the HIV transmission, as prior research estimated that those who are unaware of their sero-postive status are 3.5 times more likely to transmit HIV than those who know their serostatus.[1] Presently, there were about 30% of people living with HIV did not know their HIV status globally.[2] The HIV testing rate in China is unacceptably low, far from achieving the first of the United Nation's 90–90–90 targets– for 90% of all people with HIV to get tested and know their status by 2020. A recent meta-analysis reported that there are just 47% of the men who have sex with men (MSM) have ever been tested for HIV in China, despite the extensive combined efforts of government, public health agencies, community-based organizations in recent years.[3] Due to the stigma against homosexuality in China, MSM in fear of exposure of homosexuality-identity are less likely to take an HIV test. Besides, there are several other barriers to HIV testing, such as name-based testing, low perception of risk, long asymptomatic phase, unaware that testing is free of charge, posing significant challenges to HIV prevention and interventions among MSM in China.[4] Thus, developing more comprehensive strategies for expanding HIV testing among MSM is an urgent priority in China.

In recent years, the emergence of gay app (geosocial networking application specific to MSM) has significantly reformed the MSM's sex-seeking behaviors as well as harm-reduction behaviors.[5] Previous limited studies on the association between gay apps use and HIV testing

behavior are inclusive. Some studies found app use was associated with more HIV testing either within lifetime or in the past year,[6 7] while other studies found no difference between app users and non-users.[8] A recent systematic review found that app users are twice as likely to test for HIV within lifetime as non-app users.[5] Another study revealed that social media use was significantly associated with HIV testing in Chinese MSM.[9] Free HIV testing is now widely available in all provinces of China since 2006. Apart from the health facility-based testing service provided at hospital/clinics and Center for Disease Control and Prevention (CDC), there are also decentralized HIV testing services provided at peripheral health facilities including community-based organization (CBO), blood donation site, as well as testing service at gay venues and self-testing at home.[10] As the uptake of HIV testing among MSM is still limited, a better understanding of the testing pattern and preferences among MSM is critical to inform expanding HIV testing strategies. Furthermore, few studies exist regarding the impact of app use on the uptake and preference of HIV testing approach among MSM. Therefore, we conducted a study to investigate the relationship between app use and HIV testing uptake and approaches, and to identify the demographic and behavioral predictors of HIV testing among MSM in Shenzhen, China, where MSM accounted for the largest percentage (56.7%) of the new infections in recent years.

Methods

Source of sample

From May 2015 to the end of 2017, eligible MSM were recruited through combined offline sampling methods, primarily venue-based (Time Location Sampling) and clinics based

(Respondent-Driven Sampling; Voluntary Counseling and Testing center). Details of these methods were described in the previous study.[11] Each participant was invited to complete an anonymous questionnaire via a handheld electronic tablet and provide a written informed consent. The protocol for recruitment was approved by the Medical Ethics Committee of Shenzhen Center for Disease Control and Prevention.

Behavioral measures

All data was collected through self-administered questionnaires, including demographics, sexual behaviors, gay app use, recreational drug use, HIV testing, and HIV-related services, source of AIDS-related knowledge and HIV infection perception. HIV testing behavior was evaluated in the following measures: 1) Have you ever received HIV testing? 2) Have you taken HIV testing in the past year? 3) Where did you receive HIV testing? (Gay venue/ hospital/ CDC/ blood donation site/ CBO/ self-testing at home). The main source of AIDS-related knowledge was listed as TV, radio, newspaper, books, friends, doctors, consultation service, free promotional materials, bulletin board, internet and school education.

Statistical analysis

Demographic features and HIV testing related behaviors were compared between app-using MSM and non-app-using MSM, with categorical variables compared using *Chi-squared test* or *Fisher's exact test*. Univariate and multivariate logistic regressions adjusted for confounders (e.g., age, education, marital status, year of survey, etc.) were performed to examine the correlates between app use and testing-related behaviors. To identify the significant predictors for HIV testing within the past year and lifetime, variables with a p-

value <0.10 in the univariate logistic regression models and theoretically important covariates were included in multivariate regression models. Adjusted odds ratios (AOR) and 95% confidence intervals (CIs) were presented. All statistical analyses were performed in R (version 3.4.3, Foundation for Statistical Computing, Vienna, Austria).

Results

Among the 4935 participants recruited from 2015 to 2017, 1588 (32.2%) MSM had used at least one kind of gay app, including 1496 non-commercial MSM and 92 male sex workers (also called money boy, MB). The demographic characteristics of all recruited MSM were presented in Table 1. Comparing to non-app-using MSM, app-using MSM was more likely to be younger (28.3 vs. 28.8 years), unmarried (92.0% vs. 90.1%), have an education level of college or above (64.0% vs. 42.1%), and have monthly income higher than 7000 RMB (34.1% vs. 24.3%). There was no significant difference in ethnicity and duration of residence in Shenzhen between the two groups. There were higher percentage of app-using MSM recruited from clinics (69.6% vs. 41.6%) and recruited in 2017 (56.9% vs.34.2%) than that of non-app-using MSM. The prevalence of HIV and syphilis infection was not significantly different between the two groups, although it was significantly higher among non-app-using NcMSM (non-commercial MSM) when excluding the MBs who were less likely to use app and be positive for HIV and syphilis (data not shown).

Table 1 Demographics of app-using and non-app-using MSM

	Non-app-using MSM (N=3347), N (%)	**App-using MSM (N=1588), N (%)**	**P value**
Age			
<25	1316(39.3)	461(29.0)	<0.01

25~40	1618(48.4)	1030(64.9)	
>40	412(12.3)	97(6.1)	
Mean age(years)	28.8	28.3	<0.05
Duration of residence in Shenzhen			
<1 year	802(25.5)	360(24.0)	0.299
≥1 year	2342(74.5)	1137(76.0)	
Ethnicity			
Han	3237(97.8)	1524(97.1)	0.215
Other	74(2.2)	45(2.9)	
Education			
Junior high school or less	637(19.0)	146(9.2)	
Senior high school	1301(38.9)	425(26.8)	<0.01
College or above	1409(42.1)	1017(64.0)	
Monthly income(RMB)			
<3000	196(5.9)	123(7.7)	
3000~7000	2337(69.8)	923(58.1)	<0.01
>7000	814(24.3)	542(34.1)	
Marital status			
Unmarried	3015(90.1)	1461(92.0)	<0.05
Married	332(9.9)	127(8.0)	
Year of sample			
2015	1254(37.5)	118(7.4)	
2016	949(28.4)	567(35.7)	<0.01
2017	1144(34.2)	903(56.9)	
Source of sample			
Venue based	1953(58.4)	483(30.4)	<0.01
Clinic based	1394(41.6)	1105(69.6)	
Type of MSM			
NcMSM	2117(63.3)	1496(94.2)	<0.01
MB	1230(36.7)	92(5.8)	
HIV			
Negative	3005(89.8)	1414(89.0)	0.458
Positive	342(10.2)	174(11.0)	
Syphilis			
Negative	2983(89.1)	1419(89.4)	0.844
Positive	364(10.9)	169(10.6)	
History of diagnosis of other STDs			
No	3119(93.2)	1430(90.1)	<0.01
Yes	228(6.8)	158(9.9)	

Note: NcMSM, Non-commercial MSM; MB, Money boy (male sex worker); STD, sexually transmitted disease.

There were significant differences of testing-related behaviors between app-using MSM and non-app-using MSM in this study (Table 2). There were about 58.2% of MSM had been tested for HIV within lifetime and 43.7% had been tested within the past year in Shenzhen. App-using MSM had significant higher prevalence of HIV testing within lifetime (70.2% vs.52.6%) and the past year (52.0% vs. 39.8%) than non-app-using MSM. After controlling for age, education, monthly income, marital status, year of sample, source of sample, and type of MSM, MSM who used gay app had significant higher odds of ever been tested for HIV (AOR: 1.48, 95%CI: 1.27, 1.72) and HIV test in the past year (AOR: 1.36, 95%CI: 1.18, 1.57) than those who did not. App-using-MSM were more commonly to know their HIV testing results (AOR: 1.72, 95%CI: 1.16, 2.54) and know their last negative result with the past one year (AOR: 1.29, 95%CI: 1.09, 1.53). Generally, app-using MSM had higher perception of HIV infection risk than their counterparts (AOR: 1.43, 95%CI: 1.00, 2.06). For the approaches of HIV testing, app-using MSM were more likely to receive HIV testing at the local Center for Disease Control and Prevention (CDC) (AOR: 1.48, 95%CI: 1.24, 1.76), community-based organization (CBO) (AOR: 1.71, 95%CI: 1.44, 2.03), and take self-testing at home (AOR: 1.61, 95%CI: 1.21, 2.14); however, they were less likely to receive HIV testing at gay venues (AOR: 0.49, 95%CI: 0.37, 0.63). There were no significant differences of odds in testing at hospital and blood donation sites among the two groups. Furthermore, the choice of HIV testing sites by year was compared between the two groups in the Figure. From 2015 to 2017, there was an increasing proportion of MSM chose to take an HIV test at CDC, and a declining trend of been tested at hospital, CBOs and blood donation site among app-using MSM. Notably, there were

increasing rate of home self-testing among non-app-using MSM although the main choices were testing at venue, CDC and CBO. App-using MSM were more likely to gain AIDS-related knowledge from the internet (AOR: 3.07, 95%CI: 2.58, 3.67), books (AOR: 2.04, 95%CI: 1.72, 2.42), doctors (AOR: 1.27, 95%CI: 1.00, 1.61), free promotional materials (AOR: 1.76, 95%CI: 1.51, 2.07), bulletin board (AOR: 1.81, 95%CI: 1.50, 2.19), while less likely from TV (AOR: 0.68, 95%CI: 0.59, 0.78) than non-app-using MSM. For the other source such as radio, newspaper, friends, consultancy service, school education, there was no significant difference between the two groups.

Table 2 HIV testing related behaviors between app-using and non-app-using MSM

All	**Non-app-using MSM (N=3347), N (%)**	**App-using MSM (N=1588), N (%)**	**OR (95%CI)**	**AOR (95%CI)**
Ever tested for HIV				
No	1587(47.4)	474(29.8)	1	1
Yes	1758(52.6)	1114(70.2)	2.12(1.87,2.41)**	1.48(1.27,1.72)**
HIV test in the past year				
0	2014(60.2)	762(48.0)	1	1
1	1333(39.8)	826(52.0)	1.64(1.45,1.85)**	1.36(1.18,1.57)**
Did you know your testing results?				
Not every time	125(7.1)	42(3.8)	1	1
Yes	1635(92.9)	1072(96.2)	1.95(1.36,2.79)**	1.72(1.16,2.54)**
Last HIV negative result				
Over one year ago	922(53.0)	529(47.9)	1	1
Within the past one year	818(47.0)	576(52.1)	1.23(1.06,1.43)**	1.29(1.09,1.53)**
Perception of being infected by HIV				
No or little chance	3263(97.5)	1513(95.3)	1	1
Rather big chance	84(2.5)	75(4.7)	1.93(1.40,2.64)**	1.43(1.00,2.06)*
Where did you receive HIV testing?-Venue				
No	1203(68.4)	977(87.7)	1	1

Yes	557(31.6)	137(12.3)	0.30(0.25,0.37)**	0.49(0.37,0.63)**
Where did you receive HIV testing?-Hospital				
No	1434(81.5)	832(74.7)	1	1
Yes	326(18.5)	282(25.3)	1.49(1.24,1.78)**	1.18(0.96,1.44)
Where did you receive HIV testing?- CDC				
No	1233(70.1)	637(57.2)	1	1
Yes	527(29.9)	477(42.8)	1.75(1.50,2.05)**	1.48(1.24,1.76)**
Where did you receive HIV testing?- Blood donation site				
No	1719(97.7)	1093(98.1)	1	1
Yes	41(2.3)	21(1.9)	0.81(0.47,1.37)	0.91(0.51,1.64)
Where did you receive HIV testing?- CBO				
No	1141(64.8)	610(54.8)	1	1
Yes	619(35.2)	504(45.2)	1.52(1.31,1.78)**	1.71(1.44,2.03)**
Where did you receive HIV testing?- Home self-testing				
No	1657(94.1)	956(85.8)	1	1
Yes	103(5.9)	158(14.2)	2.66(2.05,3.45)**	1.61(1.21,2.14)**
The main source to gain knowledge of AIDS- TV				
No	1805(54.5)	1077(68.6)	1	1
Yes	1504(45.5)	492(31.4)	0.55(0.48,0.62)**	0.68(0.59,0.78)**
The main source to gain knowledge of AIDS- Radio				
No	3028(91.5)	1435(91.5)	1	1
Yes	281(8.5)	134(8.5)	1.01(0.81,1.25)	0.93(0.73,1.19)
The main source to gain knowledge of AIDS- Newspaper				
No	2757(83.3)	1278(81.5)	1	1
Yes	552(16.7)	291(18.5)	1.14(0.97,1.33)	1.10(0.92,1.31)
The main source to gain knowledge of AIDS- Books				
No	2788(84.3)	1135(72.3)	1	1
Yes	521(15.7)	434(27.7)	2.05(1.77,2.37)**	2.04(1.72,2.42)**
The main source to gain knowledge of AIDS- Friends				
No	2764(83.5)	1257(80.1)	1	1
Yes	545(16.5)	312(19.9)	1.26(1.08,1.47)**	0.92(0.77,1.09)
The main source to gain knowledge of AIDS- Doctors				
No	3016(91.1)	1405(89.5)	1	1
Yes	293(8.9)	164(10.5)	1.20(0.98,1.47)	1.27(1.00,1.61)*
The main source to gain knowledge of AIDS- Consultation service				
No	3125(94.4)	1476(94.1)	1	1
Yes	184(5.6)	93(5.9)	1.07(0.83,1.38)	0.80(0.60,1.07)
The main source to gain knowledge of AIDS- Free promotional materials				
No	2508(75.8)	1069(68.1)	1	1
Yes	801(24.2)	500(31.9)	1.46(1.28,1.67)**	1.76(1.51,2.07)**
The main source to gain knowledge of AIDS- Bulletin board				
No	2960(89.5)	1235(78.7)	1	1

Yes	349(10.5)	334(21.3)	2.29(1.95,2.70)**	1.81(1.50,2.19)**
The main source to gain knowledge of AIDS- Internet				
No	1370(41.4)	226(14.4)	1	1
Yes	1939(58.6)	1343(85.6)	4.20(3.59,4.91)**	3.07(2.58,3.67)**
The main source to gain knowledge of AIDS -School education				
No	3137(94.8)	1408(89.7)	1	1
Yes	172(5.2)	161(10.3)	2.09(1.67,2.61)**	0.98(0.76,1.26)

Note: "*", p<0.05; "**", p<0.01; OR, Odds ratio; AOR, adjusted odds ratio after controlling for age, education, monthly income, marital status, year of sample, source of sample, and type of MSM. CDC, center for disease control and prevention; CBO, community based organization.

Multivariate logistical regressions results showed that MSM with older age (25~40 years, AOR: 1.77, 95%CI: 1.56, 2.01; >40 years, AOR: 1.64, 95%CI: 1.44, 1.99), have education level of college or above (AOR: 1.29, 95%CI: 1.01, 1.65), self-identified as homosexuality (AOR: 1.23, 95%CI: 1.02, 1.46), recruited from clinic-based sampling (AOR: 1.30, 95%CI: 1.06, 1.60) was associated with higher odds of HIV testing in the past year (Table 3). Besides, other factors including engaged in group sex (AOR: 1.64, 95%CI: 1.23, 2.19) in the past six months, received offline-based AIDS-related service in the past year (AOR: 5.49, 95%CI: 4.57, 6.60), used gay app (AOR: 1.49, 95%CI: 1.21, 1.83), had high level of HIV- related knowledge (AOR: 1.33, 95%CI: 1.10, 1.61), had higher perception of HIV infection (AOR: 2.95, 95%CI: 1.40, 6.23). On the other hand, MSM who recruited from 2016 (AOR: 0.54, 95%CI: 0.45, 0.65) and 2017 (AOR: 0.66, 95%CI: 0.51, 0.86), being MB (AOR: 0.36, 95%CI: 0.28, 0.46), reported receptive sexual role during anal sex in the past six months (AOR: 0.76, 95%CI: 0.64, 0.90), and being HIV sero-positive (AOR: 0.65, 95%CI: 0.49, 0.85) had significant lower odds of HIV testing within the past year. We also performed a multivariate analysis to identify the determinants of HIV testing within lifetime, which showed similar results except for additional predictors such as older age, multiple sexual partners, previous diagnosis of Sexually

Transmitted Disease (STD) other than HIV and syphilis infections, and gained AIDS-related knowledge mainly from consultation service (data not shown).

Table 3 Factors associated with HIV testing in the past one year among MSM

Variables	Not tested (N=2776), N (%)	Tested (N=2159), N (%)	OR (95%CI)	AOR (95%CI)
Age				
<25	1153(64.9)	624(35.1)	1	
25~40	1131(51.0)	1086(49.0)	1.77(1.56,2.01)**	—
>40	491(52.2)	449(47.8)	1.69(1.44,1.99)**	—
Residence in Shenzhen				
<1 year	674(58.0)	488(42.0)	1	—
⩾1 year	1928(55.4)	1551(44.6)	1.11(0.97,1.27)	—
Ethnicity				
Han	2659(55.8)	2102(44.2)	1	—
Other	62(52.1)	57(47.9)	1.16(0.81,1.67)	—
Education				
Junior high school or less	491(62.7)	292(37.3)	1	1
Senior high school	1103(63.9)	623(36.1)	0.95(0.80,1.13)	0.90(0.70,1.15)
College or above	1182(48.7)	1244(51.3)	1.77(1.50,2.09)**	1.29(1.01,1.65)*
Monthly income				
<3000	192(60.2)	127(39.8)	1	
3000~7000	1941(59.5)	1319(40.5)	1.03(0.81,1.30)	—
>7000	643(47.4)	713(52.6)	1.68(1.31,2.15)**	—
Marital status				
Single	2540(56.7)	1936(43.3)	1	
Married	236(51.4)	223(48.6)	1.24(1.02,1.50)*	—
Year of sample				
2015	757(55.2)	615(44.8)	1	1
2016	972(64.1)	544(35.9)	0.69(0.59,0.80)**	0.54(0.45,0.65)**
2017	1047(51.1)	1000(48.9)	1.18(1.03,1.35)*	0.65(0.48,0.88)**
Type of MSM				
NcMSM	1501(61.6)	935(38.4)	1	
MB	1275(51.0)	1224(49.0)	1.54(1.38,1.73)**	0.36(0.28,0.46)**
Source of sample				
Venue based	1839(50.9)	1774(49.1)	1	1
Clinic based	937(70.9)	385(29.1)	0.43(0.37,0.49)**	1.30(1.06,1.60)*
Self-identified as homosexuality				
No	777(58.7)	546(41.3)	1	1

Yes	1999(55.3)	1613(44.7)	1.15(1.01,1.30)*	1.23(1.02,1.46)*
Receptive sexual role				
No	1764(54.2)	1490(45.8)	1	1
Yes	1012(60.2)	668(39.8)	0.78(0.69,0.88)**	0.76(0.64,0.90)**
In a relationship				
No	275(50.4)	271(49.6)	1	—
Yes	451(46.9)	510(53.1)	1.15(0.93,1.42)	—
No. of sexual partners in the past 6 months				
0	881(63.9)	498(36.1)	1	
1~5	1462(49.5)	1491(50.5)	1.8(1.58,2.06)**	—
>5	433(71.9)	169(28.1)	0.69(0.56,0.85)**	—
Engaged in ONS in the past 6 months				
No	927(61.6)	579(38.4)	1	—
Yes	918(56.1)	717(43.9)	1.25(1.08,1.44)**	—
Engaged in group sex in past 6 months				
No	1741(60.4)	1143(39.6)	1	1
Yes	104(40.3)	154(59.7)	2.26(1.74,2.93)**	1.64(1.23,2.19)**
Engaged in commercial service in past 6 months				
No	1736(59.0)	1207(41.0)	1	—
Yes	105(53.8)	90(46.2)	1.23(0.92,1.65)	—
Condom use of anal sex in the past 6 months				
No	786(52.7)	706(47.3)	1	—
Yes	1109(53.8)	954(46.2)	0.96(0.84,1.09)	—
Recreational drug use in the past year				
No	66(54.1)	56(45.9)	1	—
Yes	998(51.5)	941(48.5)	1.11(0.77,1.60)	—
Received offline-based HIV-related service in the past year				
No	1367(77.0)	408(23.0)	1	1
Yes	1409(44.6)	1751(55.4)	4.16(3.65,4.75)**	5.49(4.57,6.60)**
Gay app use				
No	2014(60.2)	1333(39.8)	1	1
Yes	762(48.0)	826(52.0)	1.64(1.45,1.85)**	1.49(1.21,1.83)**
HIV-related knowledge				
Low to medium	828(59.2)	571(40.8)	1	
High	1948(55.1)	1588(44.9)	1.18(1.04,1.34)**	1.33(1.10,1.61)**
Previous diagnosis of other STD				
No	2581(56.7)	1968(43.3)	1	—
Yes	195(50.5)	191(49.5)	1.28(1.04,1.58)*	—
HIV serostatus				
Negative	2461(55.7)	1958(44.3)	1	
Positive	315(61.0)	201(39.0)	0.80(0.67,0.97)*	0.66(0.51,0.86)**

Syphilis serostatus				
Negative	2489(56.5)	1913(43.5)	1	—
Positive	287(53.8)	246(46.2)	1.12(0.93,1.34)	—
Perception of HIV infection				
No or little chance	2744(56.4)	2118(43.6)	1	1
Rather big chance	32(43.8)	41(56.2)	1.66(1.04,2.65)*	2.95(1.40,6.23)**
The main source to gain knowledge of AIDS -TV				
No	1640(56.9)	1242(43.1)	1	—
Yes	1080(54.1)	916(45.9)	1.12(1.00,1.26)	—
The main source to gain knowledge of AIDS- Radio				
No	2508(56.2)	1955(43.8)	1	—
Yes	212(51.1)	203(48.9)	1.23(1.00,1.50)*	—
The main source to gain knowledge of AIDS- Newspaper				
No	2247(55.7)	1788(44.3)	1	—
Yes	473(56.1)	370(43.9)	0.98(0.85,1.14)	—
The main source to gain knowledge of AIDS- Books				
No	2238(57.0)	1685(43.0)	1	—
Yes	482(50.5)	473(49.5)	1.30(1.13,1.50)**	—
The main source to gain knowledge of AIDS- Friends				
No	2274(56.6)	1747(43.4)	1	—
Yes	446(52.0)	411(48.0)	1.20(1.04,1.39)*	—
The main source to gain knowledge of AIDS- Doctors				
No	2514(56.9)	1907(43.1)	1	—
Yes	206(45.1)	251(54.9)	1.61(1.32,1.95)**	—
The main source to gain knowledge of AIDS- Consultation service				
No	2614(56.8)	1987(43.2)	1	—
Yes	106(38.3)	171(61.7)	2.12(1.65,2.72)**	—
The main source to gain knowledge of AIDS- Free promotional materials				
No	2042(57.1)	1535(42.9)	1	—
Yes	678(52.1)	623(47.9)	1.22(1.08,1.39)**	—
The main source to gain knowledge of AIDS- Bulletin board				
No	2396(57.1)	1799(42.9)	1	—
Yes	324(47.4)	359(52.6)	1.48(1.25,1.74)**	—
The main source to gain knowledge of AIDS- Internet				
No	859(53.8)	737(46.2)	1	—
Yes	1861(56.7)	1421(43.3)	0.89(0.79,1.00)	—
The main source to gain knowledge of AIDS -School education				
No	2541(55.9)	2004(44.1)	1	1
Yes	179(53.8)	154(46.2)	1.09(0.87,1.36)	0.83(0.69,1.01)

Note: "*", p<0.05; "**", p<0.01; OR, Odds ratio; AOR, adjusted odds ratio; ONS, one night

stand; STD, sexually transmitted disease.

