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RESEARCH

Self-sampled multi-anatomic site testing for uncovering the community burden of undiagnosed *Chlamydia trachomatis* and *Neisseria gonorrhoeae* infection in men who have sex with men

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Abstract

Purpose To detect otherwise undiagnosed asymptomatic sexually transmitted infection (STI), and for estimating prevalence among men who have sex with men (MSM).

Methods In this community-based study in Hong Kong, adult MSM were recruited. After completion of an online survey, free multi-anatomic sites self-sampling kits (urine specimens, pharyngeal and rectal swabs) for *Chlamydia trachomatis* (CT) and *Neisseria gonorrhoeae* (NG) tests were delivered to requesting participants. Factors associated with STI positivity were analyzed in logistic regression.

Results From September 2021 to October 2022, 712 MSM were recruited, with 86% aged 18–39, and 16% reported history of chemsex engagement. A majority (81%) had previously undergone HIV testing, 68% had ever tested for STI, and 35% previously diagnosed with STI. Totally 428 (60%) had requested self-sampling kits, and 276 (39%) returned collected samples. Among participants who returned the samples, about half had never been tested in the past and had no history of STI. Overall 21% tested positive for CT and/or NG (CT/NG)—CT positive 16% and NG positive 7%. By anatomic site, 16% of rectal swabs, 7% of pharyngeal swabs, but just 3% of urine specimens were CT/NG positive. The prevalence of CT/NG was not significantly different by history of STI diagnosis and testing.

Conclusion Self-sampled STI testing is a potentially useful means for enhancing uptake of screening in MSM in the community, which could uncover otherwise undiagnosed asymptomatic infections. Internet-based self-sampling for STI testing could complement the current clinic-based STI testing for supporting epidemiologic evaluation of STI control in the community.

Keywords STI testing · Self-sampling · MSM · Rectal · Prevalence · mHealth

Introduction

Globally, *Chlamydia trachomatis* (CT) and *Neisseria gonorrhoeae* (NG) are the main causative agents of bacterial sexually transmitted infections (STI). In 2020, it was estimated that 129 million new CT and 82 million new NG infections had occurred worldwide [1]. The global pooled prevalence of CT and NG urogenital infection in male was 2.7% and 0.7%, respectively, in 2016 [2]. The prevalence of bacterial STIs is disproportionally high in men who have sex with men (MSM), whose pooled prevalence of rectal CT and NG infections was 9% and 6.1%, respectively [3]. To control the epidemic of STIs, World Health Organization (WHO) has set the 2030 coverage targets for STI, one of which being the screening of over 90% of MSM for NG and syphilis [4]. As CT and NG are often concurrently tested with the same

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Nucleic Acid Amplification Test (NAAT), the screening coverage target could cover CT also.

To minimize the population burden of curable bacterial STI, the provision of comprehensive service should be facilitated. WHO has advocated the adoption of curable STI service continuum, which highlights stages of prevention activities reached, diagnosis, treatment, and cure [4]. Testing of NG and CT constitutes a key stage along the service continuum, which involves the facilitation of diagnosis and initiation of timely treatment. The Australian Chlamydia Cascade with key components of testing, treatment, partner management, and re-testing illustrated that the greatest gaps for young men were at the diagnosis (72% undiagnosed) and re-testing steps (83% not re-tested after diagnosis) [5]. Novel strategies are important to enhance STI testing coverage in the MSM community, so as to improve the treatment and re-testing coverage.

Unlike syphilis where point-of-care (POC) testing is an option, the detection of CT and NG is mainly limited to laboratory testing. To scale-up CT and NG testing, re-testing, and/or regular testing, the logistics of sampling and linkage with testing need to be simplified and facilitated. Self-collection of samples, and mailing the samples for laboratory testing, referred as "mail-in self-testing" [6], "home-based testing for STI" [7], or "e-STI testing" [8], have been examined in some studies. Comparing with clinic-based screening, randomized controlled trials have shown that "mail-in self-testing" resulted in higher uptake rate and high test positivity rates in specimens [9]. However, studies in earlier years largely involved only urine specimen or vaginal swabs from women [10, 11]. It is not until the past decade that the self-collection of urogenital, pharyngeal, and/or rectal swabs for STI testing have become introduced [6, 8, 12]. In this study conducted in Hong Kong, China, we examined the role of self-collected multi-site specimens for CT/NG, both for establishing the community burden of prevalent infections and for evaluating the strategy for enhancing coverage of testing in the MSM community in Hong Kong, China.

Methods

Participants and study design

This is an ongoing community-based longitudinal study on STI burden in Hong Kong. MSM, aged 18 years old or above and normally living in Hong Kong, were recruited through two Non-Governmental Organizations (NGOs) providing free HIV testing and counseling service for individuals at risk of HIV infection in Hong Kong, and from online outreach to that approached potential participants through an online forum for MSM. Between September 2021 and October 2022, through the online survey link and QR code, participants provided e-consent and completed the online baseline survey. The baseline survey items included sociodemographics, sexual behaviors (chemsex engagement, group sex, type and number of sex partners, and condom usage), and sex partner networking events (including the use of gay apps, social media, frequenting sauna, and gay bar) in the past 6 months, history of HIV pre-exposure prophylaxis (PrEP), STI diagnosis and treatment, and STI testing, and preference for STI testing and treatment (Online Resource 1).

