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Missed opportunities for early HIV diagnosis: Epidemiological factors associated with the absence of previous HIV testing among HIV-infected persons in Singapore, 2012 to 2017

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ABSTRACT

Objective: To assess temporal trend and identify risk factors associated with the absence of previous HIV testing prior to their diagnosis among HIV/AIDS cases in Singapore.

Study design: Cross-sectional.

Setting and participants: We analyzed data of HIV/AIDS cases infected via sexual transmission, who were notified to the National HIV Registry in 2012–2017.

Outcomes: Epidemiological factors associated with the absence of HIV testing prior to diagnosis were determined separately for two groups: early and late stages of HIV infection at diagnosis.

Results: 2,188 cases with information on HIV testing history and CD4 cell count were included in the study. The median age at HIV diagnosis was 40 years (interquartile range [IQR], 30–51). Nearly half (45.1%) had never been tested for HIV prior to their diagnosis. The most common reason cited for no previous HIV testing was “not necessary to test” (73.7%). Among cases with previous tests, the median duration from the last negative test to HIV diagnosis was 2.1 years (IQR 1.0–4.4). The time interval was significantly longer at 3.8 years (IQR 2.0–7.3) among cases diagnosed at late-stage HIV infection compared with 1.7 years (IQR 0.8–3.2) among those diagnosed at early-stage. Anonymous test sites were most popular (32.1%), followed by primary care clinics (23.3%). The proportion diagnosed at late-stage HIV infection was significantly higher among cases who had never been tested for HIV (63.9%) compared with those who had undergone previous HIV tests (29.0%). Common risk factors associated with no previous HIV testing in these two groups were: older age at HIV diagnosis, lower educational level, detection via medical care, and HIV infection via heterosexual transmission.

Conclusion: Targeted prevention efforts and strategies are needed to raise the level of awareness of HIV/AIDS and to encourage early and regular screening among the at-risk groups by making HIV testing more accessible.

(Word count: 294)

Keywords: late-stage, HIV testing; risk factors, screening

ARTICLE SUMMARY

Strengths and limitations of this study

- We were able to use the epidemiological data collected in the National HIV Registry in Singapore, which improves the generalisability of the findings.
- The cross-sectional design of our study did not allow us to make inference about the causality of having had no previous HIV testing and the associated factors.
- Not all potential confounding factors associated with absence of prior HIV testing prior to HIV diagnosis could be included in our study, and information on drivers and barriers of HIV testing was unavailable
- As testing-related variables were ascertained based on self-reporting by HIV/AIDS cases, some extent of misclassification due to recall bias could not be avoided.

INTRODUCTION

Regular HIV testing among at-risk individuals is paramount as a preventive strategy in the programmatic response to HIV/AIDS epidemic. In recognition of the major consequences of undiagnosed HIV infection, the Joint United Nations Programme on HIV/AIDS (UNAIDS) and partners launched the 90–90–90 targets in 2014, which called for 90% of all people living with HIV (PLHIV) to be aware of their status, 90% of those diagnosed to receive antiretroviral therapy (ART), and 90% of those on ART to achieve viral suppression by 2020.[1] The corresponding estimates for PLHIV in Singapore were 80%, 91% and 91% in 2018.[2] Regular and frequent HIV testing provides an essential gateway to serostatus awareness and early diagnosis, thereby enhancing the effectiveness of all subsequent steps in the cascade of HIV care including provision of ART and counselling on behaviour. The risk of onward transmission by persons who are unaware of their HIV infection and premature deaths is also reduced with diagnosis of HIV infection at an early stage.

As of end-2019, there were 8,618 Singapore residents diagnosed with HIV infection, of whom 2,097 had died.[3] Despite the widespread availability and accessibility of HIV testing in Singapore, late diagnosis in the course of HIV infection continues to be a barrier in tackling HIV.[4] A local study revealed that over half (54%) of HIV-positive persons infected via sexual transmission in 1996–2009 had late-stage disease at diagnosis.[5] The higher short-term mortality of persons diagnosed with late-stage HIV infection underscores the importance of testing and detection at the earliest opportunity.[6] Another local study found that the median survival of HIV cases diagnosed late was 5 years, whereas the cumulative proportion of those diagnosed early surviving until the fifth year since diagnosis was 80%.[7]

This study seeks to elucidate epidemiological factors associated with the absence of previous HIV testing prior to their diagnosis among cases diagnosed at both early and late stages of HIV infection. The findings provide insights into

reviewing and tailoring public health preventive and interventional strategies to increase the uptake of HIV testing in at-risk groups, so as to reduce missed opportunities for early diagnosis and facilitate timely initiation of ART for HIV-infected persons.