Discussion

The HIV testing rates within lifetime and the past one year were significantly higher among app-using MSM than non-app using MSM. Particularly, app-using MSM were more likely to take an HIV test at CDC and CBO, and take a home self-testing than non-app-using MSM, while less likely to take a test at venues. Use of gay app was significantly associated with higher odds of lifetime HIV testing. As there were very few studies addressed the difference in choice of HIV testing approaches between app-using MSM and non-app-using MSM, this study provided significant implication for future HIV testing expanding strategies.

Our result showed that the prevalence of lifetime HIV testing among MSM in Shenzhen (58.2%) is comparable to that reported from other areas (60.3% ~63.1%) in China.[12 13] Specifically, app-using MSM had a relatively higher prevalence of lifetime HIV testing than non-app-using MSM (70.2% vs. 52.6%), similar to an online study from China (69.7% vs.55.5%).[7] The prevalence of lifetime testing among app-using MSM in this study was, however, lower than online studies from the US (83.2%-90%).[6 14] Previous research has demonstrated that some gay apps were utilized to link MSM to HIV testing promotion.[14 15] For instance, *Blued,* the most popular gay app in China, uses an "AIDS" ribbon to provide monthly banners on HIV testing, and suggests the users the nearest appropriate medical and testing facilities.[16] Secondly, as our result found non-app-using MSM had a relatively lower level of HIV-related knowledge and HIV risk perception, they may be less likely to take a HIV test than app-using MSM.

For the preference of HIV testing approaches, both app-using MSM and non-app using MSM mainly chose to take an HIV test at CDC, CBO, whereas less often at hospital. Standard public health approaches at public health agencies such as CDC, are always the mainstay of HIV/ STD services in China.[17] However, our results showed testing in hospital is less common among both app-using MSM and non-app-using MSM, compared to the two main approaches. Literature data also implied the uptake of HIV testing was usually low in a clinical setting.[18] Due to the stigma and confidential concerns, Chinese MSM were very wary of choosing test at hospitals. While, engagement of CBO in sexual health prevention may bring about positive social norms to HIV testing and reduce the stigma concerns of MSM.[19 20] Other research showed CBO based testing was a cost-effective approach to reach population who have low access to clinic-based HIV testing,[21] and it would be worthwhile for testing expansion and other intervention development and delivery in China.[22] Thus, continued efforts of CBOs in promoting HIV testing may further increase the uptake of testing among Chinese MSM.

Testing at venues generally was less frequent than other three main approaches in this study. First, it could be explained by the limited coverage of HIV prevention outreach, as we found only 64% of the MSM in this study had received the HIV-related service. The current outreach-based HIV services in Shenzhen including HIV testing and counseling, free distribution of condom and lubricate and STD diagnosis and treatment, were provided by the local public health agencies (CDC) with limited resources (budget and HIV care professionals) [23]. Secondly, literature documented that MSM were less willing to choose venue-based rapid testing than CBO-based testing among those non-clinical testing sites, due to the concerns

about the quality, cleanliness, and professionalism.[10] Recent studies also suggested testing at gay venues such as saunas and gay bars was not acceptable among Chinese MSM unless the test was guaranteed with confidentiality, quality and quick results.[24 25] Although app-using MSM showed higher testing rates for the three main testing approaches than non-app-using MSM, they were less likely to get tested at gay venues. As non-app-using MSM were more likely to patronize gay venues for sex seeking than app-using MSM, they were more likely to receive the offline-based HIV-related service (69.6% vs. 30.4%) that routinely delivered at these gay venues (e.g., bars, massage centers and saunas). This finding indicated that app-using MSM currently were not well reached by the traditional HIV prevention and intervention programs. Thus, innovative intervention strategies are greatly needed for this subpopulation. Besides, future improvement regarding the concerns of venue-based rapid testing as well as increased HIV-related resource are warranted to remove the barrier to higher uptake of HIV test at venues.

Home self-testing rate was much lower than that of other main testing approaches in general. Although home self-testing kits are now widely available and accessible in China since first approved in 2008, only 6.1% to 26.2% of MSM have ever chosen this new approach.[12 26 27] Comparing with non-app-using MSM, app-using MSM showed a higher self-testing rate. A prior study found that the most common means of obtaining self-testing kit in China were through the internet, then followed by CBOs, pharmacies and other offline means.[12] Interestingly, there was an increasing trend of home self-testing among non-app-using MSM in the study years. The underlying reason may be the scaling up campaign of self-testing in

China in recent years, which have increased the accessibility of self-testing kit among offline social networking MSM as well.[28] Home self-testing provides an anonymous and confidential way to access HIV testing that could better reach high-risk MSM. Our findings demonstrated that there was a large capacity to reach untested MSM via self-testing, especially for non-app-using MSM hard-to-reach. Promotion of home self-testing would be an alternative approach to increase the HIV testing coverage among Chinese MSM.

Our study found that MSM who had higher education level, recruited through clinic-based methods, self-identified as homosexuality, practiced receptive sexual role during anal sex, engaged in group sex, used gay-app, and had previous diagnosis of other STD were associated with higher odds of HIV testing in the past year. Additionally, older age, multiple sexual partners, previous diagnosis of other STD were associated with higher chance of lifetime HIV testing. These findings were aligned with the literature that found age, education level, history of other STD, sexual orientation and high-risk sexual behaviors (e.g., multiple male sexual partners and unprotected sexual intercourse) were associated with HIV testing.[29 30] Other studies found use of gay app, being HIV negative and recent unprotected anal intercourse were positively associated with HIV testing within lifetime and the past year.[7 14] Notably, our study found some other factors such as access to offline-based HIV-related service in the past year, having higher HIV-related knowledge and HIV risk perception were significantly associated with HIV testing within the past year, consistent with another Chinese study.[13] These findings highlighted the need for strengthened public health efforts on the HIV prevention and interventions (e.g., HIV/STD testing and AIDS education), so as to increase the HIV-related

knowledge and risk perception, and finally help to increase the uptake of HIV testing among MSM.

There are several limitations of this study need to be noted. Firstly, there are relatively fewer samples collected from 2016 than the other two years, yet, we have adjusted the confounding effect of sample year in the multivariate analysis. Secondly, this study just included eight types of gay apps, while some other gay apps may emerge in the study years. As the app, *Blued*, accounted for about 97% of all app used, the new emerged app may had very limited impact on results. Thirdly, this is a cross-sectional study which makes it difficult to establish a causal relationship, future longitudinal study would be desirable to evaluate the change of testing behavior over time. Lastly, our results may not be generalizable to MSM in other areas, caution is required for appropriate interpretation.

In conclusion, there is still a significant gap in the coverage of HIV testing among MSM in Shenzhen, China. It is necessary to expand the testing coverage among the key population for scale-up treatment, especially those non-app-using MSM. Smartphone-based gay apps could significantly reach and offer considerable potential for increasing HIV testing uptake among MSM otherwise not reachable by traditional outreach. Continued efforts in promoting HIV testing, increased resource of HIV service and innovative strategies are highly needed to achieve the first "90" target by 2020.

Contributors JC and LL conceived the work. JZ, JC and LL designed the study. LW conducted all data analysis and drafted the manuscript. CL, HZ, SL, WT and WX ran the field investigations, participated in data collection and management. LW, HZ, ZY and JZ contributed to the writing and data interpretation. WT and WX performed the experiments. LW, CL, ZY, JZ, JC and LL reviewed and edited the manuscript. All authors have seen and approved the final version of the manuscript for publication.

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Competing interests None declared.

Table 1 Demographics of app-using and non-app-using MSM

Table 2 HIV testing related behaviors between app-using and non-app-using MSM

Table 3 Factors associated with HIV testing in the past one year among MSM

Supplemental table. Factors associated with lifetime HIV testing among MSM

Figure HIV testing approaches of app-using and non-app-using MSM in Shenzhen, China, 2015-2017

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HIV testing approaches of app-using and non-app-using MSM in Shenzhen, China, 2015-2017

254x190mm (300 x 300 DPI)

Supplemental table. Factors associated with lifetime HIV testing among MSM

Variables	Never tested (N=2061), N (%)	Ever tested (N=2872), N (%)	OR (95%CI)	AOR (95%CI)
Age				
<25	1026(57.8)	750(42.2)	1	1
25~40	745(33.6)	1471(66.4)	2.7(2.37,3.08)**	1.45(1.17,1.81)**
>40	289(30.7)	651(69.3)	3.08(2.61,3.64)**	1.43(1.09,1.88)*
Residence in Shenzhen				
<1 year	545(46.9)	616(53.1)	1	—
⩾1 year	1413(40.6)	2066(59.4)	1.29(1.13,1.48)**	—
Ethnicity				
Han	2006(42.2)	2753(57.8)	1	—
Other	44(37.0)	75(63.0)	1.24(0.85,1.81)	—
Education				
Junior high school or less	394(50.3)	389(49.7)	1	1
Senior high school	923(53.5)	802(46.5)	0.88(0.74,1.04)	0.97(0.75,1.26)
College or above	744(30.7)	1681(69.3)	2.29(1.94,2.70)**	1.64(1.26,2.14)**
Monthly income				
<3000	142(44.7)	176(55.3)	1	
3000~7000	1543(47.3)	1716(52.7)	0.9(0.71,1.13)	—
>7000	376(27.7)	980(72.3)	2.1(1.64,2.70)**	—
Marital status				
Single	1911(42.7)	2563(57.3)	1	
Married	150(32.7)	309(67.3)	1.54(1.25,1.88)**	—
Year of sample				
2015	565(41.2)	806(58.8)	1	
2016	771(50.9)	744(49.1)	0.68(0.58,0.78)**	—
2017	725(35.4)	1322(64.6)	1.28(1.11,1.47)**	—
Type of MSM				
NcMSM	1170(32.4)	2442(67.6)	1	
MB	891(67.4)	430(32.6)	0.23(0.20,0.26)**	0.29(0.22,0.39)**
Source of sample				
Venue based	1275(52.4)	1160(47.6)	1	1
Clinic based	786(31.5)	1712(68.5)	2.39(2.13,2.69)**	1.68(1.35,2.10)**
Self-identified as homosexuality				
No	597(45.2)	725(54.8)	1	1
Yes	1464(40.5)	2147(59.5)	1.21(1.06,1.37)**	1.52(1.25,1.83)**
Receptive sexual role				
No	1306(40.1)	1948(59.9)	1	1
Yes	755(45.0)	924(55.0)	0.82(0.73,0.92)**	0.77(0.64,0.92)**

In a relationship				
No	175(32.1)	371(67.9)	1	—
Yes	291(30.3)	669(69.7)	1.08(0.86,1.36)	—
No. of sexual partners in the past 6 months				
0	763(55.3)	616(44.7)	1	1
1~5	930(31.5)	2022(68.5)	2.69(2.36,3.07)**	1.40(1.14,1.72)**
>5	368(61.1)	234(38.9)	0.79(0.65,0.96)*	0.70(0.50,0.99)*
Engaged in ONS in the past 6 months				
No	755(50.2)	750(49.8)	1	1
Yes	664(40.6)	971(59.4)	1.47(1.28,1.70)**	1.13(0.93,1.37)
Engaged in group sex in past 6 months				
No	1350(46.8)	1533(53.2)	1	1
Yes	69(26.7)	189(73.3)	2.41(1.81,3.21)**	1.45(1.04,2.03)*
Engaged in commercial service in the past 6 months				
No	1339(45.5)	1603(54.5)	1	—
Yes	76(39.0)	119(61.0)	1.31(0.97,1.76)	—
Condom use of anal sex in the past 6 months				
No	513(34.4)	978(65.6)	1	—
Yes	785(38.1)	1278(61.9)	0.85(0.74,0.98)*	—
Recreational drug use				
No	1362(47.4)	1511(52.6)	1	—
Yes	699(33.9)	1361(66.1)	1.76(1.56,1.98)**	—
Received offline-based HIV-related service in the past year				
No	1102(62.1)	672(37.9)	1	1
Yes	959(30.4)	2200(69.6)	3.76(3.33,4.25)**	6.22(5.11,7.57)**
Gay app use				
No	1587(47.4)	1758(52.6)	1	1
Yes	474(29.8)	1114(70.2)	2.12(1.87,2.41)**	1.72(1.37,2.16)**
HIV-related knowledge				
Low to medium	619(44.3)	778(55.7)	1	
High	1442(40.8)	2094(59.2)	1.16(1.02,1.31)*	1.42(1.16,1.73)**
Previous diagnosis of other STD				
No	1938(42.6)	2609(57.4)	1	
Yes	123(31.9)	263(68.1)	1.59(1.27,1.98)**	1.46(1.05,2.03)*
HIV serostatus				
Negative	1837(41.6)	2580(58.4)	1	
Positive	224(43.4)	292(56.6)	0.93(0.77,1.12)	0.65(0.49,0.85)**
Syphilis serostatus				
Negative	1885(42.8)	2515(57.2)	1	
Positive	176(33.0)	357(67.0)	1.52(1.26,1.84)**	1.09(0.81,1.47)
Perception of being infected by HIV				
No or little chance	2043(42.0)	2817(58.0)	1	1

Rather big chance	18(24.7)	55(75.3)	2.22(1.30,3.79)**	3.92(1.60,9.63)**
The main source to gain knowledge of AIDS -TV				
No	1208(41.9)	1674(58.1)	1	—
Yes	842(42.2)	1154(57.8)	0.99(0.88,1.11)	—
The main source to gain knowledge of AIDS- Radio				
No	1900(42.6)	2563(57.4)	1	—
Yes	150(36.1)	265(63.9)	1.31(1.06,1.62)*	—
The main source to gain knowledge of AIDS- Newspaper				
No	1687(41.8)	2348(58.2)	1	—
Yes	363(43.1)	480(56.9)	0.95(0.82,1.11)	—
The main source to gain knowledge of AIDS- Books				
No	1711(43.6)	2212(56.4)	1	—
Yes	339(35.5)	616(64.5)	1.41(1.21,1.63)**	—
The main source to gain knowledge of AIDS- Friends				
No	1732(43.1)	2289(56.9)	1	—
Yes	318(37.1)	539(62.9)	1.28(1.10,1.49)**	—
The main source to gain knowledge of AIDS- Doctors				
No	1901(43.0)	2520(57.0)	1	—
Yes	149(32.6)	308(67.4)	1.56(1.27,1.91)**	—
The main source to gain knowledge of AIDS- Consultation service				
No	1983(43.1)	2618(56.9)	1	1
Yes	67(24.2)	210(75.8)	2.37(1.79,3.14)**	1.77(1.16,2.70)**
The main source to gain knowledge of AIDS- Free promotional materials				
No	1542(43.1)	2035(56.9)	1	1
Yes	508(39.0)	793(61.0)	1.18(1.04,1.35)*	0.74(0.60,0.91)**
The main source to gain knowledge of AIDS- Bulletin board				
No	1837(43.8)	2358(56.2)	1	1
Yes	213(31.2)	470(68.8)	1.72(1.45,2.04)**	1.25(0.94,1.65)
The main source to gain knowledge of AIDS- Internet				
No	684(42.9)	912(57.1)	1	1
Yes	1366(41.6)	1916(58.4)	1.05(0.93,1.19)	0.84(0.69,1.03)
The main source to gain knowledge of AIDS -School education				
No	1924(42.3)	2621(57.7)	1	—
Yes	126(37.8)	207(62.2)	1.21(0.96,1.52)	—

Note: "*", p<0.05; "**", p<0.01; OR, Odds ratio; AOR, adjusted odds ratio; ONS, one night stand; STD, sexually transmitted disease.

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The relationship between use of gay app and HIV testing among men who have sex with men in Shenzhen, China: a serial cross-sectional study

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The relationship between use of gay app and HIV testing among men who have sex with men in Shenzhen, China: a serial cross-sectional study

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Abstract

Objectives To investigate the relationship between use of gay app and HIV testing among MSM and the associated factors of HIV testing

Design Three-year serial cross-sectional study

Setting Newly well-developed city in China

Participants 4935 MSM were recruited through offline sampling methods, 2015-2017.

Primary and secondary outcomes The primary outcome is the HIV testing rate and choice of testing approaches among app users and non-app users, as well as the risk factors associated with HIV testing.

Results There were 58.2% of the participants had been tested for HIV within lifetime and 43.7% within the past year. App-using MSM had significant higher prevalence of HIV testing within lifetime (AOR: 1.48, 95%CI: 1.27, 1.72) and the past year (AOR: 1.36, 95%CI: 1.18, 1.57) than non-app-using MSM. App-using MSM were significantly more likely to take HIV testing at center for disease control and prevention (AOR: 1.48, 95%CI: 1.24, 1.76), community-based organization (AOR: 1.71, 95%CI: 1.44, 2.03), and take home self-testing (AOR: 1.61, 95%CI: 1.21, 2.14) while less often at gay venues (AOR: 0.49, 95%CI: 0.37, 0.63). MSM with education level of college or higher (AOR: 1.29, 95%CI: 1.01, 1.65), self-identified as homosexuality (AOR: 1.23, 95%CI: 1.02, 1.46), and recruited through clinic-based sampling (AOR: 1.30, 95%CI: 1.06, 1.60) had higher odds of HIV testing in the past year. Other predictors beyond app use (AOR: 1.49, 95%CI: 1.21, 1.83) included group sex (AOR: 1.64, 95%CI: 1.23, 2.19), received HIV-related service (AOR: 5.49, 95%CI: 4.57,

6.60), higher HIV-related knowledge (AOR: 1.33, 95%CI: 1.10, 1.61) and risk perception (AOR: 2.95, 95%CI: 1.40, 6.23).

Conclusions Gay app has significantly increased the HIV testing uptake among MSM hard-to-reach by traditional outreach. It is imperative to expand HIV testing among non-app-using MSM. Continued efforts, innovative strategies and increased resource are highly needed to realize the first "90" target.

Key Words HIV testing, gay app, MSM, testing approach

Strengths and limitations of this study

- This large study represents one of the few studies that compare the HIV testing and pattern of testing approaches between app-using MSM and non-app-using MSM from a developing country setting, which has significant implication for future HIV testing expanding strategies.
- Different from most previous studies based online survey, this study used a combined offline recruitment method, which could provide complementary evidence on this topic.
- This is a cross-sectional study which makes it difficult to establish a causal relationship.
- The findings may not be generalizable to MSM from other areas or settings.

Introduction

HIV testing is an essential component of HIV prevention strategy that linked to treatment and care, lack of knowledge on the HIV serostatus would disable or postpone initiation of antiviral treatment. Also, screening for HIV among asymptomatic HIV carrier may directly reduce the HIV transmission, as prior research estimated that those who are unaware of their seropositive status are 3.5 times more likely to transmit HIV than those who know their serostatus.[1] Presently, there were about 30% of people living with HIV did not know their HIV status globally.[2] The HIV testing rate in China is unacceptably low, far from achieving the first of the United Nation's 90–90–90 targets– for 90% of all people with HIV to get tested and know their status by 2020. A recent meta-analysis reported that there are just 47% of the men who have sex with men (MSM) have ever been tested for HIV in China, despite the extensive combined efforts of government, public health agencies, community-based organizations in recent years.[3] Due to the stigma against homosexuality in China, MSM in fear of exposure of homosexuality-identity are less likely to take an HIV test. Besides, there are several other barriers to HIV testing, such as name-based testing, low perception of risk, long asymptomatic phase, unaware that testing is free of charge, posing significant challenges to HIV prevention and interventions among MSM in China.[4] Thus, developing more comprehensive strategies for expanding HIV testing among MSM is an urgent priority in China.

In recent years, the emergence of gay app (geosocial networking application specific to MSM) has significantly reformed the MSM's sex-seeking behaviours as well as harm-

reduction behaviours.[5] Previous limited studies on the association between gay apps use and HIV testing behaviour are inconclusive. Some studies found app use was associated with more HIV testing either within lifetime or in the past year,[6 7] while other studies found no difference between app users and non-users.[8] A recent systematic review found that app users are twice as likely to test for HIV within lifetime as non-app users.[5] Another study revealed that social media use was significantly associated with HIV testing in Chinese MSM.[9] Free HIV testing is now widely available in all provinces of China since 2006. Apart from the health facility-based testing service provided at hospital/clinics and Center for Disease Control and Prevention (CDC), there are also decentralized HIV testing services provided at peripheral health facilities including community-based organization (CBO), blood donation site, as well as testing service at gay venues and self-testing at home.[10] As the uptake of HIV testing among MSM is still limited, a better understanding of the testing pattern and preferences among MSM is critical to inform expanding HIV testing strategies. Furthermore, few studies exist regarding the impact of app use on the uptake and preference of HIV testing approach among MSM. Therefore, we conducted a study to investigate the relationship between app use and HIV testing uptake and approaches, and to identify the demographic and behavioural predictors of HIV testing among MSM in Shenzhen, China, where MSM accounted for the largest percentage (56.7%) of the new infections in recent years.