At the end of the survey, self-sampling for CT, NG was offered, while human papillomavirus (HPV) testing could also be included on voluntary basis without charge (Fig. 1). Per request, a self-sampling package with urine and swab (penile, pharyngeal, and rectal swabs) collection kits, paper consent form, instruction sheet, post-sampling survey in paper form, and packaging materials for return post were couriered to the designated location which was not limited to ones' residential address. As courier service rejected specimens' delivery during COVID-19 epidemic, participants were asked to return the self-collected samples, written consent form, and post-sampling survey to one of the three designated locations, including the Research Center and two NGO outlets. The samples were then delivered to the Research Laboratory for testing. The urine specimen, rectal and pharyngeal swabs were used for CT/NG detection by the Aptima Combo 2 Assay (Hologic). The post-sampling survey included scoring (1 strongly disagree to 10 strongly agree) on convenience, confidence in performing correct sampling, confidence in obtaining accurate test results, instruction clarity, and feeling of discomfort [12]. Participant received HKD25 (USD 1 ~ HKD7.8) catering voucher following completion of baseline survey and received another HKD25 voucher for returning the samples. CT and NG test results were delivered to participants, and those tested positive were referred to STI clinics in the public service or primary care doctors if requested. Repeat self-sampled testing at 1-year interval could be performed as a follow-up procedure, the results of which were not included in this manuscript. Ethical approval from the Joint Chinese University of Hong Kong-New Territories East Cluster Clinical Research Ethics Committee was obtained (approval number: CREC2020.436).

Data analysis

Baseline survey data and laboratory testing results were analyzed. The main outcome variable was bacterial STI positivity (CT and/or NG, hereafter CT/NG) in collected specimens. Secondary outcome variables included history of STI diagnosis (HIV diagnosis excluded) and history of STI testing. The prevalence of CT/NG, CT, and NG positivity was estimated with 95% confidence interval (CI) using

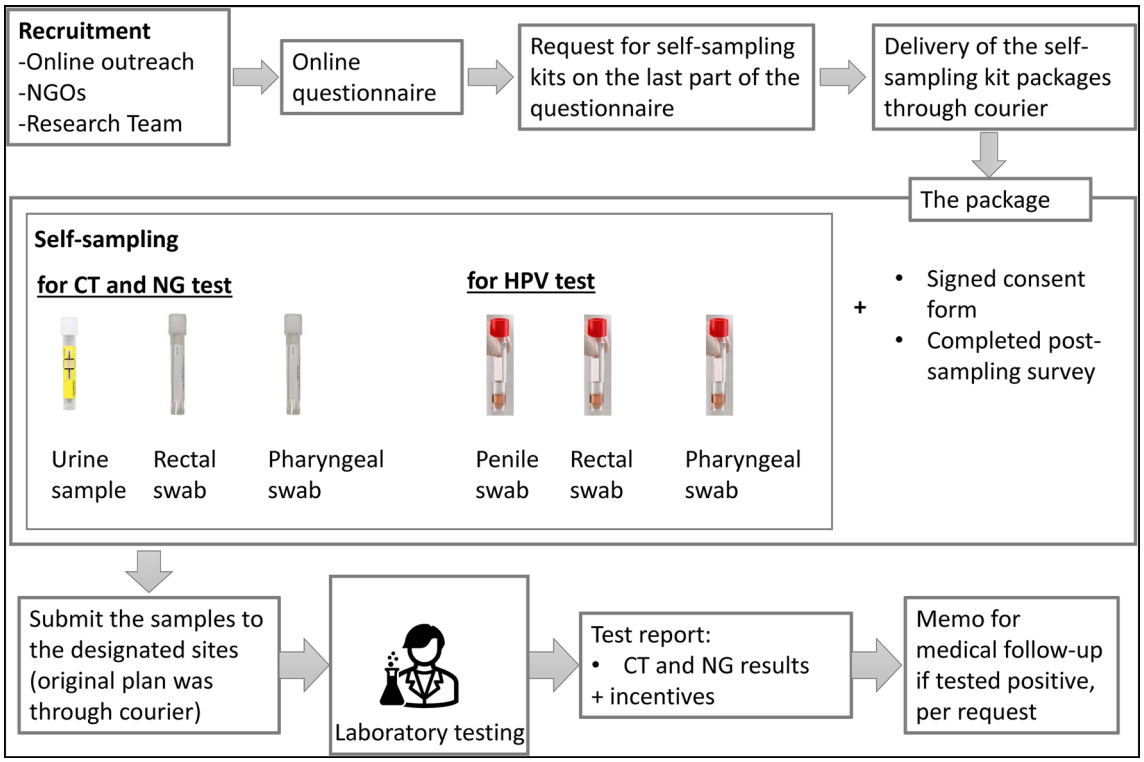

Fig. 1 Study flow chart. *CT Chlamydia trachomatis*, *NG Neisseria gonorrhoeae*, *NGOs* Non-Governmental Organizations

binomial exact method. Factors (socio-demographics, sexual behavior, experience of STI symptom, history of HIV testing in the past 1 year, history of PrEP use, and self-sampling participation in the study) associated with the main and secondary outcome variables were examined in bivariable logistic regression. If age was a significant factor, it was included as a confounder in the multivariable logistic regression. All analyses were performed in SPSS 28. Complete case analysis was performed.