MATERIALS AND METHODS

Study population

Notification of HIV/AIDS diagnosis is mandatory under the Infectious Diseases Act in Singapore[8]. Information collected in the National HIV Registry is protected under the law, and includes socio-demographic characteristics, CD4 cell count, mode of detection and exposure factors such as the mode of transmission and the type of sexual partners.

Data on self-reported history of HIV testing has been collected since 2010, and the proportion of missing data dropped from 39% in 2010 to below 20% since 2012. The majority (95.1%) of all HIV/AIDS cases reported in 1985–2017 were infected via sexual transmission, hence we restricted the analyses to those infected via sexual transmission to allow for a more homogenous group. The study population were sexually transmitted HIV/AIDS cases diagnosed and notified to the National HIV Registry in 2012–2017. Approval for this study was provided by the Ministry of Health, Singapore. As the data was collected under the Infectious Diseases Act and analyses were performed on an anonymized dataset, informed consent was not required for this study.

The analyses were stratified by stage of HIV infection at diagnosis (early or late), hence HIV/AIDS cases with either unknown HIV testing history or missing CD4 count at diagnosis were excluded. Late-stage HIV infection was defined as having either a CD4 count <200 cells/mm^3 at the time of diagnosis, or an AIDS-defining illness at diagnosis or within one year of HIV diagnosis.[5] We excluded cases whose

first available date of CD4 count was more than 90 days after their HIV diagnosis date as they would most likely to have started treatment on their first date of CD4 count, hence whether these cases had late-stage infection or not was unknown.

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of the study results.

Statistical analysis

Changes in proportions over time were analysed using the Chi-square test for trend. The Chi-square test or Fisher's exact test, where appropriate, was used for comparison of categorical variables. The Mann-Whitney U test was used to assess differences between any two groups for continuous variables. For variables with missing data proportion less than 10%, we used missForest (version 1.4), an iterative non-parametric method, to impute the missing values.[9]

The main outcome was whether the person had previous HIV tests prior to diagnosis. Crude odds ratios (OR) and adjusted odds ratio (aOR) along with 95% confidence interval (CI) were calculated based on logistic regression models. Multivariable analysis was conducted to determine factors independently associated with no previous HIV testing. Variables with p <0.10 in the univariable regression analyses were considered for inclusion in a backward selection process, and retained in the final multivariable model only when p <0.05. We performed separate logistic regression analyses for two groups: early and late stages of HIV infection at diagnosis.

All p values reported were 2-sided and statistical significance was taken as p <0.05. Statistical analyses were performed using SPSS version 24 (IBM, USA) and R version 3.5.0 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

A total of 2,579 new HIV/AIDS cases infected via sexual transmission were notified to the National HIV Registry in 2012–2017. We excluded 391 cases from this study; 282 had unknown HIV testing history and another 109 did not have CD4 cell counts measured at diagnosis. Among the 2,188 cases included in the study, 45.1% had no previous HIV testing prior to diagnosis. There was a significant decline in the annual proportion of cases with no previous HIV testing; from 53.6% in 2012 to 40.1% in 2017 ($p < 0.0005$) (Fig. 1). The annual proportion without previous HIV testing was consistently higher in cases diagnosed at late-stage than early-stage of HIV infection.

The median age of the 2,188 HIV/AIDS cases was 40 years (interquartile range [IQR], 30–51). About 93.5% of the cases were men, 71.8% were Chinese, 68.8% had never been married, 67.0% had attained post-secondary education or diploma levels (67.0%), and 62.5% worked in professional/managerial positions or administrative/service sectors (Table 1). About 45.7% of the cases were detected during the course of medical care wherein HIV testing was performed as part of the diagnostic evaluation for their presenting symptoms, while 28.1% were detected via routine programmatic HIV screening which included screening programmes for those with sexually transmitted infections (STIs), hospital inpatients and those identified through contact tracing. Over half of the cases were infected via homosexual/bisexual route of transmission (58.8%), had regular and casual sexual partners only (62.0%), were diagnosed at early-stage HIV infection (55.3%), and did not have any self-reported history of STIs (76.2%).