Methods

Source of sample

From May 2015 to the end of 2017, eligible MSM were recruited through combined offline

sampling methods, primarily venue-based (Time Location Sampling, TLS) and clinics based (Respondent-Driven Sampling, RDS; Voluntary Counseling and Testing center, VCT). In brief, TLS is to randomly invite eligible participant at all possible venue-day-time periods, which is a randomly selected peak period during a week timeframe at a randomly selected venue. RDS starts with identification of initial 'seeds' of different age, marital status, and education level based on a group communication with MSM peers. These seeds are then offered with three coded coupons to recruit new peers, who in turn further refer those they know and so on. Other participants who visited VCT were also randomly recruited. More information on these methods can be found in the previous study.[11] The criteria for recruiting is 1) male, Chinese national, aged 18 years old or above; 2) those who had a homosexual contact in the previous six months of the survey in Shenzhen. Meanwhile, the criteria for eligible MB participants included: 1) being male 18 years or older; 2) having lived in Shenzhen for more than one month at the time of survey; 3) having sold sex (oral or anal) to another male in the previous month. Each participant was invited to complete an anonymous questionnaire via a handheld electronic tablet and provide a written informed consent. Then, they were required to take a confidential HIV and syphilis test at Shenzhen Center for Disease Control and Prevention, or the voluntary counseling and testing center. The protocol for recruitment was approved by the Medical Ethics Committee of Shenzhen Center for Disease Control and Prevention.

Behavioural measures

All data was collected through self-administered questionnaires, including sociodemographic

features, sexual behaviours, use of gay app, recreational drug use, HIV testing, HIV-related services, HIV-related knowledge, previous diagnosis of Sexually Transmitted Disease (STD) other than HIV and syphilis infections, source of HIV-related knowledge, HIV and syphilis serostatus and perception of HIV infection. The HIV-related services including distribution of condom, lubricant, peer education, STI diagnosis or treatment, HIV counselling or testing, or AIDS/STI educational materials. A high level of HIV-related knowledge was defined as having correctly answered at least six out of the nine questions, otherwise, it was deemed as low to medium level. HIV testing behaviours were evaluated in the following measures: 1) Have you ever received HIV testing? 2) Have you taken HIV testing in the past year? 3) Where did you receive HIV testing? (Gay venue/ hospital/ CDC/ blood donation site/ CBO/ self-testing at home). The main source of HIV-related knowledge was listed as TV, radio, newspaper, books, friends, doctors, consultation service, free promotional materials, bulletin board, internet and school education. The behavioural measures presented in the questionnaire were developed according to the national sentinel surveillance survey for HIV/AIDS and those previously verified questionnaire.[12]

HIV and syphilis testing

HIV testing and syphilis testing were performed according to standard procedures established by the laboratory of Shenzhen Centers for Disease Control and Prevention. HIV was tested using a rapid test (Determine HIV-1/2/O; Abbott Laboratories, IL) and enzyme-linked immunosorbent assay (Wantai Biotech Inc, Beijing, China) for screening, with the positive test further confirmed by Western Blot (Genlabs Diagnostics, Singapore). Syphilis was tested

with rapid plasma regain method (Rongsheng Biotech Inc, Shanghai, China) for qualitative screening, with the positive test further confirmed by Treponema pallidum particle agglutination assay (Fujirebio Inc, Japan).

Patients and public involvement

Patients or public were not involved in the design or planning of the study.

Data availability statement

No additional data available

Statistical analysis

Sociodemographic features and HIV testing related behaviours were compared between app-using MSM and non-app-using MSM, with categorical variables compared using the *Chi-squared test* or *Fisher's exact test*. Univariate and multivariate logistic regressions adjusted for confounders (e.g., age, education, marital status, year of survey, etc.) were performed to examine the correlates between app use and testing-related behaviours. To identify the significant predictors for HIV testing within the past year and lifetime, variables with a P value <0.10 in the univariate logistic regression models and theoretically important covariates were included for step-wise selection in multivariate regression models. The covariates with a P value <0.05 were kept in the final model through manual step-wise selection. Adjusted odds ratios (AOR) and 95% confidence intervals (CIs) were presented. All statistical analyses were performed in R (version 3.4.3, Foundation for Statistical Computing, Vienna, Austria).

Results

Among the 4935 participants recruited from 2015 to 2017, 1588 (32.2%) MSM had used at

least one kind of gay app, including 1496 non-commercial MSM and 92 male sex workers (also called money boy, MB). The demographic characteristics of all recruited MSM were summarized in Table 1. Comparing to non-app-using MSM, more of the app-using MSM were younger (28.3 vs. 28.8 years), unmarried (92.0% vs. 90.1%), have an education level of college or above (64.0% vs. 42.1%), and have a monthly income higher than 7000 RMB (34.1% vs. 24.3%). There was no significant difference in ethnicity and duration of residence in Shenzhen between the two groups. There were higher percentages of app-using MSM recruited from clinics (69.6% vs. 41.6%) and recruited in 2017 (56.9% vs.34.2%) than that of non-app-using MSM. The prevalence of HIV and syphilis infection was not significantly different between the two groups, although it was significantly higher among non-app-using NcMSM (non-commercial MSM) when excluding the MBs who were less likely to use app and be positive for HIV and syphilis (data not shown).

Table 1 Demographics of app-using and non-app-using MSM

	Non-app-using MSM (N=3347), N (%)	**App-using MSM (N=1588), N (%)**	**P value***
Age			
<25	1316(39.3)	461(29.0)	
25~40	1618(48.4)	1030(64.9)	<0.01
>40	412(12.3)	97(6.1)	
Age (median, IQR**)**	26 (23, 33)	27 (24, 31)	<0.05
Duration of residence in Shenzhen			
<1 year	802(25.5)	360(24.0)	0.299
≥1 year	2342(74.5)	1137(76.0)	
Ethnicity			
Han	3237(97.8)	1524(97.1)	0.215
Other	74(2.2)	45(2.9)	
Education			
Junior high school or less	637(19.0)	146(9.2)	<0.01
Senior high school	1301(38.9)	425(26.8)	

College or above	1409(42.1)	1017(64.0)	
Monthly income(RMB)			
<3000	196(5.9)	123(7.7)	
3000~7000	2337(69.8)	923(58.1)	<0.01
>7000	814(24.3)	542(34.1)	
Marital status			
Unmarried	3015(90.1)	1461(92.0)	<0.05
Married	332(9.9)	127(8.0)	
Year of sample			
2015	1254(37.5)	118(7.4)	
2016	949(28.4)	567(35.7)	<0.01
2017	1144(34.2)	903(56.9)	
Source of sample			
Venue based	1953(58.4)	483(30.4)	<0.01
Clinic based	1394(41.6)	1105(69.6)	
Type of MSM			
NcMSM	2117(63.3)	1496(94.2)	<0.01
MB	1230(36.7)	92(5.8)	
HIV			
Negative	3005(89.8)	1414(89.0)	0.458
Positive	342(10.2)	174(11.0)	
Syphilis			
Negative	2983(89.1)	1419(89.4)	0.844
Positive	364(10.9)	169(10.6)	
Previous diagnosis of other STDs			
No	3119(93.2)	1430(90.1)	<0.01
Yes	228(6.8)	158(9.9)	

Note: NcMSM, Non-commercial MSM; MB, Money boy (male sex worker); STD, sexually transmitted disease. * All P values in this column were derived from the comparison between non-app-using MSM and app-using MSM.

There were significant differences of testing-related behaviours between app-using MSM and non-app-using MSM in this study (Table 2). There were about 58.2% of MSM had been tested for HIV within lifetime and 43.7% had been tested within the past year in Shenzhen. App-using MSM had significantly higher prevalence of HIV testing within lifetime (70.2% vs.52.6%) and the past year (52.0% vs. 39.8%) than non-app-using MSM. After controlling for age, education, monthly income, marital status, year of sample, source

of sample, and type of MSM, MSM who used gay app had significant higher odds of ever been tested for HIV (AOR: 1.48, 95%CI: 1.27, 1.72) and HIV test in the past year (AOR: 1.36, 95%CI: 1.18, 1.57) than those who did not. App-using-MSM were more commonly to know their HIV testing results (AOR: 1.72, 95%CI: 1.16, 2.54) and know their last negative result with the past year (AOR: 1.29, 95%CI: 1.09, 1.53). Generally, app-using MSM had a higher perception of HIV infection risk than their counterparts (AOR: 1.43, 95%CI: 1.00, 2.06). For the approaches of HIV testing, app-using MSM were more likely to receive HIV testing at the local Center for Disease Control and Prevention (CDC) (AOR: 1.48, 95%CI: 1.24, 1.76), community-based organization (CBO) (AOR: 1.71, 95%CI: 1.44, 2.03), and take self-testing at home (AOR: 1.61, 95%CI: 1.21, 2.14); however, they were less likely to receive HIV testing at gay venues (AOR: 0.49, 95%CI: 0.37, 0.63). There were no significant differences between the two groups for the choice of testing at hospital and blood donation sites. Furthermore, the choice of HIV testing sites by year was compared between the two groups in the Figure 1. From 2015 to 2017, there was an increasing proportion of MSM chose to take an HIV test at CDC, and a declining trend for testing at hospital, CBOs and blood donation site among app-using MSM. Notably, there were an increasing rate of home self-testing among non-app-using MSM although the main choices were testing at gay venue, CDC and CBO. App-using MSM were more likely to gain HIV-related knowledge from the internet (AOR: 3.07, 95%CI: 2.58, 3.67), books (AOR: 2.04, 95%CI: 1.72, 2.42), doctors (AOR: 1.27, 95%CI: 1.00, 1.61), free promotional materials (AOR: 1.76, 95%CI: 1.51, 2.07), bulletin board (AOR: 1.81, 95%CI: 1.50, 2.19), while less likely from TV (AOR: 0.68,

95%CI: 0.59, 0.78) than non-app-using MSM. For the other source such as radio, newspaper, friends, consultancy service, school education, there was no significant difference between the two groups.

Table 2 HIV testing related behaviours between app-using and non-app-using MSM

All	**Non-app-using MSM (N=3347), N (%)**	**App-using MSM (N=1588), N (%)**	**OR (95%CI)**	**AOR (95%CI)**
Ever tested for HIV				
No	1587(47.4)	474(29.8)	1	1
Yes	1758(52.6)	1114(70.2)	2.12(1.87,2.41)**	1.48(1.27,1.72)**
HIV test in the past year				
0	2014(60.2)	762(48.0)	1	1
1	1333(39.8)	826(52.0)	1.64(1.45,1.85)**	1.36(1.18,1.57)**
Did you know your testing results?				
Not every time	125(7.1)	42(3.8)	1	1
Yes	1635(92.9)	1072(96.2)	1.95(1.36,2.79)**	1.72(1.16,2.54)**
Last HIV negative result				
Over one year ago	922(53.0)	529(47.9)	1	1
Within the past year	818(47.0)	576(52.1)	1.23(1.06,1.43)**	1.29(1.09,1.53)**
Perception of being infected by HIV				
No or little chance	3263(97.5)	1513(95.3)	1	1
Rather big chance	84(2.5)	75(4.7)	1.93(1.40,2.64)**	1.43(1.00,2.06)*
Where did you receive HIV testing?- Gay venue				
No	1203(68.4)	977(87.7)	1	1
Yes	557(31.6)	137(12.3)	0.30(0.25,0.37)**	0.49(0.37,0.63)**
Where did you receive HIV testing?-Hospital				
No	1434(81.5)	832(74.7)	1	1
Yes	326(18.5)	282(25.3)	1.49(1.24,1.78)**	1.18(0.96,1.44)
Where did you receive HIV testing?- CDC				
No	1233(70.1)	637(57.2)	1	1
Yes	527(29.9)	477(42.8)	1.75(1.50,2.05)**	1.48(1.24,1.76)**
Where did you receive HIV testing?- Blood donation site				
No	1719(97.7)	1093(98.1)	1	1
Yes	41(2.3)	21(1.9)	0.81(0.47,1.37)	0.91(0.51,1.64)

Where did you receive HIV testing?- CBO				
No	1141(64.8)	610(54.8)	1	1
Yes	619(35.2)	504(45.2)	1.52(1.31,1.78)**	1.71(1.44,2.03)**
Where did you receive HIV testing?- Home self-testing				
No	1657(94.1)	956(85.8)	1	1
Yes	103(5.9)	158(14.2)	2.66(2.05,3.45)**	1.61(1.21,2.14)**
The main source to gain HIV-related knowledge- TV				
No	1805(54.5)	1077(68.6)	1	1
Yes	1504(45.5)	492(31.4)	0.55(0.48,0.62)**	0.68(0.59,0.78)**
The main source to gain HIV-related knowledge- Radio				
No	3028(91.5)	1435(91.5)	1	1
Yes	281(8.5)	134(8.5)	1.01(0.81,1.25)	0.93(0.73,1.19)
The main source to gain HIV-related knowledge- Newspaper				
No	2757(83.3)	1278(81.5)	1	1
Yes	552(16.7)	291(18.5)	1.14(0.97,1.33)	1.10(0.92,1.31)
The main source to gain HIV-related knowledge- Books				
No	2788(84.3)	1135(72.3)	1	1
Yes	521(15.7)	434(27.7)	2.05(1.77,2.37)**	2.04(1.72,2.42)**
The main source to gain HIV-related knowledge- Friends				
No	2764(83.5)	1257(80.1)	1	1
Yes	545(16.5)	312(19.9)	1.26(1.08,1.47)**	0.92(0.77,1.09)
The main source to gain HIV-related knowledge- Doctors				
No	3016(91.1)	1405(89.5)	1	1
Yes	293(8.9)	164(10.5)	1.20(0.98,1.47)	1.27(1.00,1.61)*
The main source to gain HIV-related knowledge- Consultation service				
No	3125(94.4)	1476(94.1)	1	1
Yes	184(5.6)	93(5.9)	1.07(0.83,1.38)	0.80(0.60,1.07)
The main source to gain HIV-related knowledge- Free promotional materials				
No	2508(75.8)	1069(68.1)	1	1
Yes	801(24.2)	500(31.9)	1.46(1.28,1.67)**	1.76(1.51,2.07)**
The main source to gain HIV-related knowledge- Bulletin board				
No	2960(89.5)	1235(78.7)	1	1
Yes	349(10.5)	334(21.3)	2.29(1.95,2.70)**	1.81(1.50,2.19)**
The main source to gain HIV-related knowledge- Internet				
No	1370(41.4)	226(14.4)	1	1
Yes	1939(58.6)	1343(85.6)	4.20(3.59,4.91)**	3.07(2.58,3.67)**
The main source to gain HIV-related knowledge- School education				
No	3137(94.8)	1408(89.7)	1	1
Yes	172(5.2)	161(10.3)	2.09(1.67,2.61)**	0.98(0.76,1.26)

Note: "*", p<0.05; "**", p<0.01; OR, Odds ratio; AOR, adjusted odds ratio after controlling for age, education, monthly income, marital status, year of sample, source of sample, and type of MSM. CDC, center for disease control and prevention; CBO, community based organization.

Based univariate analysis and manual step-wise selection, the final multivariate model was constructed with covariates including education level, year and source of sample, type of MSM, self-identified sexual identity, sexual role, group sex, app use, HIV-related knowledge and service, previous diagnosis of other STD, current HIV and syphilis serostatus, risk perception of HIV infection as well as (Table 3). Multivariate regressions results showed that MSM have education level of college or above (AOR: 1.29, 95%CI: 1.01, 1.65), recruited from clinic-based sampling (AOR: 1.30, 95%CI: 1.06, 1.60), self-identified as homosexuality (AOR: 1.23, 95%CI: 1.02, 1.46) was associated with higher odds of HIV testing in the past year (Table 3). Besides, other factors including engaged in group sex (AOR: 1.64, 95%CI: 1.23, 2.19) in the past six months, received offline-based AIDS-related service in the past year (AOR: 5.49, 95%CI: 4.57, 6.60), used gay app (AOR: 1.49, 95%CI: 1.21, 1.83), had high level of HIV- related knowledge (AOR: 1.33, 95%CI: 1.10, 1.61), had higher risk perception of HIV infection (AOR: 2.95, 95%CI: 1.40, 6.23). On the other hand, MSM who recruited from 2016 (AOR: 0.54, 95%CI: 0.45, 0.65) and 2017 (AOR: 0.66, 95%CI: 0.51, 0.86), being MB (AOR: 0.36, 95%CI: 0.28, 0.46), reported receptive sexual role during anal sex in the past six months (AOR: 0.76, 95%CI: 0.64, 0.90), and being HIV seropositive (AOR: 0.66, 95%CI: 0.51, 0.86) had significant lower odds of HIV testing within the past year. We also performed a multivariate analysis to identify the determinants of HIV testing within lifetime, which showed similar results except for additional predictors such as older age, multiple sexual partners, previous diagnosis of other STD, and gained HIV-related knowledge mainly from consultation service (Supplemental table).

Table 3 Factors associated with HIV testing in the past year among MSM

Variables	Not tested (N=2776), N (%)	Tested (N=2159), N (%)	OR (95%CI)	AOR (95%CI)
Age				
<25	1153(64.9)	624(35.1)	1	
25~40	1131(51.0)	1086(49.0)	1.77(1.56,2.01)**	—
>40	491(52.2)	449(47.8)	1.69(1.44,1.99)**	—
Residence in Shenzhen				
<1 year	674(58.0)	488(42.0)	1	—
⩾1 year	1928(55.4)	1551(44.6)	1.11(0.97,1.27)	—
Ethnicity				
Han	2659(55.8)	2102(44.2)	1	—
Other	62(52.1)	57(47.9)	1.16(0.81,1.67)	—
Education				
Junior high school or less	491(62.7)	292(37.3)	1	1
Senior high school	1103(63.9)	623(36.1)	0.95(0.80,1.13)	0.90(0.70,1.15)
College or above	1182(48.7)	1244(51.3)	1.77(1.50,2.09)**	1.29(1.01,1.65)*
Monthly income				
<3000	192(60.2)	127(39.8)	1	
3000~7000	1941(59.5)	1319(40.5)	1.03(0.81,1.30)	—
>7000	643(47.4)	713(52.6)	1.68(1.31,2.15)**	—
Marital status				
Single	2540(56.7)	1936(43.3)	1	—
Married	236(51.4)	223(48.6)	1.24(1.02,1.50)*	—
Year of sample				
2015	757(55.2)	615(44.8)	1	1
2016	972(64.1)	544(35.9)	0.69(0.59,0.80)**	0.54(0.45,0.65)**
2017	1047(51.1)	1000(48.9)	1.18(1.03,1.35)*	0.65(0.48,0.88)**
Type of MSM				
NcMSM	1501(61.6)	935(38.4)	1	
MB	1275(51.0)	1224(49.0)	1.54(1.38,1.73)**	0.36(0.28,0.46)**
Source of sample				
Venue based	1839(50.9)	1774(49.1)	1	1
Clinic based	937(70.9)	385(29.1)	0.43(0.37,0.49)**	1.30(1.06,1.60)*
Self-identified as homosexuality				
No	777(58.7)	546(41.3)	1	1
Yes	1999(55.3)	1613(44.7)	1.15(1.01,1.30)*	1.23(1.02,1.46)*
Receptive sexual role				
No	1764(54.2)	1490(45.8)	1	1

Yes	1012(60.2)	668(39.8)	0.78(0.69,0.88)**	0.76(0.64,0.90)**
In a relationship				
No	275(50.4)	271(49.6)	1	—
Yes	451(46.9)	510(53.1)	1.15(0.93,1.42)	—
No. of sexual partners in the past 6 months				
0	881(63.9)	498(36.1)	1	
1~5	1462(49.5)	1491(50.5)	1.8(1.58,2.06)**	—
>5	433(71.9)	169(28.1)	0.69(0.56,0.85)**	—
Engaged in ONS in the past 6 months				
No	927(61.6)	579(38.4)	1	—
Yes	918(56.1)	717(43.9)	1.25(1.08,1.44)**	—
Engaged in group sex in past 6 months				
No	1741(60.4)	1143(39.6)	1	1
Yes	104(40.3)	154(59.7)	2.26(1.74,2.93)**	1.64(1.23,2.19)**
Engaged in commercial service in past 6 months				
No	1736(59.0)	1207(41.0)	1	—
Yes	105(53.8)	90(46.2)	1.23(0.92,1.65)	—
Condom use of anal sex in the past 6 months				
No	786(52.7)	706(47.3)	1	—
Yes	1109(53.8)	954(46.2)	0.96(0.84,1.09)	—
Recreational drug use in the past year				
No	66(54.1)	56(45.9)	1	—
Yes	998(51.5)	941(48.5)	1.11(0.77,1.60)	—
Received offline-based HIV-related service in the past year				
No	1367(77.0)	408(23.0)	1	1
Yes	1409(44.6)	1751(55.4)	4.16(3.65,4.75)**	5.49(4.57,6.60)**
Gay app use				
No	2014(60.2)	1333(39.8)	1	1
Yes	762(48.0)	826(52.0)	1.64(1.45,1.85)**	1.49(1.21,1.83)**
HIV-related knowledge				
Low to medium	828(59.2)	571(40.8)	1	
High	1948(55.1)	1588(44.9)	1.18(1.04,1.34)**	1.33(1.10,1.61)**
Previous diagnosis of other STD				
No	2581(56.7)	1968(43.3)	1	—
Yes	195(50.5)	191(49.5)	1.28(1.04,1.58)*	—
HIV serostatus				
Negative	2461(55.7)	1958(44.3)	1	
Positive	315(61.0)	201(39.0)	0.80(0.67,0.97)*	0.66(0.51,0.86)**
Syphilis serostatus				
Negative	2489(56.5)	1913(43.5)	1	—
Positive	287(53.8)	246(46.2)	1.12(0.93,1.34)	—

Perception of HIV infection				
No or little chance	2744(56.4)	2118(43.6)	1	1
Rather big chance	32(43.8)	41(56.2)	1.66(1.04,2.65)*	2.95(1.40,6.23)**
The main source to gain HIV-related knowledge -TV				
No	1640(56.9)	1242(43.1)	1	—
Yes	1080(54.1)	916(45.9)	1.12(1.00,1.26)	—
The main source to gain HIV-related knowledge- Radio				
No	2508(56.2)	1955(43.8)	1	—
Yes	212(51.1)	203(48.9)	1.23(1.00,1.50)*	—
The main source to gain HIV-related knowledge- Newspaper				
No	2247(55.7)	1788(44.3)	1	—
Yes	473(56.1)	370(43.9)	0.98(0.85,1.14)	—
The main source to gain HIV-related knowledge- Books				
No	2238(57.0)	1685(43.0)	1	—
Yes	482(50.5)	473(49.5)	1.30(1.13,1.50)**	—
The main source to gain HIV-related knowledge- Friends				
No	2274(56.6)	1747(43.4)	1	—
Yes	446(52.0)	411(48.0)	1.20(1.04,1.39)*	—
The main source to gain HIV-related knowledge- Doctors				
No	2514(56.9)	1907(43.1)	1	—
Yes	206(45.1)	251(54.9)	1.61(1.32,1.95)**	—
The main source to gain HIV-related knowledge- Consultation service				
No	2614(56.8)	1987(43.2)	1	—
Yes	106(38.3)	171(61.7)	2.12(1.65,2.72)**	—
The main source to gain HIV-related knowledge- Free promotional materials				
No	2042(57.1)	1535(42.9)	1	—
Yes	678(52.1)	623(47.9)	1.22(1.08,1.39)**	—
The main source to gain HIV-related knowledge- Bulletin board				
No	2396(57.1)	1799(42.9)	1	—
Yes	324(47.4)	359(52.6)	1.48(1.25,1.74)**	—
The main source to gain HIV-related knowledge- Internet				
No	859(53.8)	737(46.2)	1	—
Yes	1861(56.7)	1421(43.3)	0.89(0.79,1.00)	—
The main source to gain HIV-related knowledge -School education				
No	2541(55.9)	2004(44.1)	1	1
Yes	179(53.8)	154(46.2)	1.09(0.87,1.36)	0.83(0.69,1.01)

Note: "*", p<0.05; "**", p<0.01; OR, Odds ratio; AOR, adjusted odds ratio; ONS, one night stand; STD, sexually transmitted disease.