Results

Characteristics of MSM participants

A total of 712 MSM completed the online survey. Among them, 86% were aged between 18 and 39, 99% were Chinese, 84% were in employment, and 81% had ever tested for HIV, 3% ($n=21$) self-reported HIV positive (Table 1). In the past 6 months, almost all (93%) were sexually active, 8% had engaged in chemsex, 59% had more than one non-regular sex partners, and 87% had used networking events to seek sex partners.

Regarding preference for STI testing and treatment, more than half of MSM rated convenient or very convenient for the currently available STI testing service (58%) and HIV testing service (75%) in Hong Kong, but just 37% for STI treatment service (Online Resource 2 Fig. S1). Most MSM preferred going to NGOs (72%) or performing self-tests (59%) for STI, while private clinics (65%) or public STI clinics (53%) were the most preferred venues for STI treatment.

Characteristics of MSM by history of STI diagnosis and testing

Among 712 MSM, 250 (35%) self-reported previous history of STI diagnosis, of which 36% were recently diagnosed within the past 1 year. Overall, chlamydia (91/250, 36%) was the most commonly self-reported latest STI diagnosis, followed by syphilis (70/250, 28%), gonorrhea (65/250, 26%), genital warts (48/250, 19%), genital herpes (6/250, 2%), HCV infection (4/250, 2%), *Mycoplasma genitalium* (MG) infection (2/250, 0.8%), and trichomoniasis (2/250, 0.8%). Compared to MSM without STI history, those with previous diagnosis were more likely to have self-reported HIV positive (adjusted odds ratio (aOR) = 11.95, 95% CI = 3.47–41.09), ever engaged in group sex (aOR = 3.55, 95% CI = 2.49–5.07) and chemsex (aOR = 4.26, 95% CI = 2.73–6.65 for chemsex without injection; aOR = 9.25, 95% CI = 1.94–44.16 for slamsex), and having sex partner ever engaged in chemsex (aOR = 3.74, 95% CI = 2.62–5.34 for chemsex without injection; aOR = 4.48, 95% CI = 2.04–9.85 for slamsex) (Online

Table 1 General characteristics of MSM by reported HIV status, N = 712

	Total $N=712$		HIV negative or unknown $N=691$		HIV positive $N=21$	
	n	%	*n*	%	*n*	%
Socio-demographics						
Median age (IQR), years old	30	(26–35)	30	(26–35)	30	(26.5–33.5)
Ethnicity, $N=710$						
Non-Chinese	9	1%	8	1%	1	5%
Chinese	701	99%	681	99%	20	95%
Marital status						
Married/civil union	22	3%	21	3%	1	5%
Single	690	97%	670	97%	20	95%
In employment						
No	116	16%	113	16%	3	14%
Yes	596	84%	578	84%	18	86%
Education level, $N=711$						
Secondary	103	14%	98	14%	5	24%
Above secondary	608	86%	592	86%	16	76%
Monthly income (HKD), $N=646$						
Below 15,000	155	24%	150	24%	5	25%
15,000–30,000	299	46%	289	46%	10	50%
30,000–50,000	113	17%	109	17%	4	20%
Above 50,000	79	12%	78	12%	1	5%
Ever tested for HIV, $N=705$						
No	134	19%	134	20%	0	0%
Yes	571	81%	550	80%	21	100%
Sexual behavior in the past 6 months						
History of sex						
No	47	7%	46	7%	1	5%
Yes	665	93%	645	93%	20	95%
Chemsex engagement						
No	654	92%	642	93%	12	57%
Yes	58	8%	49	7%	9	43%
History of partner seeking						
No	91	13%	90	13%	1	5%
Yes	621	87%	601	87%	20	95%
Sex partner networking events (not mutually exclusive)						
Use of gay apps	506	71%	487	81%	19	95%
Use of social media	320	45%	313	52%	7	35%
Frequenting sauna	95	13%	91	15%	4	20%
Frequenting gay bar	30	4%	28	4%	2	10%

1 USD ~ 7.8 HKD

IQR interquartile range

Resource 2 Table S1). They were also more likely to have tested for STI (aOR = 2.99, 95% CI = 2.16–4.12) and HIV (aOR = 1.93, 95% CI = 1.20–3.09) in the past 1 year, and have taken PrEP for HIV prevention (aOR = 4.39, 95% CI = 3.02–6.38).

Some 484 out of 712 (68%) of MSM reported history of STI testing, including 70% (340/484) who had tested in the past 1 year. In MSM without previous history of STI testing, half (114/228) have requested self-sampling kits, and 31% (70/228) of them returned self-collected samples for their first-time CT/NG testing in our laboratory. There was no significant difference in socio-demographics by history of ever STI testing and testing in last year (Table 2, Online Resource 2 Table S2). However, sexual behaviors,

Table 2 Factors associated with history of STI testing in bivariable logistic regression models