Compared with cases who had previous HIV testing, a significantly higher proportion of cases without previous testing were aged 45 years or older at HIV diagnosis (59.7% vs. 21.0%), women (10.6% vs. 3.2%), had ever been married

(48.9% vs. 16.6%), had a secondary education or below (29.3% vs. 11.2%), and were blue-collar workers (23.0% vs. 4.8%) or unemployed (4.4% vs. 2.2%) (Table 1). A significantly higher proportion of cases without previous HIV tests were diagnosed in the course of medical care (65.5% vs. 29.5%), infected via heterosexual transmission (64.1% vs. 22.4%), and had sex workers and social escorts as sexual partners (39.0% vs. 15.9%). The proportion without any self-reported history of STIs was significantly higher among cases without previous tests than in those who had ever been tested for HIV prior to diagnosis (81.0% vs. 72.3%). The proportion of late-stage HIV infection among cases without previous tests was about two times that of those with previous HIV tests (63.9% vs. 29.0%).

Table 1. Characteristics (%) of sexually transmitted HIV/AIDS cases by history of HIV testing prior to diagnosis in Singapore, 2012–2017.

Characteristic	Total (N=2,188)	No previous HIV tests (N=986)	Had previous HIV tests (N=1,202)	*P*-value
	n (%)	n (%)	n (%)	
Age group (years)				<0.0005
15–24	231 (10.6)	59 (6.0)	172 (14.3)	
25–34	548 (25.0)	138 (14.0)	410 (34.1)	
35–44	567 (25.9)	200 (20.3)	367 (30.5)	
45–54	487 (22.3)	303 (30.7)	184 (15.3)	
55–64	274 (12.5)	211 (21.4)	63 (5.2)	
≥65	81 (3.7)	75 (7.6)	6 (0.5)	
Gender				<0.0005
Male	2045 (93.5)	881 (89.4)	1164 (96.8)	
Female	143 (6.5)	105 (10.6)	38 (3.2)	
Ethnic group				0.092
Chinese	1571 (71.8)	700 (71.0)	871 (72.5)	
Malay	413 (18.9)	193 (19.6)	220 (18.3)	
Indian	122 (5.6)	64 (6.5)	58 (4.8)	
Others	82 (3.7)	29 (2.9)	53 (4.4)	
Marital status				<0.0005
Never married	1506 (68.8)	504 (51.1)	1002 (83.4)	
Married	469 (21.4)	326 (33.1)	143 (11.9)	
Separated/Divorced/Widowed	213 (9.7)	156 (15.8)	57 (4.7)	
Educational level				<0.0005
No formal / Primary	161 (7.4)	129 (13.1)	32 (2.7)	
Secondary	263 (12.0)	160 (16.2)	103 (8.6)	
Post-secondary / Diploma	1466 (67.0)	630 (63.9)	836 (69.6)	
University degree or higher	290 (13.3)	63 (6.4)	227 (18.9)	
Unknown	8 (0.4)	4 (0.4)	4 (0.3)	