Discussion

The HIV testing rates within lifetime and the past year were significantly higher among app-using MSM than non-app using MSM. Particularly, app-using MSM were more likely to take an HIV test at CDC and CBO, and take a home self-testing than non-app-using MSM, while less likely to take a test at gay venues. Use of gay app was significantly associated with higher odds of lifetime HIV testing. As there were very few studies addressed the difference in choice of HIV testing approaches between app-using MSM and non-app-using MSM, this study provided significant implication for future HIV testing expanding strategies.

Our result showed that the prevalence of lifetime HIV testing among MSM in Shenzhen (58.2%) is comparable to that reported from other areas (60.3% ~63.1%) in China.[13 14] Specifically, app-using MSM had a relatively higher prevalence of lifetime HIV testing than non-app-using MSM (70.2% vs. 52.6%), similar to an online study from China (69.7% vs.55.5%).[7] The prevalence of lifetime testing among app-using MSM in this study was, however, lower than online studies from the US (83.2%-90%).[6 15] Previous research has demonstrated that some gay apps were utilized to link MSM to HIV testing promotion.[15 16] For instance, *Blued,* the most popular gay app in China, uses an "AIDS" ribbon to provide monthly banners on HIV testing, and suggests the users the nearest appropriate medical and testing facilities.[17] Secondly, as our result found non-app-using MSM had a relatively lower level of HIV-related knowledge and HIV risk perception, they may be less likely to take an HIV test than app-using MSM.

For the preference of HIV testing approaches, both app-using MSM and non-app using MSM mainly chose to take an HIV test at CDC, CBO, whereas less often at hospital.

Standard public health approaches at public health agencies such as CDC, are always the mainstay of HIV/ STD services in China.[18] However, our results showed testing in hospital is less common among both app-using MSM and non-app-using MSM, compared to the two main approaches. Literature data also implied the uptake of HIV testing was usually low in a clinical setting.[19] Due to the stigma and confidential concerns, Chinese MSM were very wary of choosing test at hospitals. While, engagement of CBO in sexual health prevention may bring about positive social norms to HIV testing and reduce the stigma concerns of MSM.[20 21] Other research showed CBO based testing was a cost-effective approach to reach population who have low access to clinic-based HIV testing,[22] and it would be worthwhile for testing expansion and other intervention development and delivery in China.[23] Thus, continued efforts of CBOs in promoting HIV testing may further increase the uptake of testing among Chinese MSM.

Testing at gay venues generally was less frequent than the other three main approaches in this study. First, it could be explained by the limited coverage of HIV prevention outreach, as we found only 64% of the MSM in this study had received the HIV-related service. The current outreach-based HIV services in Shenzhen including HIV testing and counseling, free distribution of condom and lubricate and STD diagnosis and treatment, were provided by the local public health agencies (CDC) with limited resources (budget and HIV care professionals) [24]. Secondly, literature documented that MSM were less willing to choose venue-based rapid testing than CBO-based testing among those non-clinical testing sites, due to the concerns about the quality, cleanliness, and professionalism.[10] Recent studies also

suggested testing at gay venues such as saunas and gay bars was not acceptable among Chinese MSM, unless the test was guaranteed with confidentiality, quality and quick results.[25 26] Although app-using MSM showed higher testing rates for the three main testing approaches than non-app-using MSM, they were less likely to get tested at gay venues. As non-app-using MSM were more likely to patronize gay venues for sex seeking than app-using MSM, they were more likely to receive the offline-based HIV-related service (69.6% vs. 30.4%) that routinely delivered at these gay venues (e.g., bars, massage centers and saunas). This finding indicated that app-using MSM currently were not well reached by traditional HIV prevention and intervention programs. Thus, innovative intervention strategies are greatly needed for this subpopulation. Besides, future improvement regarding the concerns of venue-based rapid testing as well as increased HIV-related resource is warranted to remove the barrier to higher uptake of HIV test at gay venues.

Home self-testing rate was much lower than that of other main testing approaches in general. Although home self-testing kits are now widely available and accessible in China since first approved in 2008, only 6.1% to 26.2% of MSM have ever chosen this new approach.[13 27 28] Comparing with non-app-using MSM, app-using MSM showed a higher self-testing rate. A prior study found that the most common means of obtaining self-testing kit in China were through the internet, then followed by CBOs, pharmacies and other offline means.[13] Interestingly, there was an increasing trend of home self-testing among non-app-using MSM in our study period. The underlying reason may be the scaling up campaign of self-testing in recent years in China, which increased the accessibility of self-testing kit

among offline social networking MSM as well.[29] Home self-testing provides an anonymous and confidential way to access HIV testing for MSM, and could better reach high-risk MSM. Our findings demonstrated that there was a large capacity to reach untested MSM via self-testing, especially for those non-app-using MSM hard-to-reach. Promotion of home self-testing would be an alternative approach to increase the HIV testing coverage among Chinese MSM.

Our study found that MSM who had higher education level, recruited through clinic-based methods, self-identified as homosexuality, practiced receptive sexual role during anal sex, engaged in group sex, used gay-app, and had previous diagnosis of other STD were associated with higher odds of HIV testing in the past year. Additionally, older age, multiple sexual partners, previous diagnosis of other STD were associated with higher chance of lifetime HIV testing. These findings were aligned with the literature that found age, education level, history of other STD, sexual orientation and high-risk sexual behaviours (e.g., multiple male sexual partners and unprotected sexual intercourse) were associated with HIV testing.[30 31] Other studies found use of gay app, being HIV negative and recent unprotected anal intercourse were positively associated with HIV testing within lifetime and the past year.[7 15] Additionally, our study found some other factors such as access to offline-based HIV-related service in the past year, having higher HIV-related knowledge and HIV risk perception were significantly associated with HIV testing within the past year, consistent with another Chinese study.[14] These findings highlighted the need for strengthened public health efforts on HIV prevention and interventions (e.g., HIV/STD testing and AIDS education), to increase

the HIV-related knowledge and risk perception, and finally help to increase the uptake of HIV testing among MSM.

There are several limitations of this study need to be noted. Firstly, there were relatively fewer samples collected from 2016 than the other two years, yet, we have adjusted the confounding effect of sample year in the multivariate analysis. Secondly, this study just included eight types of gay apps, while some other gay apps may emerge in the study period. As *Blued* accounted for about 97% of all app used, the new emerged apps may had very limited impact on results. Thirdly, this is a cross-sectional study which makes it difficult to establish a causal relationship, future longitudinal study would be desirable to evaluate the change of testing behaviour over time. In addition, there might be recall bias and social desirable bias regarding the self-reported information, especially the sensitive personal behaviours. Lastly, our results may not be generalizable to MSM in other areas, caution is required for appropriate interpretation.

In conclusion, there is still a significant gap in the coverage of HIV testing among MSM in Shenzhen, China. It is imperative to expand the testing coverage among the key population for scale-up treatment, especially those non-app-using MSM. Smartphone-based gay apps could significantly reach and offer considerable potential for increasing HIV testing uptake among MSM otherwise not reachable by traditional outreach. Continued efforts in promoting HIV testing, increased resource of HIV service and innovative strategies are highly needed to achieve the first “90” target by 2020.

Contributors JC and JZ conceived the work. JZ, JC and LL designed the study. LW conducted all data analysis and drafted the manuscript. CL, HZ, SL, WT and WX ran the field investigations, participated in data collection and management. LW, HZ, ZY and JZ contributed to the writing and data interpretation. WT and WX performed the experiments. LW, CL, ZY, JZ, JC and LL reviewed and edited the manuscript. All authors have seen and approved the final version of the manuscript for publication.

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Competing interests None declared.

Table 1 Demographics of app-using and non-app-using MSM

Table 2 HIV testing related behaviours between app-using and non-app-using MSM

Table 3 Factors associated with HIV testing in the past year among MSM

Supplemental table. Factors associated with HIV testing within lifetime among MSM

Figure 1 HIV testing approaches of app-using and non-app-using MSM in Shenzhen, China, 2015-2017

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HIV testing approaches of app-using and non-app-using MSM in Shenzhen, China, 2015-2017

254x190mm (300 x 300 DPI)

Supplemental table. Factors associated with HIV testing within lifetime among MSM

Variables	Never tested (N=2061), N (%)	Ever tested (N=2872), N (%)	OR (95%CI)	AOR (95%CI)
Age				
<25	1026(57.8)	750(42.2)	1	1
25~40	745(33.6)	1471(66.4)	2.7(2.37,3.08)**	1.45(1.17,1.81)**
>40	289(30.7)	651(69.3)	3.08(2.61,3.64)**	1.43(1.09,1.88)*
Residence in Shenzhen				
<1 year	545(46.9)	616(53.1)	1	—
⩾1 year	1413(40.6)	2066(59.4)	1.29(1.13,1.48)**	—
Ethnicity				
Han	2006(42.2)	2753(57.8)	1	—
Other	44(37.0)	75(63.0)	1.24(0.85,1.81)	—
Education				
Junior high school or less	394(50.3)	389(49.7)	1	1
Senior high school	923(53.5)	802(46.5)	0.88(0.74,1.04)	0.97(0.75,1.26)
College or above	744(30.7)	1681(69.3)	2.29(1.94,2.70)**	1.64(1.26,2.14)**
Monthly income				
<3000	142(44.7)	176(55.3)	1	
3000~7000	1543(47.3)	1716(52.7)	0.9(0.71,1.13)	—
>7000	376(27.7)	980(72.3)	2.1(1.64,2.70)**	—
Marital status				
Single	1911(42.7)	2563(57.3)	1	
Married	150(32.7)	309(67.3)	1.54(1.25,1.88)**	—
Year of sample				
2015	565(41.2)	806(58.8)	1	
2016	771(50.9)	744(49.1)	0.68(0.58,0.78)**	—
2017	725(35.4)	1322(64.6)	1.28(1.11,1.47)**	—
Type of MSM				
NcMSM	1170(32.4)	2442(67.6)	1	
MB	891(67.4)	430(32.6)	0.23(0.20,0.26)**	0.29(0.22,0.39)**
Source of sample				
Venue based	1275(52.4)	1160(47.6)	1	1
Clinic based	786(31.5)	1712(68.5)	2.39(2.13,2.69)**	1.68(1.35,2.10)**
Self-identified as homosexuality				
No	597(45.2)	725(54.8)	1	1
Yes	1464(40.5)	2147(59.5)	1.21(1.06,1.37)**	1.52(1.25,1.83)**
Receptive sexual role				
No	1306(40.1)	1948(59.9)	1	1
Yes	755(45.0)	924(55.0)	0.82(0.73,0.92)**	0.77(0.64,0.92)**

In a relationship				
No	175(32.1)	371(67.9)	1	—
Yes	291(30.3)	669(69.7)	1.08(0.86,1.36)	—
No. of sexual partners in the past 6 months				
0	763(55.3)	616(44.7)	1	1
1~5	930(31.5)	2022(68.5)	2.69(2.36,3.07)**	1.40(1.14,1.72)**
>5	368(61.1)	234(38.9)	0.79(0.65,0.96)*	0.70(0.50,0.99)*
Engaged in ONS in the past 6 months				
No	755(50.2)	750(49.8)	1	1
Yes	664(40.6)	971(59.4)	1.47(1.28,1.70)**	1.13(0.93,1.37)
Engaged in group sex in past 6 months				
No	1350(46.8)	1533(53.2)	1	1
Yes	69(26.7)	189(73.3)	2.41(1.81,3.21)**	1.45(1.04,2.03)*
Engaged in commercial service in the past 6 months				
No	1339(45.5)	1603(54.5)	1	—
Yes	76(39.0)	119(61.0)	1.31(0.97,1.76)	—
Condom use of anal sex in the past 6 months				
No	513(34.4)	978(65.6)	1	—
Yes	785(38.1)	1278(61.9)	0.85(0.74,0.98)*	—
Recreational drug use				
No	1362(47.4)	1511(52.6)	1	—
Yes	699(33.9)	1361(66.1)	1.76(1.56,1.98)**	—
Received offline-based HIV-related service in the past year				
No	1102(62.1)	672(37.9)	1	1
Yes	959(30.4)	2200(69.6)	3.76(3.33,4.25)**	6.22(5.11,7.57)**
Gay app use				
No	1587(47.4)	1758(52.6)	1	1
Yes	474(29.8)	1114(70.2)	2.12(1.87,2.41)**	1.72(1.37,2.16)**
HIV-related knowledge				
Low to medium	619(44.3)	778(55.7)	1	
High	1442(40.8)	2094(59.2)	1.16(1.02,1.31)*	1.42(1.16,1.73)**
Previous diagnosis of other STD				
No	1938(42.6)	2609(57.4)	1	
Yes	123(31.9)	263(68.1)	1.59(1.27,1.98)**	1.46(1.05,2.03)*
HIV serostatus				
Negative	1837(41.6)	2580(58.4)	1	
Positive	224(43.4)	292(56.6)	0.93(0.77,1.12)	0.65(0.49,0.85)**
Syphilis serostatus				
Negative	1885(42.8)	2515(57.2)	1	
Positive	176(33.0)	357(67.0)	1.52(1.26,1.84)**	1.09(0.81,1.47)
Perception of being infected by HIV				
No or little chance	2043(42.0)	2817(58.0)	1	1

Rather big chance	18(24.7)	55(75.3)	2.22(1.30,3.79)**	3.92(1.60,9.63)**
The main source to gain HIV-related knowledge- TV				
No	1208(41.9)	1674(58.1)	1	—
Yes	842(42.2)	1154(57.8)	0.99(0.88,1.11)	—
The main source to gain HIV-related knowledge- Radio				
No	1900(42.6)	2563(57.4)	1	—
Yes	150(36.1)	265(63.9)	1.31(1.06,1.62)*	—
The main source to gain HIV-related knowledge- Newspaper				
No	1687(41.8)	2348(58.2)	1	—
Yes	363(43.1)	480(56.9)	0.95(0.82,1.11)	—
The main source to gain HIV-related knowledge- Books				
No	1711(43.6)	2212(56.4)	1	—
Yes	339(35.5)	616(64.5)	1.41(1.21,1.63)**	—
The main source to gain HIV-related knowledge- Friends				
No	1732(43.1)	2289(56.9)	1	—
Yes	318(37.1)	539(62.9)	1.28(1.10,1.49)**	—
The main source to gain HIV-related knowledge- Doctors				
No	1901(43.0)	2520(57.0)	1	—
Yes	149(32.6)	308(67.4)	1.56(1.27,1.91)**	—
The main source to gain HIV-related knowledge- Consultation service				
No	1983(43.1)	2618(56.9)	1	1
Yes	67(24.2)	210(75.8)	2.37(1.79,3.14)**	1.77(1.16,2.70)**
The main source to gain HIV-related knowledge- Free promotional materials				
No	1542(43.1)	2035(56.9)	1	1
Yes	508(39.0)	793(61.0)	1.18(1.04,1.35)*	0.74(0.60,0.91)**
The main source to gain HIV-related knowledge- Bulletin board				
No	1837(43.8)	2358(56.2)	1	1
Yes	213(31.2)	470(68.8)	1.72(1.45,2.04)**	1.25(0.94,1.65)
The main source to gain HIV-related knowledge- Internet				
No	684(42.9)	912(57.1)	1	1
Yes	1366(41.6)	1916(58.4)	1.05(0.93,1.19)	0.84(0.69,1.03)
The main source to gain HIV-related knowledge- School education				
No	1924(42.3)	2621(57.7)	1	—
Yes	126(37.8)	207(62.2)	1.21(0.96,1.52)	—

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	*na*
Study size	10	Explain how the study size was arrived at	8-9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	na
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	na
		(*e*) Describe any sensitivity analyses	na
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6,8
		(b) Give reasons for non-participation at each stage	na
		(c) Consider use of a flow diagram	na
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-10
		(b) Indicate number of participants with missing data for each variable of interest	na
Outcome data	15*	Report numbers of outcome events or summary measures	8-9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12-17
		(*b*) Report category boundaries when continuous variables were categorized	9,15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	na
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14
Discussion			
Key results	18	Summarise key results with reference to study objectives	18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	22
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18-22
Generalisability	21	Discuss the generalisability (external validity) of the study results	22
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	23

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

The relationship between gay app use and HIV testing among men who have sex with men in Shenzhen, China: a serial cross-sectional study

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Keywords:	HIV testing, gay app, testing approach, MSM

The relationship between gay app use and HIV testing among men who have sex with men in Shenzhen, China: a serial cross-sectional study

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Abstract

Objectives To investigate the relationship between gay app use and HIV testing and the associated factors.

Design Serial cross-sectional study

Setting Newly well-developed city in China

Participants 4935 MSM were recruited through offline sampling methods, 2015-2017.

Primary and secondary outcomes The primary outcome is HIV testing rate and choice of testing approaches among app users and non-app users, and the predictors of HIV testing.

Results 2872 (58.2%) and 2159 (43.7%) participated MSM had been tested for HIV within lifetime and the past year, respectively. App-using MSM had significant higher prevalence of HIV testing within lifetime (AOR: 1.48, 95%CI: 1.27, 1.72) and HIV testing in the past year (AOR: 1.36, 95%CI: 1.18, 1.57) than non-app-using MSM. App-using MSM were significantly more likely to take HIV testing at Center for Disease Control and Prevention (AOR: 1.48, 95%CI: 1.24, 1.76), community-based organization (AOR: 1.71, 95%CI: 1.44, 2.03), whereas less often at gay venues (AOR: 0.49, 95%CI: 0.37, 0.63) than non-app-using MSM. Meanwhile, app-using MSM were more likely to take self-testing (AOR: 1.61, 95%CI: 1.21, 2.14). Predictors of HIV testing in the past year were: having education level of college or higher (AOR: 1.29, 95%CI: 1.01, 1.65), being self-identified as homosexuality (AOR: 1.23, 95%CI: 1.02, 1.46), being recruited through clinic-based sampling (AOR: 1.30, 95%CI: 1.06, 1.60), using gay app (AOR: 1.49, 95%CI: 1.21, 1.83), engaging in group sex (AOR: 1.64, 95%CI: 1.23, 2.19), having received HIV-related service (AOR: 5.49, 95%CI: 4.57,

6.60), having high level of HIV-related knowledge (AOR: 1.33, 95%CI: 1.10, 1.61) and high risk perception (AOR: 2.95, 95%CI: 1.40, 6.23).

Conclusions Gay app was significantly associated with increased HIV testing among MSM hard-to-reach by traditional outreach. It is imperative to expand HIV testing among non-app-using MSM. Continued efforts, innovative strategies and increased resource are highly needed to realize the first "90" target.

Key Words HIV testing, gay app, MSM, testing approach

Strengths and limitations of this study

- This study represents one of the few studies that compare the HIV testing and pattern of testing approaches between app-using MSM and non-app-using MSM from a developing country setting, which has significant implication for future HIV testing expanding strategies.
- Different from most previous online surveys, this study used a combined offline recruitment method, which could provide complementary evidence on this topic.
- This is a cross-sectional study which makes it difficult to establish a causal relationship.
- The findings may not be generalizable to MSM in other areas or settings.

Introduction

HIV testing is an essential component of HIV prevention strategy that linked to treatment and care. Lack of knowledge on the HIV serostatus would disable or postpone the initiation of antiviral treatment. Also, HIV screening among asymptomatic HIV carrier may directly reduce HIV transmission, as prior research estimated that those who are unaware of their seropositive status are 3.5 times more likely to transmit HIV than those who know their serostatus.[1] There are about 30% of people living with HIV who do not know their HIV status globally.[2] The first goal of the United Nation's 90–90–90 targets is that 90% of all people with HIV will get tested and know their status by 2020, however, HIV testing rate in China is much lower than 90%. A recent meta-analysis reported that there are just 47% of the men who have sex with men (MSM) have ever been tested for HIV in China, despite the extensive combined efforts of government, public health agencies, community-based organizations in recent years.[3] Due to the stigma against homosexuality in China, MSM in fear of exposure of homosexual identity are less likely to take an HIV test. Besides, there are several other barriers to HIV testing, such as name-based testing, low perception of risk, long asymptomatic phase, unaware that testing is free of charge, posing significant challenges to HIV prevention and interventions among MSM in China.[4] Thus, developing more comprehensive strategies for promoting HIV testing among MSM is an urgent priority in China.