	Never tested ($N=228$)		Ever tested ($N=484$)		Logistic regression for ever STI testing		Logistic regression for STI testing in the past 1 year	
	n	%	*n*	%	OR	95% CI	OR	95% CI
Socio-demographics								
Median age (IQR), years old	30	(26–34)	30	(26–36)	1.006	(0.99–1.03)	0.995	(0.98–1.01)
In employment (ref: no)	184	81%	412	85%	1.37	(0.91–2.07)	0.98	(0.66–1.45)
Attained above secondary school (ref: secondary school) $N=711$	194	85%	414	86%	1.05	(0.67–1.64)	1.33	(0.87–2.03)
Sexual behavior								
Ever chemsex engagement								
Never	215	94%	385	80%	ref			
Yes, without injection	13	6%	89	18%	3.82*	(2.09–7.00)	2.29*	(1.48–3.54)
Yes, with injection	0	0%	10	2%	/		2.91	(0.75–11.36)
Sex partner(s) ever engaged in chemsex								
Never	194	85%	297	61%	ref			
Yes, without injection	30	13%	163	34%	3.55*	(2.31–5.45)	2.32*	(1.65–3.26)
Yes, with injection	4	2%	24	5%	3.92*	(1.34–11.47)	3.61*	(1.56–8.35)
History of sex in the past 6 months (ref: no)	200	88%	465	96%	3.43*	(1.87–6.28)	3.64*	(1.78–7.45)
Chemsex engagement in the past 6 months (ref: no)	4	2%	54	11%	7.03*	(2.51–19.67)	2.62*	(1.47–4.67)
Number of sex partners in the past 6 months, $N=656$								
Non-regular sex partners								
0	64	33%	133	29%	ref			
1–4	91	46%	154	33%	0.81	(0.55–1.21)	1.09	(0.75–1.60)
5 or more	41	21%	173	38%	2.03*	(1.29–3.19)	2.60*	(1.75–3.87)
Regular sex partners or boyfriends								
0	64	33%	113	25%	ref			
1	67	34%	147	32%	1.24	(0.82–1.89)	1.12	(0.75–1.67)
2 or more	65	33%	200	43%	1.74*	(1.15–2.64)	1.67*	(1.14–2.45)
Commercial sex partners								
0	174	89%	432	94%	ref			
At least 1	22	11%	28	6%	0.51*	(0.29–0.92)	0.79	(0.44–1.40)
Consistent condom use in the past 6 months (ref: no) $N=648$	74	38%	114	25%	0.54*	(0.38–0.77)	0.63*	(0.45–0.88)
History of partner seeking in the past 6 months (ref: no)	187	82%	434	90%	1.90*	(1.22–2.98)	2.03*	(1.27–3.23)
Sex partner networking events in the past 6 months (not mutually exclusive)								
Use of gay apps	147	64%	359	74%	1.58*	(1.13–2.22)	1.53*	(1.10–2.12)
Use of social media	102	45%	218	45%	1.01	(0.74–1.39)	1.08	(0.80–1.45)
Frequenting sauna	16	7%	79	16%	2.58*	(1.47–4.54)	2.17*	(1.39–3.40)
Frequenting gay bar	7	3%	23	5%	1.58	(0.67–3.73)	1.45	(0.70–3.04)
Ever experienced with STI symptoms (ref: never)	25	11%	235	49%	7.66*	(4.88–12.04)	2.18*	(1.60–2.98)
Tested for HIV in the past 1 year (ref: no)	105	46%	367	76%	3.67*	(2.63–5.13)	5.33*	(3.25–8.72)
History of PrEP use (ref: never) $N=703$	19	8%	142	30%	4.55*	(2.73–7.57)	4.05*	(2.74–5.97)
Self-sampling participation in the study								
Requested self-sampling kit in the study (ref: no)	114	50%	314	65%	1.85*	(1.34–2.54)	1.59*	(1.17–2.15)
Received self-sampling kit (ref: no) $N=453$	107	89%	304	91%	1.27	(0.64–2.54)	1.71	(0.90–3.26)
Returned the samples for lab testing (ref: no) $N=411$	70	65%	206	68%	1.11	(0.70–1.77)	1.17	(0.78–1.77)

IQR interquartile range, *OR* odds ratio, *PrEP* pre-exposure prophylaxis, *STI* sexually transmitted infections

*$P<.05$

experience of STI symptoms (ever STI testing OR = 7.66, 95% CI = 4.88–12.04; STI testing in last year OR = 2.18, 95% CI = 1.60–2.98), history of HIV testing in the past 1 year (ever STI testing OR = 3.67, 95% CI = 2.63–5.13; STI testing in last year OR = 5.33, 95% CI = 3.25–8.72), and history of PrEP use (ever STI testing OR = 4.55, 95% CI = 2.73–7.57; STI testing in last year OR = 4.05, 95% CI = 2.74–5.97) were significant factors for both having ever STI tested and testing in last 1 year.

Self-collected samples for STI testing and test results

A total of 387 (54%) MSM had requested self-sampling kits and 60 (8.4%) indicated their interest and were approached by the Research Team for self-sampling. Eventually 428 (60%) had requested self-sampling kits, and 276 out of 411 (39%) who had received the sampling kits (67%) returned samples for laboratory testing. Of note, 51 participants (18%) self-sampled and submitted the samples at NGO collection site in one visit. Higher education level attainment, higher sexual behavior risk, past history of STI and HIV testing were positively associated with requesting self-sampling kits (Online Resource 2 Table S3).