Characteristic	Total (N=2,188)	No previous HIV tests (N=986)	Had previous HIV tests (N=1,202)	*P*-value
Occupational type				<0.0005
Professional / executive	463 (21.2)	155 (15.7)	308 (25.6)	
Administrative / service	904 (41.3)	380 (38.5)	524 (43.6)	
Blue-collar worker	285 (13.0)	227 (23.0)	58 (4.8)	
Unemployed	69 (3.2)	43 (4.4)	26 (2.2)	
Others	302 (13.8)	112 (11.4)	190 (15.8)	
Unknown	165 (7.5)	69 (7.0)	96 (8.0)	
Mode of detection				<0.0005
Voluntary screening	452 (20.7)	69 (7.0)	383 (31.9)	
Medical care	1001 (45.7)	646 (65.5)	355 (29.5)	
Routine programmatic HIV screening‡	615 (28.1)	241 (24.4)	374 (31.1)	
Others	120 (5.5)	30 (3.0)	90 (7.5)	
Mode of HIV transmission				<0.0005
Homosexual/bisexual	1287 (58.8)	354 (35.9)	933 (77.6)	
Heterosexual	901 (41.2)	632 (64.1)	269 (22.4)	
Type of sexual partners				<0.0005
Regular only	246 (11.2)	126 (12.8)	120 (10.0)	
Regular and casual only	1357 (62.0)	471 (47.8)	886 (73.7)	
Sex workers and social escorts	576 (26.3)	385 (39.0)	191 (15.9)	
Unknown	9 (0.4)	4 (0.4)	5 (0.4)	
Self-reported history of STIs				<0.0005
No	1668 (76.2)	799 (81.0)	869 (72.3)	
Yes	520 (23.8)	187 (19.0)	333 (27.7)	
Stage of HIV infection				<0.0005
Early	1210 (55.3)	356 (36.1)	854 (71.0)	
Late	978 (44.7)	630 (63.9)	348 (29.0)	

STIs, sexually transmitted infections.
‡ Routine programmatic HIV screening includes screening programmes for those with STIs, hospital inpatients and those identified through contact tracing.

Among the 1,202 cases who had previous HIV tests, 1,122 (93.3%) reported a negative result for the last test prior to diagnosis and their median duration from the last negative test to HIV diagnosis was 2.1 years (IQR 1.0–4.4). This interval was significantly longer at 3.8 years (IQR 2.0–7.3) among the 320 cases diagnosed at late-stage HIV infection compared with 1.7 years (IQR 0.8–3.2) among the 802 cases diagnosed early ($p < 0.0005$) (Fig. 2).

Popular test sites among cases with previous HIV tests were anonymous test sites (32.1%), primary care clinics (23.3%) and the Department of STI Control (DSC) Clinic, a specialist outpatient clinic for the diagnosis, treatment and control of STIs (12.8%). The median duration from the last negative test to HIV diagnosis was 1.5

years (IQR 0.7–2.9) at anonymous test sites, compared with 2.5 years (IQR 1.2–5.2) at other test sites (p<0.0005).

About 49.4% of the 360 cases who previously tested negative at anonymous test sites were subsequently diagnosed with HIV via voluntary outpatient screening, while the rest were diagnosed via medical care or routine programmatic HIV screening. About 79.4% of these cases had early-stage HIV infection at diagnosis. Among HIV/AIDS cases who had previous HIV tests, the proportion last tested negative at anonymous test sites was significantly higher in those diagnosed at early-stage than late-stage of HIV infection (35.7% vs 23.1%) (p<0.0005) (Fig. 3).

The most common reason cited by cases who did not have any previous HIV testing prior to diagnosis was “not necessary to test” (73.7%), followed by “does not want to know status” (8.1%) and “fear of stigmatisation / rejection” (4.5%). There was a significantly higher proportion of cases diagnosed late (76.3%) who cited “not necessary to test” compared with those diagnosed early (69.1%) (p=0.01) (Fig. 4).

Four factors were independently associated with no previous HIV testing among cases diagnosed at late-stage of infection: older age at HIV diagnosis (≥55 years vs 15–24 years), lower educational level (vs university degree or higher), detection via medical care (vs voluntary screening), and HIV infection via heterosexual transmission (vs homosexual/bisexual transmission) (Table 2). The following six factors were independently associated with no previous HIV testing among cases diagnosed at early-stage: older age at HIV diagnosis (≥45 years vs 15–24 years), women, Malays (vs Chinese), lower educational level (vs university degree or higher), detection via medical care and routine programmatic HIV screening (vs voluntary screening), and HIV infection via heterosexual transmission (vs homosexual/bisexual transmission) (Table 3).

Table 2. Proportion and odds ratios of absence of previous HIV testing in sexually transmitted HIV/AIDS cases diagnosed at late-stage HIV infection in Singapore, 2012–2017.