In recent years, the emergence of gay app (geosocial networking application specific to MSM) has significantly reformed the MSM's sex-seeking behaviours as well as harm-

reduction behaviors.[5] Previous limited studies on the association between gay apps use and HIV testing behaviour are inconclusive. Some studies found app use was associated with more HIV testing either within lifetime or in the past year,[6 7] while other studies found no difference between app users and non-users.[8] A recent systematic review found that app users are twice as likely to test for HIV than non-app users within lifetime.[5] Another study revealed that social media use was significantly associated with HIV testing in Chinese MSM.[9] Free HIV testing is now available in all provinces of China since 2006. Apart from the health facility-based testing service provided at hospital/clinics and Center for Disease Control and Prevention (CDC), there are also decentralized HIV testing services provided at peripheral health facilities including community-based organization (CBO), blood donation site, as well as testing service at gay venues and self-testing at home.[10] As the uptake of HIV testing among MSM is still limited, a better understanding of the testing pattern and preferences among MSM is critical to inform HIV testing expanding strategies. Furthermore, few studies exist regarding the impact of app use on the uptake and preference of HIV testing approach among MSM. Therefore, we conducted a study to investigate the relationship between app use and HIV testing, and to identify the demographic and behavioral predictors of HIV testing among MSM in Shenzhen, China, where MSM accounted for the largest percentage (56.7%) of new infections in recent years.

Methods

Source of sample

From May 2015 to the end of 2017, eligible MSM were recruited through combined offline

sampling methods, primarily venue-based method (Time Location Sampling, TLS), and clinics based methods (Respondent-Driven Sampling, RDS; Voluntary Counseling and Testing center, VCT). In brief, TLS is to recruit eligible participant at MSM venues based on a random selection strategy of venue-day-time. RDS starts with identification of initial 'seeds' of MSM peers. These seeds are then offered with three coded coupons to recruit new peers, who in turn further refer to those they know and so on. Other participants who visited VCT were also randomly recruited. More information on these methods can be found in the previous study.[11] The criteria for recruiting is 1) male, Chinese resident, aged 18 years old or above; 2) those who had a homosexual contact in the previous six months of the survey in Shenzhen. Meanwhile, the criteria for eligible male sex workers (also called money boy, MB) participants included: 1) being male 18 years or older; 2) having lived in Shenzhen for more than one month at the time of survey; 3) having sold sex (oral or anal) to another male in the previous month. Each participant was invited to complete an anonymous questionnaire via a handheld electronic tablet and provide a written informed consent. Then, they were required to take a confidential HIV and syphilis test at Shenzhen Center for Disease Control and Prevention, or the voluntary counseling and testing center. The protocol for recruitment was approved by the Medical Ethics Committee of Shenzhen Center for Disease Control and Prevention.

Behavioural measures

All data was collected through self-administered questionnaires, including sociodemographic features, sexual behaviours, gay app use, recreational drug use, HIV testing, HIV-related

services, HIV-related knowledge, previous diagnosis of Sexually Transmitted Disease (STD) other than HIV and syphilis infections, source of HIV-related knowledge, HIV and syphilis serostatus and perception of HIV infection. The HIV-related services including distribution of condom, lubricant, peer education, STI diagnosis or treatment, HIV counselling or testing, or AIDS/STI educational materials. A high level of HIV-related knowledge was defined as having correctly answered at least six out of the nine questions, otherwise, it was deemed as low to medium level. HIV testing behaviours were evaluated in the following measures: 1) Have you ever received HIV testing? 2) Have you taken HIV testing in the past year? 3) Where did you receive HIV testing? (Gay venue/ hospital/ CDC/ blood donation site/ CBO/ self-testing at home). The main source of HIV-related knowledge was listed as TV, radio, newspaper, books, friends, doctors, consultation service, free promotional materials, bulletin board, internet and school education. The behavioural measures presented in the questionnaire were developed according to the national sentinel surveillance survey for HIV/AIDS and those previously verified questionnaire.[12]

HIV and syphilis testing

HIV testing and syphilis testing were performed according to standard procedures established by the laboratory of Shenzhen Centers for Disease Control and Prevention. HIV was tested using a rapid test (Determine HIV-1/2/O; Abbott Laboratories, IL) and enzyme-linked immunosorbent assay (Wantai Biotech Inc, Beijing, China) for screening, with the positive test further confirmed by Western Blot (Genlabs Diagnostics, Singapore). Syphilis was tested with rapid plasma regain method (Rongsheng Biotech Inc, Shanghai, China) for qualitative

screening, with the positive test further confirmed by Treponema pallidum particle agglutination assay (Fujirebio Inc, Japan).

Patients and public involvement

Patients or public were not involved in the design or planning of the study.

Data availability statement

No additional data available

Statistical analysis

Sociodemographic features and HIV testing related behaviours were compared between app-using MSM and non-app-using MSM, with categorical variables compared using the *Chi-squared test* or *Fisher's exact test*. Univariate and multivariate logistic regressions adjusted for confounders (e.g., age, education, marital status, year of survey, etc.) were performed to examine the correlates between app use and testing-related behaviours. To identify the significant predictors for HIV testing within the past year and lifetime, variables with a P value <0.10 in the univariate logistic regression models and theoretically important covariates were included for step-wise selection in multivariate regression models. The covariates with a P value <0.05 were kept in the final model through manual step-wise selection. Adjusted odds ratios (AOR) and 95% confidence intervals (CIs) were presented. All statistical analyses were performed in R (version 3.4.3, Foundation for Statistical Computing, Vienna, Austria).

Results

Among the 4935 participants recruited from 2015 to 2017, 1588 (32.2%) MSM had used at least one kind of gay app, including 1496 non-commercial MSM and 92 MBs. The

demographic characteristics of all recruited MSM were summarized in Table 1. Compared to non-app-using MSM, app-using MSM were younger (28.3 vs. 28.8 years), and were more likely to be unmarried (92.0% vs. 90.1%), having an education level of college or above (64.0% vs. 42.1%), and having a monthly income higher than 7000 RMB (34.1% vs. 24.3%). There was no significant difference in ethnicity and duration of residence in Shenzhen between the two groups. There were higher percentages of app-using MSM recruited from clinics (69.6% vs. 41.6%) and recruited in 2017 (56.9% vs.34.2%) than that of non-app-using MSM. The prevalence of HIV and syphilis infection was not significantly different between the two groups. However, the prevalence of both HIV and syphilis was significantly higher among non-app-using non-commercial MSM (NcMSM), but not significant for MBs who were less likely to use app and be positive for HIV and syphilis (data not shown).

Table 1 Demographics of app-using and non-app-using MSM

	Non-app-using MSM (N=3347), N (%)	**App-using MSM (N=1588), N (%)**	**P value***
Age			
<25	1316(39.3)	461(29.0)	
25~40	1618(48.4)	1030(64.9)	<0.01
>40	412(12.3)	97(6.1)	
Age (median, IQR)	26 (23, 33)	27 (24, 31)	<0.05
Duration of residence in Shenzhen			
<1 year	802(25.5)	360(24.0)	0.299
≥1 year	2342(74.5)	1137(76.0)	
Ethnicity			
Han	3237(97.8)	1524(97.1)	0.215
Other	74(2.2)	45(2.9)	
Education			
Junior high school or less	637(19.0)	146(9.2)	
Senior high school	1301(38.9)	425(26.8)	<0.01
College or above	1409(42.1)	1017(64.0)	
Monthly income(RMB)			

<3000	196(5.9)	123(7.7)	
3000~7000	2337(69.8)	923(58.1)	<0.01
>7000	814(24.3)	542(34.1)	
Marital status			
Unmarried	3015(90.1)	1461(92.0)	<0.05
Married	332(9.9)	127(8.0)	
Year of sample			
2015	1254(37.5)	118(7.4)	
2016	949(28.4)	567(35.7)	<0.01
2017	1144(34.2)	903(56.9)	
Source of sample			
Venue based	1953(58.4)	483(30.4)	<0.01
Clinic based	1394(41.6)	1105(69.6)	
Type of MSM			
NcMSM	2117(63.3)	1496(94.2)	<0.01
MB	1230(36.7)	92(5.8)	
HIV			
Negative	3005(89.8)	1414(89.0)	0.458
Positive	342(10.2)	174(11.0)	
Syphilis			
Negative	2983(89.1)	1419(89.4)	0.844
Positive	364(10.9)	169(10.6)	
Previous diagnosis of other STDs			
No	3119(93.2)	1430(90.1)	<0.01
Yes	228(6.8)	158(9.9)	

Note: NcMSM, Non-commercial MSM; MB, Money boy (male sex worker); STD, sexually transmitted disease. * All P values in this column were derived from the comparison between non-app-using MSM and app-using MSM.

There were significant differences of testing-related behaviors between app-using MSM and non-app-using MSM in this study (Table 2). About 58.2% of MSM had been tested for HIV within lifetime and 43.7% had been tested within the past year in Shenzhen. App-using MSM had significantly higher prevalence of HIV testing within lifetime (70.2% vs.52.6%) and the past year (52.0% vs. 39.8%) than non-app-using MSM. After controlling for age, education, monthly income, marital status, year of sampling, source of sample, and type of MSM, MSM who used gay app had significant higher odds of lifetime HIV test (AOR: 1.48,

95%CI: 1.27, 1.72) and HIV test in the past year (AOR: 1.36, 95%CI: 1.18, 1.57) than those who did not. App-using-MSM were more commonly to know their HIV testing results (AOR: 1.72, 95%CI: 1.16, 2.54) and know their last negative result within the past year (AOR: 1.29, 95%CI: 1.09, 1.53). Generally, app-using MSM had higher risk perception of HIV infection than their counterparts (AOR: 1.43, 95%CI: 1.00, 2.06). For the approaches of HIV testing, app-using MSM were more likely to receive HIV testing at local CDC (AOR: 1.48, 95%CI: 1.24, 1.76) or community-based organization (CBO) (AOR: 1.71, 95%CI: 1.44, 2.03), and take self-testing (AOR: 1.61, 95%CI: 1.21, 2.14); however, they were less likely to receive HIV testing at gay venues (AOR: 0.49, 95%CI: 0.37, 0.63). There were no significant differences between the two groups for the choices of testing at hospital and blood donation sites. Furthermore, the choices of HIV testing approach by year was compared between the two groups in Figure 1. From 2015 to 2017, the proportion of app-using MSM taking HIV test at CDC has increased, while testing at hospital, CBOs and blood donation site has declined. Notably, there were an increasing rate of self-testing among non-app-using MSM although the main choices were testing at gay venue, CDC and CBO. App-using MSM were more likely to gain HIV-related knowledge from internet (AOR: 3.07, 95%CI: 2.58, 3.67), books (AOR: 2.04, 95%CI: 1.72, 2.42), doctors (AOR: 1.27, 95%CI: 1.00, 1.61), free promotional materials (AOR: 1.76, 95%CI: 1.51, 2.07), bulletin board (AOR: 1.81, 95%CI: 1.50, 2.19), while less likely from TV (AOR: 0.68, 95%CI: 0.59, 0.78) than non-app-using MSM. For the other source such as radio, newspaper, friends, consultancy service, school education, there was no significant difference between the two groups.

Table 2 HIV testing related behaviors between app-using and non-app-using MSM

All	Non-app-using MSM (N=3347), N (%)	App-using MSM (N=1588), N (%)	OR (95%CI)	AOR (95%CI)
Ever tested for HIV				
No	1587(47.4)	474(29.8)	1	1
Yes	1758(52.6)	1114(70.2)	2.12(1.87,2.41)**	1.48(1.27,1.72)**
HIV test in the past year				
0	2014(60.2)	762(48.0)	1	1
1	1333(39.8)	826(52.0)	1.64(1.45,1.85)**	1.36(1.18,1.57)**
Did you know your testing results?				
Not every time	125(7.1)	42(3.8)	1	1
Yes	1635(92.9)	1072(96.2)	1.95(1.36,2.79)**	1.72(1.16,2.54)**
Last HIV negative result				
Over one year ago	922(53.0)	529(47.9)	1	1
Within the past year	818(47.0)	576(52.1)	1.23(1.06,1.43)**	1.29(1.09,1.53)**
Perception of being infected by HIV				
No or little chance	3263(97.5)	1513(95.3)	1	1
Rather big chance	84(2.5)	75(4.7)	1.93(1.40,2.64)**	1.43(1.00,2.06)*
Where did you receive HIV testing?- Gay venue				
No	1203(68.4)	977(87.7)	1	1
Yes	557(31.6)	137(12.3)	0.30(0.25,0.37)**	0.49(0.37,0.63)**
Where did you receive HIV testing?-Hospital				
No	1434(81.5)	832(74.7)	1	1
Yes	326(18.5)	282(25.3)	1.49(1.24,1.78)**	1.18(0.96,1.44)
Where did you receive HIV testing?- CDC				
No	1233(70.1)	637(57.2)	1	1
Yes	527(29.9)	477(42.8)	1.75(1.50,2.05)**	1.48(1.24,1.76)**
Where did you receive HIV testing?- Blood donation site				
No	1719(97.7)	1093(98.1)	1	1
Yes	41(2.3)	21(1.9)	0.81(0.47,1.37)	0.91(0.51,1.64)
Where did you receive HIV testing?- CBO				
No	1141(64.8)	610(54.8)	1	1
Yes	619(35.2)	504(45.2)	1.52(1.31,1.78)**	1.71(1.44,2.03)**
Where did you receive HIV testing?- Self-testing				
No	1657(94.1)	956(85.8)	1	1

Yes	103(5.9)	158(14.2)	2.66(2.05,3.45)**	1.61(1.21,2.14)**
The main source to gain HIV-related knowledge- TV				
No	1805(54.5)	1077(68.6)	1	1
Yes	1504(45.5)	492(31.4)	0.55(0.48,0.62)**	0.68(0.59,0.78)**
The main source to gain HIV-related knowledge- Radio				
No	3028(91.5)	1435(91.5)	1	1
Yes	281(8.5)	134(8.5)	1.01(0.81,1.25)	0.93(0.73,1.19)
The main source to gain HIV-related knowledge- Newspaper				
No	2757(83.3)	1278(81.5)	1	1
Yes	552(16.7)	291(18.5)	1.14(0.97,1.33)	1.10(0.92,1.31)
The main source to gain HIV-related knowledge- Books				
No	2788(84.3)	1135(72.3)	1	1
Yes	521(15.7)	434(27.7)	2.05(1.77,2.37)**	2.04(1.72,2.42)**
The main source to gain HIV-related knowledge- Friends				
No	2764(83.5)	1257(80.1)	1	1
Yes	545(16.5)	312(19.9)	1.26(1.08,1.47)**	0.92(0.77,1.09)
The main source to gain HIV-related knowledge- Doctors				
No	3016(91.1)	1405(89.5)	1	1
Yes	293(8.9)	164(10.5)	1.20(0.98,1.47)	1.27(1.00,1.61)*
The main source to gain HIV-related knowledge- Consultation service				
No	3125(94.4)	1476(94.1)	1	1
Yes	184(5.6)	93(5.9)	1.07(0.83,1.38)	0.80(0.60,1.07)
The main source to gain HIV-related knowledge- Free promotional materials				
No	2508(75.8)	1069(68.1)	1	1
Yes	801(24.2)	500(31.9)	1.46(1.28,1.67)**	1.76(1.51,2.07)**
The main source to gain HIV-related knowledge- Bulletin board				
No	2960(89.5)	1235(78.7)	1	1
Yes	349(10.5)	334(21.3)	2.29(1.95,2.70)**	1.81(1.50,2.19)**
The main source to gain HIV-related knowledge- Internet				
No	1370(41.4)	226(14.4)	1	1
Yes	1939(58.6)	1343(85.6)	4.20(3.59,4.91)**	3.07(2.58,3.67)**
The main source to gain HIV-related knowledge- School education				
No	3137(94.8)	1408(89.7)	1	1
Yes	172(5.2)	161(10.3)	2.09(1.67,2.61)**	0.98(0.76,1.26)

Note: "*", p<0.05; "**", p<0.01; OR, Odds ratio; AOR, adjusted odds ratio after controlling for age, education, monthly income, marital status, year of sample, source of sample, and type of MSM. CDC, center for disease control and prevention; CBO, community based organization.

Based on univariate analysis and manual step-wise selection, the final multivariate model was constructed with covariates including year of sampling, source of sample, type of

MSM, education level, self-identified sexual identity, sexual role, group sex, app use, HIV-related knowledge and service, previous diagnosis of other STI, risk perception of HIV infection, as well as current HIV and syphilis serostatus (Table 3). Multivariate regression results showed the factors associated with higher odds of HIV testing in the past year (Table 3) were as following: having education level of college or above (AOR: 1.29, 95%CI: 1.01, 1.65), being recruited by clinic-based sampling methods (AOR: 1.30, 95%CI: 1.06, 1.60), being self-identified as homosexuality (AOR: 1.23, 95%CI: 1.02, 1.46), engaging in group sex (AOR: 1.64, 95%CI: 1.23, 2.19) in the past six months, using gay app (AOR: 1.49, 95%CI: 1.21, 1.83), having received offline-based AIDS-related service in the past year (AOR: 5.49, 95%CI: 4.57, 6.60), having high level of HIV- related knowledge (AOR: 1.33, 95%CI: 1.10, 1.61), and having high risk perception of HIV infection (AOR: 2.95, 95%CI: 1.40, 6.23). On the other hand, MSM who were recruited in 2016 (AOR: 0.54, 95%CI: 0.45, 0.65) and 2017 (AOR: 0.66, 95%CI: 0.51, 0.86), being MB (AOR: 0.36, 95%CI: 0.28, 0.46), having reported receptive sexual role during anal sex in the past six months (AOR: 0.76, 95%CI: 0.64, 0.90), and being HIV seropositive (AOR: 0.66, 95%CI: 0.51, 0.86) had significant lower odds of HIV testing within the past year. We also performed a multivariate analysis to identify the determinants of HIV testing within lifetime, which showed similar results except for additional predictors such as older age, multiple sexual partners, previous diagnosis of other STD, and gaining HIV-related knowledge mainly from consultation service (Supplemental table).

Table 3 Factors associated with HIV testing in the past year among MSM

Variables	Not tested (N=2776), N (%)	Tested (N=2159), N (%)	OR (95%CI)	AOR (95%CI)
Age				
<25	1153(64.9)	624(35.1)	1	
25~40	1131(51.0)	1086(49.0)	1.77(1.56,2.01)**	—
>40	491(52.2)	449(47.8)	1.69(1.44,1.99)**	—
Residence in Shenzhen				
<1 year	674(58.0)	488(42.0)	1	—
⩾1 year	1928(55.4)	1551(44.6)	1.11(0.97,1.27)	—
Ethnicity				
Han	2659(55.8)	2102(44.2)	1	—
Other	62(52.1)	57(47.9)	1.16(0.81,1.67)	—
Education				
Junior high school or less	491(62.7)	292(37.3)	1	1
Senior high school	1103(63.9)	623(36.1)	0.95(0.80,1.13)	0.90(0.70,1.15)
College or above	1182(48.7)	1244(51.3)	1.77(1.50,2.09)**	1.29(1.01,1.65)*
Monthly income				
<3000	192(60.2)	127(39.8)	1	
3000~7000	1941(59.5)	1319(40.5)	1.03(0.81,1.30)	—
>7000	643(47.4)	713(52.6)	1.68(1.31,2.15)**	—
Marital status				
Single	2540(56.7)	1936(43.3)	1	—
Married	236(51.4)	223(48.6)	1.24(1.02,1.50)*	—
Year of sample				
2015	757(55.2)	615(44.8)	1	1
2016	972(64.1)	544(35.9)	0.69(0.59,0.80)**	0.54(0.45,0.65)**
2017	1047(51.1)	1000(48.9)	1.18(1.03,1.35)*	0.65(0.48,0.88)**
Type of MSM				
NcMSM	1501(61.6)	935(38.4)	1	
MB	1275(51.0)	1224(49.0)	1.54(1.38,1.73)**	0.36(0.28,0.46)**
Source of sample				
Venue based	1839(50.9)	1774(49.1)	1	1
Clinic based	937(70.9)	385(29.1)	0.43(0.37,0.49)**	1.30(1.06,1.60)*
Self-identified as homosexuality				
No	777(58.7)	546(41.3)	1	1
Yes	1999(55.3)	1613(44.7)	1.15(1.01,1.30)*	1.23(1.02,1.46)*
Receptive sexual role				
No	1764(54.2)	1490(45.8)	1	1
Yes	1012(60.2)	668(39.8)	0.78(0.69,0.88)**	0.76(0.64,0.90)**

In a relationship				
No	275(50.4)	271(49.6)	1	—
Yes	451(46.9)	510(53.1)	1.15(0.93,1.42)	—
No. of sexual partners in the past 6 months				
0	881(63.9)	498(36.1)	1	
1~5	1462(49.5)	1491(50.5)	1.8(1.58,2.06)**	—
>5	433(71.9)	169(28.1)	0.69(0.56,0.85)**	—
Engaged in ONS in the past 6 months				
No	927(61.6)	579(38.4)	1	—
Yes	918(56.1)	717(43.9)	1.25(1.08,1.44)**	—
Engaged in group sex in past 6 months				
No	1741(60.4)	1143(39.6)	1	1
Yes	104(40.3)	154(59.7)	2.26(1.74,2.93)**	1.64(1.23,2.19)**
Engaged in commercial service in past 6 months				
No	1736(59.0)	1207(41.0)	1	—
Yes	105(53.8)	90(46.2)	1.23(0.92,1.65)	—
Condom use of anal sex in the past 6 months				
No	786(52.7)	706(47.3)	1	—
Yes	1109(53.8)	954(46.2)	0.96(0.84,1.09)	—
Recreational drug use in the past year				
No	66(54.1)	56(45.9)	1	—
Yes	998(51.5)	941(48.5)	1.11(0.77,1.60)	—
Received offline-based HIV-related service in the past year				
No	1367(77.0)	408(23.0)	1	1
Yes	1409(44.6)	1751(55.4)	4.16(3.65,4.75)**	5.49(4.57,6.60)**
Gay app use				
No	2014(60.2)	1333(39.8)	1	1
Yes	762(48.0)	826(52.0)	1.64(1.45,1.85)**	1.49(1.21,1.83)**
HIV-related knowledge				
Low to medium	828(59.2)	571(40.8)	1	
High	1948(55.1)	1588(44.9)	1.18(1.04,1.34)**	1.33(1.10,1.61)**
Previous diagnosis of other STD				
No	2581(56.7)	1968(43.3)	1	—
Yes	195(50.5)	191(49.5)	1.28(1.04,1.58)*	—
HIV serostatus				
Negative	2461(55.7)	1958(44.3)	1	
Positive	315(61.0)	201(39.0)	0.80(0.67,0.97)*	0.66(0.51,0.86)**
Syphilis serostatus				
Negative	2489(56.5)	1913(43.5)	1	—
Positive	287(53.8)	246(46.2)	1.12(0.93,1.34)	—
Perception of HIV infection				

No or little chance	2744(56.4)	2118(43.6)	1	1
Rather big chance	32(43.8)	41(56.2)	1.66(1.04,2.65)*	2.95(1.40,6.23)**
The main source to gain HIV-related knowledge -TV				
No	1640(56.9)	1242(43.1)	1	—
Yes	1080(54.1)	916(45.9)	1.12(1.00,1.26)	—
The main source to gain HIV-related knowledge- Radio				
No	2508(56.2)	1955(43.8)	1	—
Yes	212(51.1)	203(48.9)	1.23(1.00,1.50)*	—
The main source to gain HIV-related knowledge- Newspaper				
No	2247(55.7)	1788(44.3)	1	—
Yes	473(56.1)	370(43.9)	0.98(0.85,1.14)	—
The main source to gain HIV-related knowledge- Books				
No	2238(57.0)	1685(43.0)	1	—
Yes	482(50.5)	473(49.5)	1.30(1.13,1.50)**	—
The main source to gain HIV-related knowledge- Friends				
No	2274(56.6)	1747(43.4)	1	—
Yes	446(52.0)	411(48.0)	1.20(1.04,1.39)*	—
The main source to gain HIV-related knowledge- Doctors				
No	2514(56.9)	1907(43.1)	1	—
Yes	206(45.1)	251(54.9)	1.61(1.32,1.95)**	—
The main source to gain HIV-related knowledge- Consultation service				
No	2614(56.8)	1987(43.2)	1	—
Yes	106(38.3)	171(61.7)	2.12(1.65,2.72)**	—
The main source to gain HIV-related knowledge- Free promotional materials				
No	2042(57.1)	1535(42.9)	1	—
Yes	678(52.1)	623(47.9)	1.22(1.08,1.39)**	—
The main source to gain HIV-related knowledge- Bulletin board				
No	2396(57.1)	1799(42.9)	1	—
Yes	324(47.4)	359(52.6)	1.48(1.25,1.74)**	—
The main source to gain HIV-related knowledge- Internet				
No	859(53.8)	737(46.2)	1	—
Yes	1861(56.7)	1421(43.3)	0.89(0.79,1.00)	—
The main source to gain HIV-related knowledge -School education				
No	2541(55.9)	2004(44.1)	1	1
Yes	179(53.8)	154(46.2)	1.09(0.87,1.36)	0.83(0.69,1.01)

Note: "*", p<0.05; "**", p<0.01; OR, Odds ratio; AOR, adjusted odds ratio; ONS, one night stand; STD, sexually transmitted disease.