Totally 59 (21%, 95% CI = 17–26%) MSM had samples testing positive for CT and/or NG (CT/NG)—16% (95% CI = 12–20%) were CT positive alone (highest at rectal site, 14%, 95% CI = 10–18%), 7% (95% CI = 4–10%) NG positive alone (highest at pharyngeal site, 5%, 95% CI = 2–7%) (Fig. 2). Among 21 MSM diagnosed with CT recently (within 6 months before survey), 2 were still tested CT positive, while 12 were tested negative and 7 did not participate in self-sampling. Among 15 MSM diagnosed with NG recently, 1 tested NG positive, 8 were negative, and 6 did not participate in self-sampling. By anatomic sites, the positivity rate of any STI was the highest for rectal specimen (16%, 95% CI = 12–20%).

Having at least five non-regular sex partners (0 as reference, odds ratio (OR) = 2.01, 95% CI = 1.06–3.80) in the past 6 months was the only factor significantly associated with CT/NG positivity (Table 3). The factor was also significantly associated with CT infection alone (OR = 8.36, 95% CI = 2.43–28.74), rectal CT/NG infection (OR = 4.35, 95% CI = 1.58–11.95), and rectal CT infection alone (OR = 6.75, 95% CI = 1.95–23.38) (Table 3, Online Resource 2 Table S4). For lone CT positive results, consistent condom use (OR = 0.39, 95% CI = 0.16–0.96) was in negative association while having sought sex partners through gay apps (OR = 2.68, 95% CI = 1.01–7.11) in the past 6 months was in positive association. Significant factors associated with rectal CT/NG infection included younger age (aged 40 or above as reference; 18–29 years old OR = 6.06, 95% CI = 1.38–26.65; 30–39 years old OR = 4.80, 95% CI = 1.06–21.67), and seeking sex partners through gay apps in the past 6 months (OR = 3.49, 95% CI = 1.20–10.16). No significant factors were observed for NG infection alone, pharyngeal CT/NG infection, and urogenital CT/NG infection. The prevalence of CT/NG infection was not significantly different between MSM previously tested and never tested for STI.

Among 265 post-sampling surveys received, the scoring of self-sampling process varied by the sampling site. Urine specimen self-collection was scored the highest in terms of convenience, confidence of sampling correctly, accurate detection of infection status, clear and easy instruction, and comfort (Fig. 3). This was followed by self-collection of pharyngeal swabs with lower median score on convenience (9, IQR = 7–10), confidence (8, IQR = 7–10), accuracy (9,

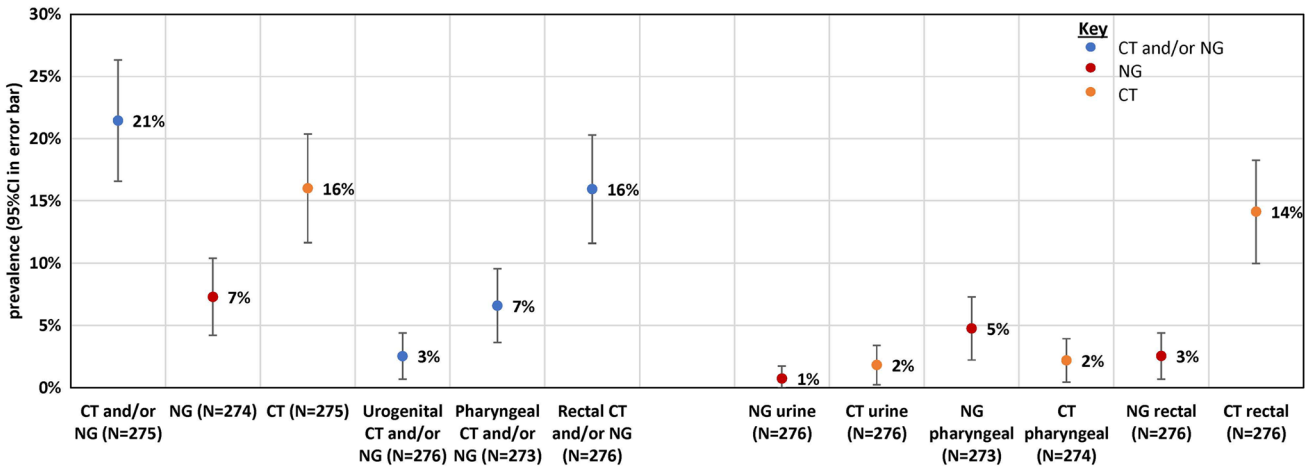

Fig. 2 Prevalence of *Chlamydia trachomatis* and *Neisseria gonorrhoeae* infection (95% CI) of all self-collected samples. *CI* confidence interval, *CT Chlamydia trachomatis*, *NG Neisseria gonorrhoeae*

Table 3 Factors associated with STI testing results in bivariable logistic regression models