Characteristic	% without previous HIV testing	Univariable model			Multivariable model		
		cOR	(95% CI)	*p* value	aOR	(95% CI)	*p* value
Age at diagnosis (years)				<0.0005			<0.0005
15–24	44.4	1.00	Referent		1.00	Referent	
25–34	38.4	0.78	(0.34–1.78)	0.552	0.76	(0.31–1.85)	0.546
35–44	49.6	1.23	(0.55–2.73)	0.610	0.89	(0.38–2.11)	0.794
45–54	73.6	3.48	(1.56–7.76)	0.002	1.97	(0.83–4.68)	0.126
55–64	83.6	6.37	(2.72–14.92)	<0.0005	2.71	(1.07–6.85)	0.035
≥65	93.4	17.81	(5.02–63.20)	<0.0005	6.14	(1.60–23.50)	0.008
Gender							
Male	62.8	1.00	Referent				
Female	83.1	2.91	(1.58–5.37)	0.001			
Ethnic group				0.087			
Chinese	65.6	1.00	Referent				
Malay	60.3	0.80	(0.57–1.12)	0.194			
Indian	73.3	1.44	(0.73–2.84)	0.290			
Others	50.0	0.52	(0.27–1.01)	0.053			
Marital status				<0.0005			
Single	51.7	1.00	Referent				
Married	82.2	4.30	(3.02–6.13)	<0.0005			
Divorced/ separated/ widowed	81.3	4.05	(2.58–6.35)	<0.0005			
Educational level†				<0.0005			0.039
No formal / Primary	88.9	14.45	(6.87–30.39)	<0.0005	3.23	(1.40–7.46)	0.006
Secondary	66.9	3.65	(2.09–6.37)	<0.0005	1.51	(0.81–2.84)	0.195
Post-secondary / Diploma	63.6	3.16	(1.98–5.04)	<0.0005	1.75	(1.03–2.96)	0.038
University degree or higher	35.6	1.00	Referent		1.00	Referent	
Occupational type†				<0.0005			
Professional / executive	49.0	1.00	Referent				
Administrative / service	58.7	1.48	(1.05–2.07)	0.023			
Blue-collar worker	84.5	5.66	(3.58–8.95)	<0.0005			
Unemployed	80.4	4.27	(2.03–8.98)	<0.0005			
Others	68.2	2.23	(1.31–3.81)	0.003			
Mode of detection				<0.0005			<0.0005
Voluntary screening	26.7	1.00	Referent		1.00	Referent	
Medical care	72.7	7.30	(4.40–12.10)	<0.0005	4.15	(2.35–7.33)	<0.0005
Routine programmatic HIV screening‡	54.1	3.23	(1.82–5.71)	<0.0005	1.90	(0.99–3.65)	0.054

Characteristic	% without previous HIV testing	Univariable model			Multivariable model		
		cOR	(95% CI)	*p* value	aOR	(95% CI)	*p* value
Others	36.4	1.57	(0.67–3.68)	0.304	0.89	(0.34–2.34)	0.819
Mode of sexual transmission							
Homosexual/bisexual	43.1	1.00	Referent		1.00	Referent	
Heterosexual	81.3	5.76	(4.32–7.67)	<0.0005	3.46	(2.50–4.80)	<0.0005
Type of sexual partners†				<0.0005			
Regular only	74.5	1.00	Referent				
Regular and casual only	52.9	0.39	(0.24–0.63)	<0.0005			
Sex workers and social escorts	78.8	1.27	(0.75–2.14)	0.369			
History of STIs							
Yes	57.7	1.00	Referent				
No	65.8	1.41	(1.00–1.98)	0.048			

cOR, crude odds ratio; aOR, adjusted odds ratio; STIs, sexually transmitted infections.

‡ Routine programmatic HIV screening includes screening programmes for those with STIs, hospital inpatients and those identified through contact tracing.

† Missing data were imputed.

Table 3. Proportion and odds ratios of absence of previous HIV testing in sexually transmitted HIV/AIDS cases diagnosed at early-stage HIV infection in Singapore, 2012–2017.