Discussion

The HIV testing rates within lifetime and the past year were significantly higher among app-

using MSM than non-app using MSM. Particularly, app-using MSM were more likely to take an HIV test at CDC and CBO, and take a self-testing than non-app-using MSM, while less likely to take a test at gay venues. Gay app use was significantly associated with higher odds of lifetime HIV testing. As there were very few studies addressed the difference in choice of HIV testing approaches between app-using MSM and non-app-using MSM, this study provided significant implication for future HIV testing expanding strategies.

Our result showed that the prevalence of lifetime HIV testing among MSM in Shenzhen (58.2%) was comparable to that reported from other areas (60.3% ~63.1%) in China.[13 14] Specifically, app-using MSM had a relatively higher prevalence of lifetime HIV testing than non-app-using MSM (70.2% vs. 52.6%), similar to an online study from China (69.7% vs.55.5%).[7] The prevalence of lifetime testing among app-using MSM in this study was, however, lower than online studies from the US (83.2%-90%).[6 15] Previous research has demonstrated that some gay apps were utilized to link MSM to HIV testing promotion.[15 16] For instance, *Blued,* the most popular gay app in China, uses an "AIDS" ribbon to provide monthly banners on HIV testing, and suggests its users the nearest medical and testing facilities.[17] Secondly, as our result found non-app-using MSM had a relatively lower level of HIV-related knowledge and HIV risk perception, they may be less likely to take an HIV test than app-using MSM.

For the preference of HIV testing approaches, both app-using MSM and non-app using MSM mainly chose to take an HIV test at CDC, CBO, whereas less often at hospital. Standard public health approaches at public health agencies such as CDC, are always the

mainstay of HIV/ STD services in China.[18] However, our results showed testing in hospital was less common among both app-using MSM and non-app-using MSM, compared to the two main approaches. Literature data also implied the uptake of HIV testing was usually low in a clinical setting.[19] Due to the stigma and confidential concerns, Chinese MSM are very wary of taking HIV test at hospitals. While, engagement of CBO in sexual health prevention may bring about positive social norms to HIV testing and reduce the stigma concerns of MSM.[20 21] Other research showed CBO-based testing was a cost-effective approach to reach population who had low access to clinic-based HIV testing,[22] and it would be worthwhile for testing expansion and other intervention development and delivery in China.[23] Thus, continued efforts of CBOs in promoting HIV testing may further increase the uptake of testing among Chinese MSM.

Testing at gay venues generally was less frequent than the other three main approaches in this study. First, it could be explained by the limited coverage of HIV prevention outreach, as we found only 64% of the MSM in this study had received the HIV-related service. The current outreach-based HIV services in Shenzhen including HIV testing and counseling, free distribution of condoms and lubricants and STD diagnosis and treatment, were provided by the local public health agencies (CDC) with limited resources (budget and HIV care professionals) [24]. Secondly, literature documented that MSM were less willing to choose venue-based rapid testing than CBO-based testing among those non-clinical testing sites, due to the concerns about the quality, cleanliness, and professionalism.[10] Recent studies also suggested testing at gay venues such as saunas and gay bars was not acceptable among

Chinese MSM, unless the test was guaranteed with confidentiality, quality and quick results.[25 26] Although app-using MSM showed higher testing rates for the three main testing approaches than non-app-using MSM, they were less likely to get tested at gay venues. As non-app-using MSM were more often to patronize gay venues for sex seeking than app-using MSM, they were more likely to receive the offline-based HIV-related service (69.6% vs. 30.4%) that routinely delivered at gay venues (e.g., bars, massage centers and saunas). This finding indicated that app-using MSM currently were not well reached by traditional HIV prevention and intervention programs. Thus, innovative intervention strategies are greatly needed for this subpopulation. Besides, future improvement regarding concerns about venue-based rapid testing as well as increased HIV-related resource is warranted to remove the barrier to higher uptake of HIV test at gay venues.

The rate of self-testing was much lower than that of other main testing approaches in general. Although self-testing kits are now widely accessible in China since first approved in 2008, only 6.1% to 26.2% of MSM have ever chosen this new approach.[13 27 28] Compared with non-app-using MSM, app-using MSM showed a higher self-testing rate. A prior study found that the most common means of obtaining self-testing kit in China was the internet, then followed by CBOs, pharmacies and other offline means.[13] Interestingly, there was an increasing trend of self-testing among non-app-using MSM in our study period. The underlying reason may be the scaling up campaign of self-testing in recent years in China, which increased the accessibility of self-testing kit among offline social networking MSM as well.[29] Self-testing provides an anonymous and confidential way of HIV testing for MSM,

and could better reach high-risk MSM. Our findings demonstrated that there was a large capacity to reach untested MSM via self-testing, especially for those non-app-using MSM who were hard-to-reach. Promotion of self-testing would be an alternative approach to increase the HIV testing coverage among Chinese MSM.

Our study found that MSM who had higher education level, recruited through clinic-based methods, self-identified as homosexuality, practiced receptive sexual role during anal sex, engaged in group sex, used gay-app, and had previous diagnosis of other STD had higher odds of HIV testing in the past year. Additionally, older age, multiple sexual partners, previous diagnosis of other STD were associated with higher chance of lifetime HIV testing. These findings were aligned with the literature that found age, education level, history of other STD, sexual orientation and high-risk sexual behaviours (e.g., multiple male sexual partners and unprotected sexual intercourse) were associated with HIV testing.[30 31] Other studies found app use, HIV negative serostatus and recent unprotected anal intercourse were positively associated with HIV testing within lifetime and the past year.[7 15] Besides, our study found some other factors such as access to offline-based HIV-related service in the past year, having higher HIV-related knowledge and HIV risk perception were significantly associated with HIV testing within the past year, consistent with another Chinese study.[14] These findings highlighted the need for strengthened public health efforts in HIV prevention and interventions to increase the uptake of HIV testing among MSM.

There are several limitations of this study need to be noted. Firstly, there were relatively fewer samples collected from 2016 than the other two years, yet, we have adjusted the

confounding effect of sampling year in the multivariate analysis. Secondly, this study just included eight types of gay apps, whereas some new gay apps may emerge in the study period. As *Blued* accounted for about 97% of all app used, newly emerged apps may have very limited impact on results. Thirdly, this is a cross-sectional study which makes it difficult to establish a causal relationship, future longitudinal study would be desirable to evaluate the change of testing behavior over time. In addition, there might be recall bias and social desirable bias regarding self-reported information, especially sensitive personal behaviours. Lastly, our results may not be generalizable to MSM in other areas, caution is required for appropriate interpretation.

In conclusion, there is still a significant gap in the coverage of HIV testing among MSM in Shenzhen, China. It is imperative to expand HIV testing coverage among key population for scale-up treatment, especially those non-app-using MSM. Smartphone-based gay apps may have considerable potential for increasing HIV testing uptake among MSM otherwise not reachable by traditional outreach. Continued efforts in promoting HIV testing, increased resources of HIV services and innovative strategies are highly needed to achieve the first "90" target by 2020.

Contributors JC and JZ conceived the work. JZ, JC and LL designed the study. LW conducted all data analysis and drafted the manuscript. LC, HZ, SL, WT and WX ran the field investigations, participated in data collection and management. LW, HZ, ZY and JZ contributed to the writing and data interpretation. WT and WX performed the experiments. LW, LC, ZY, JZ, JC and LL reviewed and edited the manuscript. All authors have seen and approved the final version of the manuscript for publication.

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Competing interests None declared.

Table 1 Demographics of app-using and non-app-using MSM

Table 2 HIV testing related behaviours between app-using and non-app-using MSM

Table 3 Factors associated with HIV testing in the past year among MSM

Supplemental table. Factors associated with HIV testing within lifetime among MSM

Figure 1 HIV testing approaches of app-using and non-app-using MSM in Shenzhen, China, 2015-2017

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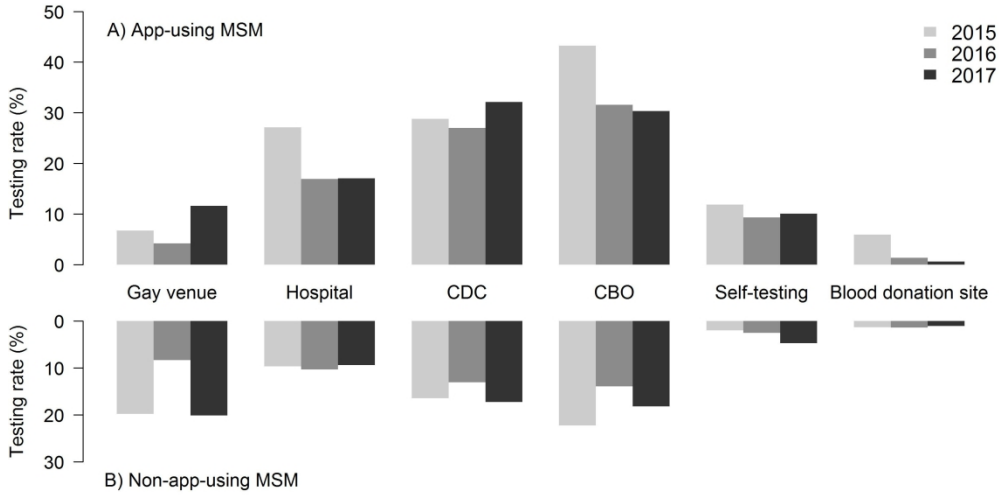

HIV testing approaches of app-using and non-app-using MSM in Shenzhen, China, 2015-2017

270x177mm (300 x 300 DPI)

Supplemental table. Factors associated with HIV testing within lifetime among MSM

Variables	Never tested (N=2061), N (%)	Ever tested (N=2872), N (%)	OR (95%CI)	AOR (95%CI)
Age				
<25	1026(57.8)	750(42.2)	1	1
25~40	745(33.6)	1471(66.4)	2.7(2.37,3.08)**	1.45(1.17,1.81)**
>40	289(30.7)	651(69.3)	3.08(2.61,3.64)**	1.43(1.09,1.88)*
Residence in Shenzhen				
<1 year	545(46.9)	616(53.1)	1	—
⩾1 year	1413(40.6)	2066(59.4)	1.29(1.13,1.48)**	—
Ethnicity				
Han	2006(42.2)	2753(57.8)	1	—
Other	44(37.0)	75(63.0)	1.24(0.85,1.81)	—
Education				
Junior high school or less	394(50.3)	389(49.7)	1	1
Senior high school	923(53.5)	802(46.5)	0.88(0.74,1.04)	0.97(0.75,1.26)
College or above	744(30.7)	1681(69.3)	2.29(1.94,2.70)**	1.64(1.26,2.14)**
Monthly income				
<3000	142(44.7)	176(55.3)	1	
3000~7000	1543(47.3)	1716(52.7)	0.9(0.71,1.13)	—
>7000	376(27.7)	980(72.3)	2.1(1.64,2.70)**	—
Marital status				
Single	1911(42.7)	2563(57.3)	1	
Married	150(32.7)	309(67.3)	1.54(1.25,1.88)**	—
Year of sample				
2015	565(41.2)	806(58.8)	1	
2016	771(50.9)	744(49.1)	0.68(0.58,0.78)**	—
2017	725(35.4)	1322(64.6)	1.28(1.11,1.47)**	—
Type of MSM				
NcMSM	1170(32.4)	2442(67.6)	1	
MB	891(67.4)	430(32.6)	0.23(0.20,0.26)**	0.29(0.22,0.39)**
Source of sample				
Venue based	1275(52.4)	1160(47.6)	1	1
Clinic based	786(31.5)	1712(68.5)	2.39(2.13,2.69)**	1.68(1.35,2.10)**
Self-identified as homosexuality				
No	597(45.2)	725(54.8)	1	1
Yes	1464(40.5)	2147(59.5)	1.21(1.06,1.37)**	1.52(1.25,1.83)**
Receptive sexual role				
No	1306(40.1)	1948(59.9)	1	1
Yes	755(45.0)	924(55.0)	0.82(0.73,0.92)**	0.77(0.64,0.92)**

In a relationship				
No	175(32.1)	371(67.9)	1	—
Yes	291(30.3)	669(69.7)	1.08(0.86,1.36)	—
No. of sexual partners in the past 6 months				
0	763(55.3)	616(44.7)	1	1
1~5	930(31.5)	2022(68.5)	2.69(2.36,3.07)**	1.40(1.14,1.72)**
>5	368(61.1)	234(38.9)	0.79(0.65,0.96)*	0.70(0.50,0.99)*
Engaged in ONS in the past 6 months				
No	755(50.2)	750(49.8)	1	1
Yes	664(40.6)	971(59.4)	1.47(1.28,1.70)**	1.13(0.93,1.37)
Engaged in group sex in past 6 months				
No	1350(46.8)	1533(53.2)	1	1
Yes	69(26.7)	189(73.3)	2.41(1.81,3.21)**	1.45(1.04,2.03)*
Engaged in commercial service in the past 6 months				
No	1339(45.5)	1603(54.5)	1	—
Yes	76(39.0)	119(61.0)	1.31(0.97,1.76)	—
Condom use of anal sex in the past 6 months				
No	513(34.4)	978(65.6)	1	—
Yes	785(38.1)	1278(61.9)	0.85(0.74,0.98)*	—
Recreational drug use				
No	1362(47.4)	1511(52.6)	1	—
Yes	699(33.9)	1361(66.1)	1.76(1.56,1.98)**	—
Received offline-based HIV-related service in the past year				
No	1102(62.1)	672(37.9)	1	1
Yes	959(30.4)	2200(69.6)	3.76(3.33,4.25)**	6.22(5.11,7.57)**
Gay app use				
No	1587(47.4)	1758(52.6)	1	1
Yes	474(29.8)	1114(70.2)	2.12(1.87,2.41)**	1.72(1.37,2.16)**
HIV-related knowledge				
Low to medium	619(44.3)	778(55.7)	1	
High	1442(40.8)	2094(59.2)	1.16(1.02,1.31)*	1.42(1.16,1.73)**
Previous diagnosis of other STD				
No	1938(42.6)	2609(57.4)	1	
Yes	123(31.9)	263(68.1)	1.59(1.27,1.98)**	1.46(1.05,2.03)*
HIV serostatus				
Negative	1837(41.6)	2580(58.4)	1	
Positive	224(43.4)	292(56.6)	0.93(0.77,1.12)	0.65(0.49,0.85)**
Syphilis serostatus				
Negative	1885(42.8)	2515(57.2)	1	
Positive	176(33.0)	357(67.0)	1.52(1.26,1.84)**	1.09(0.81,1.47)
Perception of being infected by HIV				
No or little chance	2043(42.0)	2817(58.0)	1	1

Rather big chance	18(24.7)	55(75.3)	2.22(1.30,3.79)**	3.92(1.60,9.63)**
The main source to gain HIV-related knowledge- TV				
No	1208(41.9)	1674(58.1)	1	—
Yes	842(42.2)	1154(57.8)	0.99(0.88,1.11)	—
The main source to gain HIV-related knowledge- Radio				
No	1900(42.6)	2563(57.4)	1	—
Yes	150(36.1)	265(63.9)	1.31(1.06,1.62)*	—
The main source to gain HIV-related knowledge- Newspaper				
No	1687(41.8)	2348(58.2)	1	—
Yes	363(43.1)	480(56.9)	0.95(0.82,1.11)	—
The main source to gain HIV-related knowledge- Books				
No	1711(43.6)	2212(56.4)	1	—
Yes	339(35.5)	616(64.5)	1.41(1.21,1.63)**	—
The main source to gain HIV-related knowledge- Friends				
No	1732(43.1)	2289(56.9)	1	—
Yes	318(37.1)	539(62.9)	1.28(1.10,1.49)**	—
The main source to gain HIV-related knowledge- Doctors				
No	1901(43.0)	2520(57.0)	1	—
Yes	149(32.6)	308(67.4)	1.56(1.27,1.91)**	—
The main source to gain HIV-related knowledge- Consultation service				
No	1983(43.1)	2618(56.9)	1	1
Yes	67(24.2)	210(75.8)	2.37(1.79,3.14)**	1.77(1.16,2.70)**
The main source to gain HIV-related knowledge- Free promotional materials				
No	1542(43.1)	2035(56.9)	1	1
Yes	508(39.0)	793(61.0)	1.18(1.04,1.35)*	0.74(0.60,0.91)**
The main source to gain HIV-related knowledge- Bulletin board				
No	1837(43.8)	2358(56.2)	1	1
Yes	213(31.2)	470(68.8)	1.72(1.45,2.04)**	1.25(0.94,1.65)
The main source to gain HIV-related knowledge- Internet				
No	684(42.9)	912(57.1)	1	1
Yes	1366(41.6)	1916(58.4)	1.05(0.93,1.19)	0.84(0.69,1.03)
The main source to gain HIV-related knowledge- School education				
No	1924(42.3)	2621(57.7)	1	—
Yes	126(37.8)	207(62.2)	1.21(0.96,1.52)	—

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	*na*
Study size	10	Explain how the study size was arrived at	8-9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	na
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	na
		(*e*) Describe any sensitivity analyses	na
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6,8
		(b) Give reasons for non-participation at each stage	na
		(c) Consider use of a flow diagram	na
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-10
		(b) Indicate number of participants with missing data for each variable of interest	na
Outcome data	15*	Report numbers of outcome events or summary measures	8-9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12-17
		(*b*) Report category boundaries when continuous variables were categorized	9,15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	na
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14
Discussion			
Key results	18	Summarise key results with reference to study objectives	18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	22
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18-22
Generalisability	21	Discuss the generalisability (external validity) of the study results	22
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	23

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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The relationship between gay app use and HIV testing among men who have sex with men in Shenzhen, China: a serial cross-sectional study

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The relationship between gay app use and HIV testing among men who have sex with men in Shenzhen, China: a serial cross-sectional study

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Word counts 3413

Abstract

Objectives To investigate the relationship between gay app use and HIV testing among men who have sex with men (MSM).

Design Serial cross-sectional study

Setting A newly well-developed city in China

Participants 4935 MSM were recruited through offline sampling methods from 2015 to 2017.

Primary and secondary outcomes The primary outcome is the difference in HIV testing between app and non-app users.

Results 2872 (58.2%) and 2159 (43.7%) participated MSM had been tested for HIV within lifetime and the past year, respectively. Compared with non-app-using MSM, app-using MSM had a significantly higher prevalence of HIV testing within lifetime (AOR: 1.48, 95%CI: 1.27, 1.72) and the past year (AOR: 1.36, 95%CI: 1.18, 1.57). App-using MSM were more likely to take an HIV test at the Center for Disease Control and Prevention (AOR: 1.48, 95%CI: 1.24, 1.76) and community-based organizations (AOR: 1.71, 95%CI: 1.44, 2.03), but less often at gay venues (AOR: 0.49, 95%CI: 0.37, 0.63). Meanwhile, app-using MSM were more likely to take self-testing (AOR: 1.61, 95%CI: 1.21, 2.14). Predictors of HIV testing in the past year were: having an education level of college or higher (AOR: 1.29, 95%CI: 1.01, 1.65), being self-identified as a homosexual (AOR: 1.23, 95%CI: 1.02, 1.46), being recruited through clinic-based sampling (AOR: 1.30, 95%CI: 1.06, 1.60), using gay app (AOR: 1.49, 95%CI: 1.21, 1.83), engaging in group sex (AOR: 1.64, 95%CI: 1.23, 2.19), having received

HIV-related service (AOR: 5.49, 95%CI: 4.57, 6.60), having a high level of HIV-related knowledge (AOR: 1.33, 95%CI: 1.10, 1.61) and high risk perception (AOR: 2.95, 95%CI: 1.40, 6.23).

Conclusions Gay app use was significantly associated with increased HIV testing among MSM hard-to-reach by traditional outreach. Therefore, it is imperative to expand HIV testing among non-app-using MSM. Continued efforts, innovative strategies and increased resource are highly needed to realize the first "90" target.