Prevalence (95% CI)	CT and/or NG infection in any anatomic site(s)	NG infection in any anatomic site(s)	CT infection in any anatomic site(s)	Rectal CT and/or NG infection	Pharyngeal CT and/or NG infection	Urogenital CT and/or NG infection
	0.21 (0.17–0.26), N = 275	0.07 (0.04–0.10), N = 274	0.16 (0.12–0.20), N = 275	0.16 (0.12–0.20), N = 276	0.07 (0.04–0.10), N = 273	0.03 (0.01–0.04), N = 276
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Socio-demographics						
Age group (years old)						
18–29	1.96 (0.80–4.81)	1.69 (0.46–6.28)	2.62 (0.86–8.01)	6.06* (1.38–26.65)	2.12 (0.45–10.06)	0.26 (0.04–1.59)
30–39	1.71 (0.68–4.33)	0.82 (0.19–3.56)	2.33 (0.74–7.33)	4.80* (1.06–21.67)	1.53 (0.30–7.88)	0.31 (0.05–1.94)
40 or above		ref	ref			
In employment (ref: no)	1.03 (0.44–2.38)	1.44 (0.32–6.47)	1.02 (0.40–2.60)	0.82 (0.33–1.99)	0.77 (0.21–2.80)	/
Above secondary education level (ref: secondary)	1.40 (0.46–4.28)	/	0.95 (0.31–2.92)	1.00 (0.32–3.05)	1.61 (0.20–12.64)	/
Sexual behavior in the past 6 months						
Chemsex engagement in the past 6 months (ref: no)	0.82 (0.30–2.26)	1.69 (0.46–6.19)	0.39 (0.09–1.72)	0.87 (0.29–2.63)	0.52 (0.07–4.05)	/
Sex in the past 6 months	1.10 (0.23–5.31)	0.70 (0.08–5.80)	1.74 (0.22–14.12)	1.74 (0.21–14.05)	0.62 (0.07–5.20)	/
No. of non-regular sex partners in the past 6 months						
0	ref	ref	ref			
1–4	1.92 (0.75–4.92)	1.46 (0.42–5.06)	2.86 (0.77–10.69)	1.66 (0.55–5.03)	5.29 (0.64–44.07)	1.45 (0.13–16.33)
> = 5	4.04* (1.67–9.8)	1.13 (0.32–4.02)	8.36* (2.43–28.74)	4.35* (1.58–11.95)	6.29 (0.78–50.86)	2.64 (0.29–24.14)
No. of regular sex partners in the past 6 months						
0	ref	ref	ref			
1	1.09 (0.46–2.60)	1.43 (0.33–6.24)	0.93 (0.35–2.44)	0.82 (0.32–2.11)	2.18 (0.41–11.65)	1.70 (0.15–19.22)
> = 2	1.69 (0.79–3.64)	2.02 (0.54–7.50)	1.48 (0.64–3.41)	1.23 (0.55–2.77)	2.79 (0.59–13.15)	2.10 (0.23–19.19)
At least 1 commercial sex partners in the past 6 months (ref: none)	0.46 (0.10–2.09)	0.79 (0.10–6.29)	0.30 (0.04–2.35)	0.67 (0.15–3.04)	/	/
Consistent use of condom in the past 6 months (ref: inconsistent)	0.51 (0.24–1.07)	0.70 (0.22–2.19)	0.39* (0.16–0.96)	0.48 (0.20–1.13)	0.34 (0.08–1.52)	1.09 (0.21–5.75)
Sex networking						
Sourced sex partners in the past 6 months (ref: not sourced)	2.44 (0.71–8.39)	1.03 (0.23–4.67)	5.69 (0.75–43.02)	5.66 (0.75–42.81)	0.91 (0.20–4.17)	/
Through gay apps (ref: no)	2.23 (0.998–4.99)	0.91 (0.32–2.60)	2.68* (1.01–7.11)	3.49* (1.20–10.16)	1.08 (0.34–3.40)	1.83 (0.22–15.53)

Table 3 (continued)

Prevalence (95% CI)	CT and/or NG infection in any anatomic site(s)	NG infection in any anatomic site(s)	CT infection in any anatomic site(s)	Rectal CT and/or NG infection	Pharyngeal CT and/or NG infection	Urogenital CT and/or NG infection
	0.21 (0.17–0.26), N = 275	0.07 (0.04–0.10), N = 274	0.16 (0.12–0.20), N = 275	0.16 (0.12–0.20), N = 276	0.07 (0.04–0.10), N = 273	0.03 (0.01–0.04), N = 276
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Through social media (ref: no)	0.89 (0.50–1.61)	0.96 (0.38–2.43)	0.99 (0.51–1.91)	0.78 (0.40–1.52)	1.18 (0.45–3.09)	1.07 (0.23–4.86)
Through gay sauna (ref: no)	0.90 (0.41–1.99)	0.25 (0.03–1.93)	1.17 (0.50–2.71)	1.13 (0.49–2.63)	/	0.83 (0.10–7.06)
Through gay bars (ref: no)	1.00 (0.27–3.70)	/	1.46 (0.39–5.47)	1.47 (0.39–5.50)	/	/
Ever STI tester (ref: never)	0.65 (0.35–1.22)	0.61 (0.23–1.60)	0.60 (0.30–1.21)	0.53 (0.27–1.05)	0.89 (0.31–2.59)	0.85 (0.16–4.46)
STI testing in the past 1 year (ref: not tested)	0.74 (0.42–1.33)	0.66 (0.26–1.64)	0.79 (0.41–1.51)	0.63 (0.33–1.21)	0.82 (0.32–2.14)	1.09 (0.24–4.96)
Ever diagnosed with STI (ref: never)	1.16 (0.64–2.07)	0.80 (0.31–2.08)	1.19 (0.62–2.29)	1.05 (0.55–2.03)	0.95 (0.36–2.54)	2.05 (0.45–9.34)
STI diagnosis in the past 1 year (ref: not diagnosed)	0.81 (0.35–1.85)	1.89 (0.65–5.49)	0.49 (0.17–1.45)	0.83 (0.33–2.10)	0.65 (0.14–2.93)	0.90 (0.11–7.64)
PrEP experienced (ref: naïve)	1.02 (0.56–1.86)	0.77 (0.29–2.07)	1.19 (0.61–2.31)	1.34 (0.69–2.59)	0.69 (0.24–2.01)	0.30 (0.04–2.53)