Strengths and limitations of this study

- This study represents one of the few studies that have compared HIV testing and the preference for testing approaches between app-using MSM and non-app-using MSM in developing countries, which has significant implication for future HIV testing expanding strategies.
- Different from most previous online surveys, this study adopted combined offline recruitment methods, providing complementary evidence on this topic.
- A causal relationship was not established because of the cross-sectional study design.
- The findings may not be generalized to the MSM in other areas or settings.

Introduction

HIV testing is an essential component of HIV prevention strategy linked to treatment and care. A lack of knowledge on HIV serostatus could disable or postpone the initiation of antiviral treatment. Moreover, the HIV screening among asymptomatic HIV carrier may directly reduce HIV transmission, based on the prior findings that those who are unaware of their seropositive status are 3.5 times more likely to transmit HIV than those who know their serostatus.[1] About 30% of people living with HIV globally who do not know their HIV status.[2] The first goal of the United Nation's 90–90–90 targets is that 90% of all people with HIV will get tested and know their status by 2020. However, the HIV testing rate in China is far from 90%. A recent meta-analysis reported that 47% of men who have sex with men (MSM) have been tested for HIV in China, despite the extensive combined efforts of government, public health agencies, and community-based organizations in recent years.[3] Owing to the stigma against homosexuality in China, MSM are less likely to take an HIV test in fear of the exposure of homosexual identity. Furthermore, there are several other barriers to HIV testing, such as name-based testing, low perception of risk, long asymptomatic phase, and a lack of awareness that testing is free of charge, posing significant challenges to HIV prevention and interventions among MSM in China.[4] Therefore, developing comprehensive strategies for the promotion of HIV testing among MSM is an urgent priority in China.

In recent years, gay app (geosocial networking application specific to MSM) has reformed significantly the sex-seeking and harm-reduction behaviours of MSM.[5] Studies on the association between gay app use and HIV testing behaviour are limited and inconclusive.

Some studies associated app use with increasing HIV testing either within lifetime or in the past year,[6 7] whereas others found no difference between app and non-users.[8] A recent systematic review found that app users are twice likely to test for HIV than non-app users within lifetime.[5] Another study revealed that social media use was positively associated with HIV testing in Chinese MSM.[9] Free HIV testing has been available in all provinces of China since 2006. Apart from the health facility-based testing service provided at hospitals/clinics and the Center for Disease Control and Prevention (CDC), there are also decentralized HIV testing services at peripheral health facilities including community-based organizations (CBO) and blood donation sites, and testing service at gay venues and self-testing at home.[10] As the uptake of HIV testing among MSM is still limited, a better understanding of the testing pattern and preferences among MSM is critical to inform strategies on expanding HIV testing. In addition, few studies exist regarding the impact of app use on the uptake and preference for HIV testing approach among MSM. Therefore, this study aimed to investigate the relationship between app use and HIV testing, and to identify the demographic and behavioral predictors of HIV testing among MSM in Shenzhen, China, where MSM accounted for the largest percentage (56.7%) of new infections in recent years.

Methods

Source of sample

From May 2015 to the end of 2017, eligible MSM were recruited through combined offline sampling methods, primarily venue-based method (time location sampling, TLS), and clinics based methods (respondent-driven sampling, RDS; voluntary counseling and testing center,

VCT). TLS recruited eligible participants at MSM venues based on a random selection strategy of venue-day-time. RDS started with the identification of initial "seeds" of MSM peers. These seeds were then offered with three coded coupons to recruit new peers, who, in turn, referred those they know and so on. Other participants who visited a VCT were also randomly recruited. More information on these methods can be found in the previous study.[11] The criteria for recruiting were 1) male, Chinese resident, aged 18 years or above; and 2) having had a homosexual contact six months prior to the survey in Shenzhen. Meanwhile, the eligibility criteria for male sex workers (also called money boy, MB) participants were: 1) male aged 18 years or older; 2) having lived in Shenzhen for more than one month at the time of survey; and 3) having sold sex (oral or anal) to another male in the previous month. Each participant was invited to complete an anonymous questionnaire via a handheld electronic tablet and provide a written informed consent. Then, they were required to take a confidential HIV and syphilis test at Shenzhen Center for Disease Control and Prevention, or a voluntary counseling and testing center. The protocol for recruitment was approved by the Medical Ethics Committee of Shenzhen Center for Disease Control and Prevention.

Behavioural measures

All data were collected through self-administered questionnaires with information on sociodemographic features, sexual behaviours, gay app use, recreational drug use, HIV testing, HIV-related services, HIV-related knowledge, previous diagnosis of sexually transmitted disease (STD) other than HIV and syphilis infections, source of HIV-related knowledge, HIV and syphilis serostatus and perception of HIV infection. The HIV-related

services included distribution of condom, lubricant, peer education, STI diagnosis or treatment, HIV counselling or testing, or AIDS/STI educational materials. A high level of HIV-related knowledge was defined as having correctly answered at least six of the nine questions, otherwise, it was deemed as low to medium level. HIV testing behaviours were evaluated in the following measures: 1) Have you ever taken an HIV test? 2) Have you taken an HIV test in the past year? 3) Where did you receive an HIV test? (Test at gay venue/ hospital/ CDC/ blood donation site/ CBO/ at home with self-testing kit). The main source of HIV-related knowledge was listed as TV, radio, newspaper, books, friends, doctors, consultation service, free promotional materials, bulletin board, internet and school education. The behavioural measures presented in the questionnaire were developed according to the national sentinel surveillance survey for HIV/AIDS and previously verified questionnaires.[12]

HIV and syphilis testing

HIV and syphilis testing were performed according to the standard procedures established by the laboratory of the Shenzhen Center for Disease Control and Prevention. HIV was tested using a rapid test (Determine HIV-1/2/O; Abbott Laboratories, IL) and enzyme-linked immunosorbent assay (Wantai Biotech Inc, Beijing, China) for screening, with the positive test confirmed by Western Blot (Genlabs Diagnostics, Singapore). Syphilis was tested with rapid plasma regain method (Rongsheng Biotech Inc, Shanghai, China) for qualitative screening, with the positive test confirmed by Treponema pallidum particle agglutination assay (Fujirebio Inc, Japan).

Patients and public involvement

Patients or the public were not involved in the design or planning of the study.

Data availability statement

No additional data available

Statistical analysis

The sociodemographic features and HIV testing related behaviours were compared between app-using MSM and non-app-using MSM, with categorical variables compared using the *chi-squared test* or *Fisher's exact test*. Univariate and multivariate logistic regressions adjusted for confounders (e.g., age, education, marital status, year of survey, etc.) were performed to examine the correlates between app use and testing-related behaviours. To identify the significant predictors of HIV testing within the past year and lifetime, variables with a P value <0.10 in the univariate logistic regression models and theoretically important covariates were included for step-wise selection in multivariate regression models. The covariates with a P value <0.05 were kept in the final model via manual step-wise selection. Adjusted odds ratios (AOR) and 95% confidence intervals (CIs) were presented. All statistical analyses were performed in R (version 3.4.3, Foundation for Statistical Computing, Vienna, Austria).

Results

Among the 4935 participants recruited from 2015 to 2017, 1588 (32.2%) MSM had used at least one kind of gay app, including 1496 non-commercial MSM and 92 MBs. The demographic characteristics of all recruited MSM are summarized in Table 1. Compared with non-app-using MSM, app-using MSM were younger (28.3 vs. 28.8 years), more likely to be unmarried (92.0% vs. 90.1%), having an education level of college or above (64.0% vs.

42.1%), and having a monthly income higher than 7000 RMB (34.1% vs. 24.3%). There was no significant difference in ethnicity and duration of residence in Shenzhen between the two groups. There was higher percentage of app-using MSM recruited from clinics (69.6% vs. 41.6%) and in 2017 (56.9% vs.34.2%) than that of non-app-using MSM. The prevalence of HIV and syphilis infection was not significantly different between the two groups. However, the prevalence of both HIV and syphilis was significantly higher among non-app-using non-commercial MSM (NcMSM), but not significant for MBs who were less likely to use app and be positive for HIV and syphilis (data not shown).

Table 1 Demographics of app-using and non-app-using MSM

	Non-app-using MSM (N=3347), N (%)	**App-using MSM (N=1588), N (%)**	**P value***
Age			
<25	1316(39.3)	461(29.0)	
25~40	1618(48.4)	1030(64.9)	<0.01
>40	412(12.3)	97(6.1)	
Age (median, IQR)	26 (23, 33)	27 (24, 31)	<0.05
Duration of residence in Shenzhen			
<1 year	802(25.5)	360(24.0)	0.299
≥1 year	2342(74.5)	1137(76.0)	
Ethnicity			
Han	3237(97.8)	1524(97.1)	0.215
Other	74(2.2)	45(2.9)	
Education			
Junior high school or less	637(19.0)	146(9.2)	
Senior high school	1301(38.9)	425(26.8)	<0.01
College or above	1409(42.1)	1017(64.0)	
Monthly income(RMB)			
<3000	196(5.9)	123(7.7)	
3000~7000	2337(69.8)	923(58.1)	<0.01
>7000	814(24.3)	542(34.1)	
Marital status			
Unmarried	3015(90.1)	1461(92.0)	<0.05
Married	332(9.9)	127(8.0)	

Year of sample			
2015	1254(37.5)	118(7.4)	
2016	949(28.4)	567(35.7)	<0.01
2017	1144(34.2)	903(56.9)	
Source of sample			
Venue based	1953(58.4)	483(30.4)	<0.01
Clinic based	1394(41.6)	1105(69.6)	
Type of MSM			
NcMSM	2117(63.3)	1496(94.2)	<0.01
MB	1230(36.7)	92(5.8)	
HIV			
Negative	3005(89.8)	1414(89.0)	0.458
Positive	342(10.2)	174(11.0)	
Syphilis			
Negative	2983(89.1)	1419(89.4)	0.844
Positive	364(10.9)	169(10.6)	
Previous diagnosis of other STDs			
No	3119(93.2)	1430(90.1)	<0.01
Yes	228(6.8)	158(9.9)	

Note: NcMSM, Non-commercial MSM; MB, Money boy (male sex worker); STD, sexually transmitted disease. * All P values in this column were derived from the comparison between non-app-using MSM and app-using MSM.

There were significant differences in testing-related behaviors between app-using and non-app-using MSM in this study (Table 2). About 58.2% and 43.7% of MSM had been tested for HIV within lifetime and the past year, respectively, in Shenzhen. App-using MSM had significantly higher prevalence of HIV testing within lifetime (70.2% vs.52.6%) and the past year (52.0% vs. 39.8%) than non-app-using MSM. After controlling for age, education, monthly income, marital status, year of sampling, source of sample, and type of MSM, MSM who used gay app had significant higher odds of lifetime HIV test (AOR: 1.48, 95%CI: 1.27, 1.72) and HIV test in the past year (AOR: 1.36, 95%CI: 1.18, 1.57) than those who did not. App-using-MSM more commonly know their HIV testing results (AOR: 1.72, 95%CI: 1.16, 2.54) and their last negative result within the past year (AOR: 1.29, 95%CI: 1.09, 1.53).

Generally, app-using MSM had higher risk perception of HIV infection than non-app-using MSM (AOR: 1.43, 95%CI: 1.00, 2.06). For HIV testing approaches, app-using MSM were more likely to have taken an HIV test at a local CDC (AOR: 1.48, 95%CI: 1.24, 1.76) or CBO (AOR: 1.71, 95%CI: 1.44, 2.03) and self-testing (AOR: 1.61, 95%CI: 1.21, 2.14). However, they were less likely to have taken an HIV test at gay venues (AOR: 0.49, 95%CI: 0.37, 0.63). There were no significant differences between the two groups for the choices of testing at hospitals and blood donation sites. Moreover, the choices of HIV testing approach by year was compared between the two groups in Figure 1. From 2015 to 2017, the proportion of app-using MSM taking an HIV test at CDC increased, whereas testing at hospitals, CBOs and blood donation sites declined. Notably, there was an increasing rate of self-testing among non-app-using MSM, although the main choices were testing at gay venue, CDC and CBO. Compared with non-app-using MSM, app-using MSM were more likely to gain HIV-related knowledge from the internet (AOR: 3.07, 95%CI: 2.58, 3.67), books (AOR: 2.04, 95%CI: 1.72, 2.42), doctors (AOR: 1.27, 95%CI: 1.00, 1.61), free promotional materials (AOR: 1.76, 95%CI: 1.51, 2.07), and bulletin board (AOR: 1.81, 95%CI: 1.50, 2.19), but less likely from TV (AOR: 0.68, 95%CI: 0.59, 0.78). For the other source such as radio, newspaper, friends, consultancy service, and school education, there was no significant difference between the two groups.

Table 2 HIV testing related behaviors between app-using and non-app-using MSM

All	**Non-app-using MSM (N=3347), N (%)**	**App-using MSM (N=1588), N (%)**	**OR (95%CI)**	**AOR (95%CI)**
Ever tested for HIV				

No	1587(47.4)	474(29.8)	1	1
Yes	1758(52.6)	1114(70.2)	2.12(1.87,2.41)**	1.48(1.27,1.72)**
HIV test in the past year				
0	2014(60.2)	762(48.0)	1	1
1	1333(39.8)	826(52.0)	1.64(1.45,1.85)**	1.36(1.18,1.57)**
Did you know your testing results?				
Not every time	125(7.1)	42(3.8)	1	1
Yes	1635(92.9)	1072(96.2)	1.95(1.36,2.79)**	1.72(1.16,2.54)**
Last HIV negative result				
Over one year ago	922(53.0)	529(47.9)	1	1
Within the past year	818(47.0)	576(52.1)	1.23(1.06,1.43)**	1.29(1.09,1.53)**
Perception of being infected by HIV				
No or little chance	3263(97.5)	1513(95.3)	1	1
Rather big chance	84(2.5)	75(4.7)	1.93(1.40,2.64)**	1.43(1.00,2.06)*
Where did you receive HIV testing?- Gay venue				
No	1203(68.4)	977(87.7)	1	1
Yes	557(31.6)	137(12.3)	0.30(0.25,0.37)**	0.49(0.37,0.63)**
Where did you receive HIV testing?-Hospital				
No	1434(81.5)	832(74.7)	1	1
Yes	326(18.5)	282(25.3)	1.49(1.24,1.78)**	1.18(0.96,1.44)
Where did you receive HIV testing?- CDC				
No	1233(70.1)	637(57.2)	1	1
Yes	527(29.9)	477(42.8)	1.75(1.50,2.05)**	1.48(1.24,1.76)**
Where did you receive HIV testing?- Blood donation site				
No	1719(97.7)	1093(98.1)	1	1
Yes	41(2.3)	21(1.9)	0.81(0.47,1.37)	0.91(0.51,1.64)
Where did you receive HIV testing?- CBO				
No	1141(64.8)	610(54.8)	1	1
Yes	619(35.2)	504(45.2)	1.52(1.31,1.78)**	1.71(1.44,2.03)**
Where did you receive HIV testing?- Self-testing				
No	1657(94.1)	956(85.8)	1	1
Yes	103(5.9)	158(14.2)	2.66(2.05,3.45)**	1.61(1.21,2.14)**
The main source to gain HIV-related knowledge- TV				
No	1805(54.5)	1077(68.6)	1	1
Yes	1504(45.5)	492(31.4)	0.55(0.48,0.62)**	0.68(0.59,0.78)**
The main source to gain HIV-related knowledge- Radio				
No	3028(91.5)	1435(91.5)	1	1
Yes	281(8.5)	134(8.5)	1.01(0.81,1.25)	0.93(0.73,1.19)

The main source to gain HIV-related knowledge- Newspaper				
No	2757(83.3)	1278(81.5)	1	1
Yes	552(16.7)	291(18.5)	1.14(0.97,1.33)	1.10(0.92,1.31)
The main source to gain HIV-related knowledge- Books				
No	2788(84.3)	1135(72.3)	1	1
Yes	521(15.7)	434(27.7)	2.05(1.77,2.37)**	2.04(1.72,2.42)**
The main source to gain HIV-related knowledge- Friends				
No	2764(83.5)	1257(80.1)	1	1
Yes	545(16.5)	312(19.9)	1.26(1.08,1.47)**	0.92(0.77,1.09)
The main source to gain HIV-related knowledge- Doctors				
No	3016(91.1)	1405(89.5)	1	1
Yes	293(8.9)	164(10.5)	1.20(0.98,1.47)	1.27(1.00,1.61)*
The main source to gain HIV-related knowledge- Consultation service				
No	3125(94.4)	1476(94.1)	1	1
Yes	184(5.6)	93(5.9)	1.07(0.83,1.38)	0.80(0.60,1.07)
The main source to gain HIV-related knowledge- Free promotional materials				
No	2508(75.8)	1069(68.1)	1	1
Yes	801(24.2)	500(31.9)	1.46(1.28,1.67)**	1.76(1.51,2.07)**
The main source to gain HIV-related knowledge- Bulletin board				
No	2960(89.5)	1235(78.7)	1	1
Yes	349(10.5)	334(21.3)	2.29(1.95,2.70)**	1.81(1.50,2.19)**
The main source to gain HIV-related knowledge- Internet				
No	1370(41.4)	226(14.4)	1	1
Yes	1939(58.6)	1343(85.6)	4.20(3.59,4.91)**	3.07(2.58,3.67)**
The main source to gain HIV-related knowledge- School education				
No	3137(94.8)	1408(89.7)	1	1
Yes	172(5.2)	161(10.3)	2.09(1.67,2.61)**	0.98(0.76,1.26)

Note: "*", p<0.05; "**", p<0.01; OR, Odds ratio; AOR, adjusted odds ratio after controlling for age, education, monthly income, marital status, year of sample, source of sample, and type of MSM. CDC, center for disease control and prevention; CBO, community based organization.

Based on univariate analysis and manual step-wise selection, the final multivariate model was constructed with covariates including year of sampling, source of sample, type of MSM, education level, self-identified sexual identity, sexual role, group sex, app use, HIV-related knowledge and service, previous diagnosis of other STI, risk perception of HIV infection, and current HIV and syphilis serostatus (Table 3). Multivariate regression results showed the following were factors associated with higher odds of HIV testing in the past year

(Table 3): having an education level of college or higher (AOR: 1.29, 95%CI: 1.01, 1.65), being recruited through clinic-based sampling methods (AOR: 1.30, 95%CI: 1.06, 1.60), being self-identified as homosexuality (AOR: 1.23, 95%CI: 1.02, 1.46), engaging in group sex (AOR: 1.64, 95%CI: 1.23, 2.19) in the past six months, using gay apps (AOR: 1.49, 95%CI: 1.21, 1.83), having received offline-based AIDS-related service in the past year (AOR: 5.49, 95%CI: 4.57, 6.60), having a high level of HIV- related knowledge (AOR: 1.33, 95%CI: 1.10, 1.61), and having high risk perception of HIV infection (AOR: 2.95, 95%CI: 1.40, 6.23). Meanwhile, MSM who were recruited in 2016 (AOR: 0.54, 95%CI: 0.45, 0.65) and 2017 (AOR: 0.66, 95%CI: 0.51, 0.86), being MB (AOR: 0.36, 95%CI: 0.28, 0.46), having reported a receptive sexual role during anal sex in the past six months (AOR: 0.76, 95%CI: 0.64, 0.90), and being HIV seropositive (AOR: 0.66, 95%CI: 0.51, 0.86) had significantly lower odds of HIV testing within the past year. We also performed a multivariate analysis to identify the determinants of HIV testing within lifetime, which showed similar results, except for additional predictors, such as older age, multiple sexual partners, previous diagnosis of other STD, and gaining HIV-related knowledge mainly from consultation services (Supplemental table).

Table 3 Factors associated with HIV testing in the past year among MSM

Variables	Not tested (N=2776), N (%)	Tested (N=2159), N (%)	OR (95%CI)	AOR (95%CI)
Age				
<25	1153(64.9)	624(35.1)	1	
25~40	1131(51.0)	1086(49.0)	1.77(1.56,2.01)**	—
>40	491(52.2)	449(47.8)	1.69(1.44,1.99)**	—
Residence in Shenzhen				
<1 year	674(58.0)	488(42.0)	1	—

⩾1 year	1928(55.4)	1551(44.6)	1.11(0.97,1.27)	—
Ethnicity				
Han	2659(55.8)	2102(44.2)	1	—
Other	62(52.1)	57(47.9)	1.16(0.81,1.67)	—
Education				
Junior high school or less	491(62.7)	292(37.3)	1	1
Senior high school	1103(63.9)	623(36.1)	0.95(0.80,1.13)	0.90(0.70,1.15)
College or above	1182(48.7)	1244(51.3)	1.77(1.50,2.09)**	1.29(1.01,1.65)*
Monthly income				
<3000	192(60.2)	127(39.8)	1	
3000~7000	1941(59.5)	1319(40.5)	1.03(0.81,1.30)	—
>7000	643(47.4)	713(52.6)	1.68(1.31,2.15)**	—
Marital status				
Single	2540(56.7)	1936(43.3)	1	—
Married	236(51.4)	223(48.6)	1.24(1.02,1.50)*	—
Year of sample				
2015	757(55.2)	615(44.8)	1	1
2016	972(64.1)	544(35.9)	0.69(0.59,0.80)**	0.54(0.45,0.65)**
2017	1047(51.1)	1000(48.9)	1.18(1.03,1.35)*	0.65(0.48,0.88)**
Type of MSM				
NcMSM	1501(61.6)	935(38.4)	1	
MB	1275(51.0)	1224(49.0)	1.54(1.38,1.73)**	0.36(0.28,0.46)**
Source of sample				
Venue based	1839(50.9)	1774(49.1)	1	1
Clinic based	937(70.9)	385(29.1)	0.43(0.37,0.49)**	1.30(1.06,1.60)*
Self-identified as a homosexual				
No	777(58.7)	546(41.3)	1	1
Yes	1999(55.3)	1613(44.7)	1.15(1.01,1.30)*	1.23(1.02,1.46)*
Receptive sexual role				
No	1764(54.2)	1490(45.8)	1	1
Yes	1012(60.2)	668(39.8)	0.78(0.69,0.88)**	0.76(0.64,0.90)**
In a relationship				
No	275(50.4)	271(49.6)	1	—
Yes	451(46.9)	510(53.1)	1.15(0.93,1.42)	—
No. of sexual partners in the past 6 months				
0	881(63.9)	498(36.1)	1	
1~5	1462(49.5)	1491(50.5)	1.8(1.58,2.06)**	—
>5	433(71.9)	169(28.1)	0.69(0.56,0.85)**	—
Engaged in ONS in the past 6 months				
No	927(61.6)	579(38.4)	1	—

Yes	918(56.1)	717(43.9)	1.25(1.08,1.44)**	—
Engaged in group sex in past 6 months				
No	1741(60.4)	1143(39.6)	1	1
Yes	104(40.3)	154(59.7)	2.26(1.74,2.93)**	1.64(1.23,2.19)**
Engaged in commercial service in past 6 months				
No	1736(59.0)	1207(41.0)	1	—
Yes	105(53.8)	90(46.2)	1.23(0.92,1.65)	—
Condom use of anal sex in the past 6 months				
No	786(52.7)	706(47.3)	1	—
Yes	1109(53.8)	954(46.2)	0.96(0.84,1.09)	—
Recreational drug use in the past year				
No	66(54.1)	56(45.9)	1	—
Yes	998(51.5)	941(48.5)	1.11(0.77,1.60)	—
Received offline-based HIV-related service in the past year				
No	1367(77.0)	408(23.0)	1	1
Yes	1409(44.6)	1751(55.4)	4.16(3.65,4.75)**	5.49(4.57,6.60)**
Gay app use				
No	2014(60.2)	1333(39.8)	1	1
Yes	762(48.0)	826(52.0)	1.64(1.45,1.85)**	1.49(1.21,1.83)**
HIV-related knowledge				
Low to medium	828(59.2)	571(40.8)	1	
High	1948(55.1)	1588(44.9)	1.18(1.04,1.34)**	1.33(1.10,1.61)**
Previous diagnosis of other STD				
No	2581(56.7)	1968(43.3)	1	—
Yes	195(50.5)	191(49.5)	1.28(1.04,1.58)*	—
HIV serostatus				
Negative	2461(55.7)	1958(44.3)	1	
Positive	315(61.0)	201(39.0)	0.80(0.67,0.97)*	0.66(0.51,0.86)**
Syphilis serostatus				
Negative	2489(56.5)	1913(43.5)	1	—
Positive	287(53.8)	246(46.2)	1.12(0.93,1.34)	—
Perception of HIV infection				
No or little chance	2744(56.4)	2118(43.6)	1	1
Rather big chance	32(43.8)	41(56.2)	1.66(1.04,2.65)*	2.95(1.40,6.23)**
The main source to gain HIV-related knowledge -TV				
No	1640(56.9)	1242(43.1)	1	—
Yes	1080(54.1)	916(45.9)	1.12(1.00,1.26)	—
The main source to gain HIV-related knowledge- Radio				
No	2508(56.2)	1955(43.8)	1	—
Yes	212(51.1)	203(48.9)	1.23(1.00,1.50)*	—
The main source to gain HIV-related knowledge- Newspaper				

No	2247(55.7)	1788(44.3)	1	—
Yes	473(56.1)	370(43.9)	0.98(0.85,1.14)	—
The main source to gain HIV-related knowledge- Books				
No	2238(57.0)	1685(43.0)	1	—
Yes	482(50.5)	473(49.5)	1.30(1.13,1.50)**	—
The main source to gain HIV-related knowledge- Friends				
No	2274(56.6)	1747(43.4)	1	—
Yes	446(52.0)	411(48.0)	1.20(1.04,1.39)*	—
The main source to gain HIV-related knowledge- Doctors				
No	2514(56.9)	1907(43.1)	1	—
Yes	206(45.1)	251(54.9)	1.61(1.32,1.95)**	—
The main source to gain HIV-related knowledge- Consultation service				
No	2614(56.8)	1987(43.2)	1	—
Yes	106(38.3)	171(61.7)	2.12(1.65,2.72)**	—
The main source to gain HIV-related knowledge- Free promotional materials				
No	2042(57.1)	1535(42.9)	1	—
Yes	678(52.1)	623(47.9)	1.22(1.08,1.39)**	—
The main source to gain HIV-related knowledge- Bulletin board				
No	2396(57.1)	1799(42.9)	1	—
Yes	324(47.4)	359(52.6)	1.48(1.25,1.74)**	—
The main source to gain HIV-related knowledge- Internet				
No	859(53.8)	737(46.2)	1	—
Yes	1861(56.7)	1421(43.3)	0.89(0.79,1.00)	—
The main source to gain HIV-related knowledge -School education				
No	2541(55.9)	2004(44.1)	1	1
Yes	179(53.8)	154(46.2)	1.09(0.87,1.36)	0.83(0.69,1.01)

Note: "*", p<0.05; "**", p<0.01; OR, Odds ratio; AOR, adjusted odds ratio; ONS, one night stand; STD, sexually transmitted disease.

Discussion

The HIV testing rates within lifetime and the past year were significantly higher among app-using than non-app using MSM. Particularly, app-using MSM were more likely to take an HIV test at CDC and CBO, and a self-testing than non-app-using MSM, but less likely to take a test at gay venues. Gay app use was significantly associated with higher odds of lifetime HIV testing. As there were few studies addressed the difference in choices of HIV testing

approaches between app-using and non-app-using MSM, this study provided significant implication for future HIV testing expanding strategies.

Our result showed that the prevalence of lifetime HIV testing among MSM in Shenzhen (58.2%) was comparable to that reported in other areas (60.3% ~63.1%) in China.[13 14] Specifically, app-using MSM had a relatively higher prevalence of lifetime HIV testing than non-app-using MSM (70.2% vs. 52.6%), which is similar to an online study from China (69.7% vs.55.5%).[7] The prevalence of lifetime testing among app-using MSM in this study was, however, lower than that in online studies from the United States (83.2%–90%).[6 15] Previous research has demonstrated that some gay apps were utilized to link MSM to HIV testing promotion.[15 16] For instance, *Blued,* the most popular gay app in China, uses an "AIDS" ribbon to provide monthly banners on HIV testing, and suggests its users the nearest medical and testing facilities.[17] Second, as our results found that non-app-using MSM had a relatively lower level of HIV-related knowledge and HIV risk perception, they may be less likely to take an HIV test than app-using MSM.

For the HIV testing approaches preference, both app-using and non-app using MSM mainly chose to take an HIV test at CDC and CBO, but less often at hospital. The standard public health approaches at public health agencies, such as CDC, are always the mainstay of HIV/ STD services in China.[18] However, our results showed that compared to the two main approaches, testing in hospitals was less common among both app-using and non-app-using MSM. The literature data also implied the uptake of HIV testing was usually low in a clinical setting.[19] Owing to the stigma and confidential concerns, Chinese MSM are very wary of

taking an HIV test at hospitals. Meanwhile, engagement of CBO in sexual health prevention may bring about positive social norms to HIV testing and reduce the stigma concerns of MSM.[20 21] Other research showed that the CBO-based testing was a cost-effective approach to reach the population who have low access to clinic-based HIV testing,[22] and it would be worthwhile for testing expansion and other intervention development and delivery in China.[23] Therefore, continued efforts of CBOs in promoting HIV testing may further increase the uptake of testing among Chinese MSM.

Testing at gay venues generally was less frequent than the other three main approaches in this study. First, the limited coverage of HIV prevention outreach could explain this finding, as we found only 64% of the MSM in this study had received the HIV-related service. The current outreach-based HIV services in Shenzhen including HIV testing and counseling, free distribution of condoms and lubricants and STD diagnosis and treatment, were provided by the local public health agencies (CDC) with limited resources (budget and HIV care professionals) [24]. Second, the literature has documented that MSM were less willing to choose venue-based rapid testing than CBO-based testing among those non-clinical testing sites because of the concerns about quality, cleanliness, and professionalism.[10] Recent studies have also suggested that testing at gay venues, such as saunas and gay bars, was not acceptable among Chinese MSM, unless the test is guaranteed with confidentiality, quality, and quick results.[25 26] Although app-using MSM showed higher testing rates for the three main testing approaches than non-app-using MSM, they were less likely to get tested at gay venues. As non-app-using MSM more often patronize gay venues to seek sexual partner than

app-using MSM do, they were more likely to receive the offline-based HIV-related service (69.6% vs. 30.4%) that is routinely delivered at gay venues (e.g., bars, massage centers, and saunas). This finding indicates that app-using MSM currently are currently not well-reached by traditional HIV prevention and intervention programs. Thus, innovative intervention strategies are greatly needed for this subpopulation. Besides, future improvement regarding concerns about venue-based rapid testing and increasing HIV-related resource are warranted to remove the barrier to higher uptake of HIV test at gay venues.

The rate of self-testing was much lower than that of other main testing approaches. Although self-testing kits have been widely accessible in China since its distribution was approved in 2008, only 6.1% to 26.2% of MSM have ever chosen this new approach.[13 27 28] Compared with non-app-using MSM, app-using MSM showed a higher self-testing rate. A prior study found that the most common means of obtaining self-testing kit in China was the internet, followed by CBOs, pharmacies and other offline means.[13] Interestingly, there was an increasing trend in self-testing among non-app-using MSM in our study period. The underlying reason may be the scaling up campaign of self-testing in recent years in China, which increases the accessibility of self-testing kit among offline social networking MSM.[29] Self-testing provides an anonymous and confidential way of HIV testing for MSM, and could better reach high-risk MSM. Our findings demonstrate that there is a large capacity to reach untested MSM via self-testing, especially for those non-app-using MSM who are hard-to-reach. Therefore, promotion of self-testing would be an alternative approach to increase the HIV testing coverage among Chinese MSM.

Our study found that MSM who were self-identified as homosexuality, had higher education level, recruited through clinic-based methods, practiced receptive sexual role during anal sex, engaged in group sex, used any gay app, and had previous diagnosis of other STD had higher odds of HIV testing in the past year. Additionally, older age, multiple sexual partners, and previous diagnosis of other STD were associated with higher chance of lifetime HIV testing. These findings were aligned with the literature that associated age, education level, history of other STD, sexual orientation, and high-risk sexual behaviours (e.g., multiple male sexual partners and unprotected sexual intercourse) with HIV testing.[30 31] Other studies found that app use, HIV negative serostatus, and recent unprotected anal intercourse were positively associated with HIV testing within lifetime and the past year.[7 15] Our study also found some other factors, such as access to offline-based HIV-related service in the past year, having a high level of HIV-related knowledge, and high HIV risk perception were significantly associated with HIV testing within the past year, which is consistent with another Chinese study.[14] These findings highlighted the need for strengthened public health efforts in HIV prevention and interventions to increase the uptake of HIV testing among MSM.

There are several limitations of this study need to be noted. Firstly, relatively fewer samples were collected in 2016 than in the other two years; therefore, we have adjusted the confounding effect of sampling year in the multivariate analysis. Secondly, this study included eight types of gay apps; some new gay apps may emerge in the study period. As *Blued* accounted for about 97% of all app used in this study, newly emerged apps may have

limited impact on the results. Thirdly, as this is a cross-sectional study, we are unable to establish a causal relationship; future longitudinal study would be desirable to evaluate the change of testing behavior over time. In addition, there might be recall bias and socially desirable bias regarding self-reported information, especially sensitive personal behaviours. Lastly, our results may not be generalized to MSM in other areas, caution is required for appropriate interpretation.

In conclusion, there is still a significant gap in the coverage of HIV testing among MSM in Shenzhen, China. It is imperative to expand HIV testing coverage among key population for scale-up treatment, especially among the non-app-using MSM. Smartphone-based gay apps may have considerable potential for increasing HIV testing uptake among the MSM who are otherwise not reachable by traditional outreach. Continued efforts in promoting HIV testing, increased resources of HIV services, and innovative strategies are highly needed to achieve the first "90" target by 2020.

Contributors JC and JZ conceived the work. JZ, JC and LL designed the study. LW conducted all data analysis and drafted the manuscript. LC, HZ, SL, WT and WX ran the field investigations, participated in data collection and management. LW, HZ, ZY and JZ contributed to the writing and data interpretation. WT and WX performed the experiments. LW, LC, ZY, JZ, JC and LL reviewed and edited the manuscript. All authors have seen and approved the final version of the manuscript for publication.

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Competing interests None declared.

Table 1 Demographics of app-using and non-app-using MSM

Table 2 HIV testing related behaviours between app-using and non-app-using MSM

Table 3 Factors associated with HIV testing in the past year among MSM

Supplemental table. Factors associated with HIV testing within lifetime among MSM

Figure 1 HIV testing approaches of app-using and non-app-using MSM in Shenzhen, China, 2015-2017

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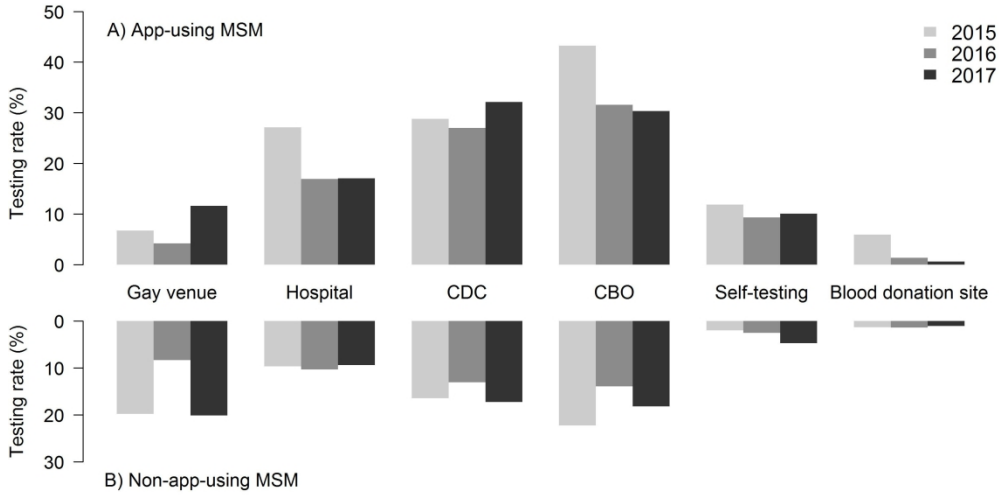

HIV testing approaches of app-using and non-app-using MSM in Shenzhen, China, 2015-2017

270x177mm (300 x 300 DPI)

Supplemental table. Factors associated with HIV testing within lifetime among MSM

Variables	Never tested (N=2061), N (%)	Ever tested (N=2872), N (%)	OR (95%CI)	AOR (95%CI)
Age				
<25	1026(57.8)	750(42.2)	1	1
25~40	745(33.6)	1471(66.4)	2.7(2.37,3.08)**	1.45(1.17,1.81)**
>40	289(30.7)	651(69.3)	3.08(2.61,3.64)**	1.43(1.09,1.88)*
Residence in Shenzhen				
<1 year	545(46.9)	616(53.1)	1	—
⩾1 year	1413(40.6)	2066(59.4)	1.29(1.13,1.48)**	—
Ethnicity				
Han	2006(42.2)	2753(57.8)	1	—
Other	44(37.0)	75(63.0)	1.24(0.85,1.81)	—
Education				
Junior high school or less	394(50.3)	389(49.7)	1	1
Senior high school	923(53.5)	802(46.5)	0.88(0.74,1.04)	0.97(0.75,1.26)
College or above	744(30.7)	1681(69.3)	2.29(1.94,2.70)**	1.64(1.26,2.14)**
Monthly income				
<3000	142(44.7)	176(55.3)	1	
3000~7000	1543(47.3)	1716(52.7)	0.9(0.71,1.13)	—
>7000	376(27.7)	980(72.3)	2.1(1.64,2.70)**	—
Marital status				
Single	1911(42.7)	2563(57.3)	1	
Married	150(32.7)	309(67.3)	1.54(1.25,1.88)**	—
Year of sample				
2015	565(41.2)	806(58.8)	1	
2016	771(50.9)	744(49.1)	0.68(0.58,0.78)**	—
2017	725(35.4)	1322(64.6)	1.28(1.11,1.47)**	—
Type of MSM				
NcMSM	1170(32.4)	2442(67.6)	1	
MB	891(67.4)	430(32.6)	0.23(0.20,0.26)**	0.29(0.22,0.39)**
Source of sample				
Venue based	1275(52.4)	1160(47.6)	1	1
Clinic based	786(31.5)	1712(68.5)	2.39(2.13,2.69)**	1.68(1.35,2.10)**
Self-identified as homosexuality				
No	597(45.2)	725(54.8)	1	1
Yes	1464(40.5)	2147(59.5)	1.21(1.06,1.37)**	1.52(1.25,1.83)**
Receptive sexual role				
No	1306(40.1)	1948(59.9)	1	1
Yes	755(45.0)	924(55.0)	0.82(0.73,0.92)**	0.77(0.64,0.92)**

In a relationship				
No	175(32.1)	371(67.9)	1	—
Yes	291(30.3)	669(69.7)	1.08(0.86,1.36)	—
No. of sexual partners in the past 6 months				
0	763(55.3)	616(44.7)	1	1
1~5	930(31.5)	2022(68.5)	2.69(2.36,3.07)**	1.40(1.14,1.72)**
>5	368(61.1)	234(38.9)	0.79(0.65,0.96)*	0.70(0.50,0.99)*
Engaged in ONS in the past 6 months				
No	755(50.2)	750(49.8)	1	1
Yes	664(40.6)	971(59.4)	1.47(1.28,1.70)**	1.13(0.93,1.37)
Engaged in group sex in past 6 months				
No	1350(46.8)	1533(53.2)	1	1
Yes	69(26.7)	189(73.3)	2.41(1.81,3.21)**	1.45(1.04,2.03)*
Engaged in commercial service in the past 6 months				
No	1339(45.5)	1603(54.5)	1	—
Yes	76(39.0)	119(61.0)	1.31(0.97,1.76)	—
Condom use of anal sex in the past 6 months				
No	513(34.4)	978(65.6)	1	—
Yes	785(38.1)	1278(61.9)	0.85(0.74,0.98)*	—
Recreational drug use				
No	1362(47.4)	1511(52.6)	1	—
Yes	699(33.9)	1361(66.1)	1.76(1.56,1.98)**	—
Received offline-based HIV-related service in the past year				
No	1102(62.1)	672(37.9)	1	1
Yes	959(30.4)	2200(69.6)	3.76(3.33,4.25)**	6.22(5.11,7.57)**
Gay app use				
No	1587(47.4)	1758(52.6)	1	1
Yes	474(29.8)	1114(70.2)	2.12(1.87,2.41)**	1.72(1.37,2.16)**
HIV-related knowledge				
Low to medium	619(44.3)	778(55.7)	1	
High	1442(40.8)	2094(59.2)	1.16(1.02,1.31)*	1.42(1.16,1.73)**
Previous diagnosis of other STD				
No	1938(42.6)	2609(57.4)	1	
Yes	123(31.9)	263(68.1)	1.59(1.27,1.98)**	1.46(1.05,2.03)*
HIV serostatus				
Negative	1837(41.6)	2580(58.4)	1	
Positive	224(43.4)	292(56.6)	0.93(0.77,1.12)	0.65(0.49,0.85)**
Syphilis serostatus				
Negative	1885(42.8)	2515(57.2)	1	
Positive	176(33.0)	357(67.0)	1.52(1.26,1.84)**	1.09(0.81,1.47)
Perception of being infected by HIV				
No or little chance	2043(42.0)	2817(58.0)	1	1

Rather big chance	18(24.7)	55(75.3)	2.22(1.30,3.79)**	3.92(1.60,9.63)**
The main source to gain HIV-related knowledge- TV				
No	1208(41.9)	1674(58.1)	1	—
Yes	842(42.2)	1154(57.8)	0.99(0.88,1.11)	—
The main source to gain HIV-related knowledge- Radio				
No	1900(42.6)	2563(57.4)	1	—
Yes	150(36.1)	265(63.9)	1.31(1.06,1.62)*	—
The main source to gain HIV-related knowledge- Newspaper				
No	1687(41.8)	2348(58.2)	1	—
Yes	363(43.1)	480(56.9)	0.95(0.82,1.11)	—
The main source to gain HIV-related knowledge- Books				
No	1711(43.6)	2212(56.4)	1	—
Yes	339(35.5)	616(64.5)	1.41(1.21,1.63)**	—
The main source to gain HIV-related knowledge- Friends				
No	1732(43.1)	2289(56.9)	1	—
Yes	318(37.1)	539(62.9)	1.28(1.10,1.49)**	—
The main source to gain HIV-related knowledge- Doctors				
No	1901(43.0)	2520(57.0)	1	—
Yes	149(32.6)	308(67.4)	1.56(1.27,1.91)**	—
The main source to gain HIV-related knowledge- Consultation service				
No	1983(43.1)	2618(56.9)	1	1
Yes	67(24.2)	210(75.8)	2.37(1.79,3.14)**	1.77(1.16,2.70)**
The main source to gain HIV-related knowledge- Free promotional materials				
No	1542(43.1)	2035(56.9)	1	1
Yes	508(39.0)	793(61.0)	1.18(1.04,1.35)*	0.74(0.60,0.91)**
The main source to gain HIV-related knowledge- Bulletin board				
No	1837(43.8)	2358(56.2)	1	1
Yes	213(31.2)	470(68.8)	1.72(1.45,2.04)**	1.25(0.94,1.65)
The main source to gain HIV-related knowledge- Internet				
No	684(42.9)	912(57.1)	1	1
Yes	1366(41.6)	1916(58.4)	1.05(0.93,1.19)	0.84(0.69,1.03)
The main source to gain HIV-related knowledge- School education				
No	1924(42.3)	2621(57.7)	1	—
Yes	126(37.8)	207(62.2)	1.21(0.96,1.52)	—

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	*na*
Study size	10	Explain how the study size was arrived at	8-9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	na
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	na
		(*e*) Describe any sensitivity analyses	na
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6,8
		(b) Give reasons for non-participation at each stage	na
		(c) Consider use of a flow diagram	na
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-10
		(b) Indicate number of participants with missing data for each variable of interest	na
Outcome data	15*	Report numbers of outcome events or summary measures	8-9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12-17
		(*b*) Report category boundaries when continuous variables were categorized	9,15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	na
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14
Discussion			
Key results	18	Summarise key results with reference to study objectives	18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	22
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18-22
Generalisability	21	Discuss the generalisability (external validity) of the study results	22
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	23

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Correction: Relationship between gay app use and HIV testing among men who have sex with men in Shenzhen, China: a serial cross-sectional study

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