CI confidence interval, *CT Chlamydia trachomatis*, *NG Neisseria gonorrhoeae*, *OR* odds ratio, *PrEP* pre-exposure prophylaxis, *STI* sexually transmitted infections

*$P < .05$

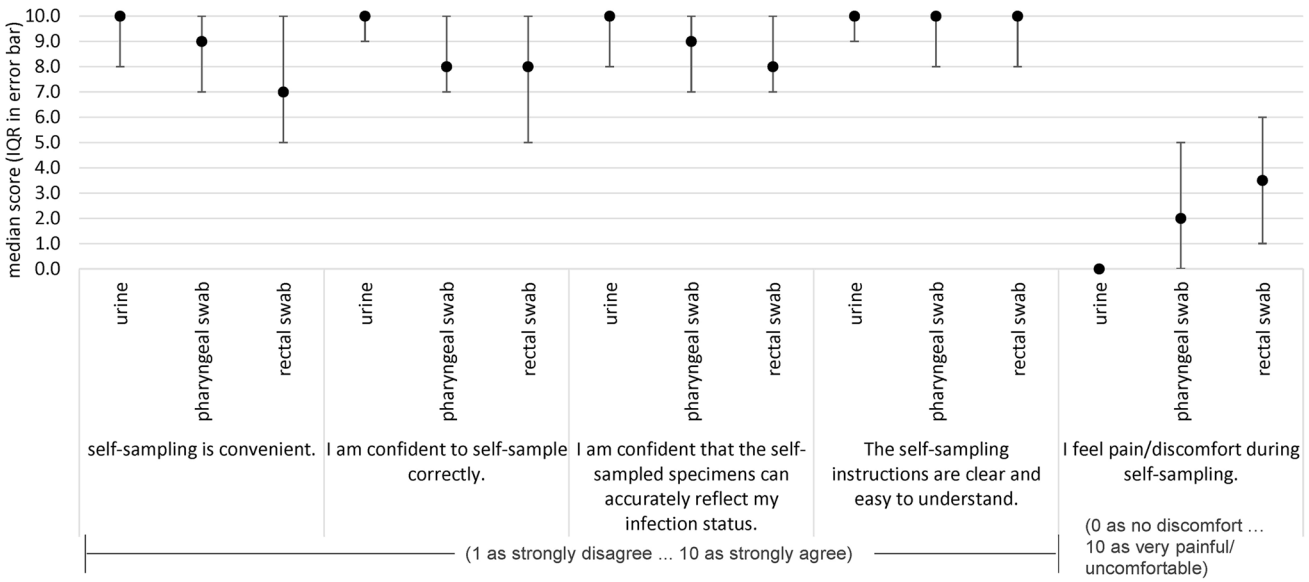

Fig. 3 Scoring of the self-sampling process, $N = 265$

IQR = 7–10), and higher median score on discomfort (2, IQR = 0–5, 0 as no discomfort and 10 as very uncomfortable). Self-collection of rectal swabs was scored the lowest, with median of 7 (IQR 5–10) in terms of convenience, and 3.5 (IQR = 1–6) in terms of comfort. Reported discomfort included the swab being too dry, and uncertainty in the sampling depth at rectum and pharyngeal sites.

Discussion

Comparing with reported pooled prevalence of rectal CT and NG estimation in MSM in a systematic review [3], our estimated rectal CT prevalence was higher (9% in systematic review vs 14% in this study) while rectal NG prevalence was lower (6.1% in systematic review vs 3% in this study). Our estimated prevalence was also lower than that in China, South Africa, and Paris [13–15], and locally in Hong Kong [12, 16, 17], but comparable with a local screening of asymptomatic CT and NG infection study in 2014/2015 [18] (Online Resource 2 Fig. S2). The discrepancy between ours and other local studies might be due to the different proportion of MSM with higher risk sexual behavior, as illustrated by history of chemsex engagement (8% in this study vs 38% in 2019/2020 study [12]). The high proportion of recent diagnosis and treatment of CT and NG might have contributed to the lower detection rate in samples received. However, comparing with a local behavioral surveillance study in 2020 which recruited MSM mainly through NGOs [19], the proportions of ever HIV testing (81.9% vs 81% in this study) and chemsex engagement in the past 6 months (8.6% vs 8.1% in this study) were similar.

In conventional STI testing with collection of urine specimen alone, the prevalence of CT and NG was very low, which might have underestimated the STI burden in the MSM community. The STI prevalence could be more than double in rectal and pharyngeal samples, as shown in this study (3% for urogenital CT/NG infection vs 16% for rectal and 7% for pharyngeal CT/NG infection) and previous studies (14%-85% rectal and pharyngeal CT/NG infections missed with urine screening alone [20]; 3.4% for urethral CT/NG infection vs 13% for rectal CT/NG infection [21]). Consistent with studies in 2016–2021 in China, Morocco, and Paris [13, 15, 22], the prevalence of rectal CT and NG infection was very high, ranging between 12.5–31.25% and 5.5–23.4%, respectively. While our estimated prevalence of pharyngeal CT infection was similarly low as that in an Australian study (1.1% vs 2.2% in this study) [3], the high prevalence of pharyngeal NG infection estimated in this (4.8%) and previous local studies (7.3% and 9%) [12, 17] suggested that testing of pharyngeal swabs in CT/NG NAAT was important locally.

Similar to previous studies in China and Germany [23–25], MSM with higher number of sex partners and inconsistent condom use were associated with CT and/or NG infection. Likewise, history of STI diagnosis, history of group sex, chemsex engagement, and higher number of sex partners were significant factors in this and other studies for positive CT/NG results [26–28]. Some 35% of our recruited MSM self-reported history of STI diagnosis, of which CT, syphilis, and NG were most commonly reported. This figure could, however, likely to be the tip of iceberg as only 68% MSM had ever tested for STI. Undiagnosed STI, especially among those who had never

tested, could contribute to ongoing STI transmission in the community.

Conventional STI testing at clinical setting aside, this study offered free STI testing with delivered self-collected samples. Overall, 60% of participating MSM showed willingness to participate in self-sampling for STI testing. Seeking sex partners through gay apps was associated with history of STI testing and willingness to participate in self-sampling for testing. This was consistent with the positive association of meeting sex partners online with STI testing in Bangkok [29]. The findings further supported the strategy of using geosocial networking applications (apps) as the platform for promoting prevention and intervention for HIV/STI control [30–32]. In particular, the apps could enhance their STI "knowledge", which was positively associated with STI testing in a UK study [20]. Our study findings also showed positive association between education level attainment and willingness to participate in self-sampling. In the smartphone era with increasing popularity of chatbot, the promotion of HIV/STI testing and prevention information, ordering of test kits or sampling kits, supporting service, and consultation could be easily implemented online.

Although participants who have ever tested for STI were more keen to participate in self-sampling, some 50% and 56% of MSM without experience of STI testing and diagnosis, respectively, had requested for self-sampling. We observed a similar proportion of sample return for STI testing and similar positivity of CT and NG in collected samples of participants ever and never tested. Previous study targeting young population who never tested illustrated higher CT and NG testing rate in e-STI testing group (44.3%) than clinic testing group (24.1%) [33]. With 13% of MSM unaware of STI testing location and 30% considering testing service inconvenient or very inconvenient, their access to convenient STI testing in diverse channels, such as self-sampled STI testing, could enable a wider spectrum of MSM with different characteristics and testing preferences to undergo testing [34]. The convenience, confidence to self-collection, and detection of test results of the self-sampled testing approach were rated high in our post-sampling survey, which was similar to our previous study [12]. Discomfort in self-collection of pharyngeal and rectal swab as experienced by some participants might become a deterrent of future self-sampled testing. However, based on the feedback collected, the discomfort could be reduced through improvement of sampling instruction or materials for swabbing. As shown in our sub-analysis results, recent risk exposure was likely an important factor for motivating first-time STI testing. Regular promotion or periodic reminder of STI testing in the community might also be useful for initiating first-time testing should there be recent risk exposure.

There were a few limitations in this study. First, convenience sampling was used by our Research Team, NGOs, and online outreach, while the survey was limited to access through online self-administration only. While this was a commonly adopted recruitment method for MSM community studies, we were mindful on the potential sampling bias and self-selection bias of recruiting MSM who were younger and able to answer the survey online. Second, affected by COVID-19 epidemic, the designated courier service had suspended the delivery of samples. Whereas we could deliver sampling kits to participants following online request, the delivery of collected samples from participants directly to the laboratory could not be done. Instead, participants had to return the samples to the three designated sites for the Research Team to collect and deliver to the laboratory. The decreased convenience of the alternative approach might have reduced the participation rate and 33% of participants actually failed to return samples for laboratory testing. The participation and sample returning rate could be higher when the courier service for samples resumed after COVID-19 policy was lifted. Third, the test results may be affected by the self-sampling techniques, but we believed that the impact was small with high detection rate in the samples [12]. Fourth, this study did not include the option of STI testing at clinic setting as a control group. The impact of STI self-sampling for testing could not be evaluated directly.

To conclude, self-sampled STI testing offers an accessible option, which may complement the conventional STI testing at clinic setting. Facilitated by promotion strategy, it could be a potentially useful means to enhance the initiation of first-time testing and detection of asymptomatic infection through regular testing in MSM at risk of infection. With the detection of undiagnosed CT/NG followed by treatment, the STI epidemiological situation could be better evaluated, and the epidemic of CT/NG could be under better control.

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Availability of data and materials The aggregated data for this study will be made available to other academic researchers.

Declarations

Conflict of interest The authors declare no competing interests.

Ethical approval E-consent has been obtained before online survey start, and written consent form was obtained from participant who self-collected samples for testing. Ethical approval from the Joint Chinese University of Hong Kong-New Territories East Cluster Clinical Research Ethics Committee was obtained (approval number: CREC2020.436).

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