Characteristic	% without previous HIV testing	Univariable model			Multivariable model		
		cOR	(95% CI)	*p* value	aOR	(95% CI)	*p* value
Age at diagnosis (years)				<0.0005			<0.0005
15–24	23.0	1.00	Referent		1.00	Referent	
25–34	20.4	0.86	(0.57–1.29)	0.453	1.07	(0.69–1.67)	0.758
35–44	23.5	1.02	(0.67–1.56)	0.909	1.07	(0.67–1.71)	0.769
45–54	44.1	2.64	(1.71–4.08)	<0.0005	2.26	(1.38–3.73)	0.001
55–64	62.4	5.53	(3.20–9.56)	<0.0005	3.18	(1.70–5.96)	<0.0005
≥65	90.0	30.06	(6.73–134.30)	<0.0005	13.17	(2.80–62.03)	0.001
Gender							
Male	27.5	1.00	Referent		1.00	Referent	
Female	62.1	4.32	(2.58–7.22)	<0.0005	2.07	(1.13–3.78)	0.018
Ethnic group				0.002			0.004
Chinese	26.7	1.00	Referent		1.00	Referent	
Malay	36.8	1.60	(1.18–2.17)	0.002	1.76	(1.24–2.50)	0.002
Indian	40.3	1.85	(1.14–2.99)	0.012	1.21	(0.70–2.08)	0.499
Others	22.7	0.81	(0.39–1.66)	0.561	0.53	(0.24–1.18)	0.119
Marital status				<0.0005			

Characteristic	% without previous HIV testing	Univariable model			Multivariable model		
		cOR	(95% CI)	*p* value	aOR	(95% CI)	*p* value
Single	22.5	1.00	Referent				
Married	52.5	3.80	(2.77–5.22)	<0.0005			
Divorced/ separated/ widowed	56.5	4.47	(2.71–7.37)	<0.0005			
Educational level*				<0.0005			<0.0005
No formal / Primary	63.0	8.81	(4.52–17.15)	<0.0005	2.22	(1.04–4.75)	0.040
Secondary	53.0	5.85	(3.47–9.87)	<0.0005	2.80	(1.56–5.04)	0.001
Post-secondary / Diploma	27.2	1.94	(1.30–2.90)	0.001	1.15	(0.74–1.79)	0.538
University degree or higher	16.2	1.00	Referent		1.00	Referent	
Occupational type†				<0.0005			
Professional / executive	21.4	1.00	Referent				
Administrative / service	28.0	1.43	(1.02–2.00)	0.038			
Blue-collar worker	61.6	5.88	(3.67–9.43)	<0.0005			
Unemployed	36.8	2.14	(1.05–4.37)	0.037			
Others	26.0	1.29	(0.86–1.93)	0.223			
Mode of detection				<0.0005			<0.0005
Voluntary screening	12.6	1.00	Referent		1.00	Referent	
Medical care	45.5	5.81	(3.96–8.53)	<0.0005	3.66	(2.39–5.59)	<0.0005
Routine programmatic HIV screening‡	34.0	3.58	(2.49–5.16)	<0.0005	2.66	(1.79–3.95)	<0.0005
Others	20.7	1.81	(0.99–3.32)	0.053	1.41	(0.74–2.70)	0.294
Mode of sexual transmission							
Homosexual/bisexual	19.6	1.00	Referent		1.00	Referent	
Heterosexual	53.0	4.60	(3.52–6.02)	<0.0005	2.17	(1.55–3.04)	<0.0005
Type of sexual partners†				<0.0005			
Regular only	36.0	1.00	Referent				
Regular and casual only	23.3	0.54	(0.37–0.78)	0.001			
Sex workers and social escorts	47.8	1.63	(1.06–2.48)	0.025			
History of STIs							
Yes	25.6	1.00	Referent				
No	31.0	1.31	(0.99–1.73)	0.060			

cOR, crude odds ratio; aOR, adjusted odds ratio; STIs, sexually transmitted infections.

‡ Routine programmatic HIV screening includes screening programmes for those with STIs, hospital inpatients and those identified through contact tracing.

† Missing data were imputed.

DISCUSSION

This study highlights the missed opportunities for early diagnosis in persons at risk of HIV infection who do not undergo regular testing. Slightly less than half of the HIV/AIDS cases reported no previous HIV test prior to diagnosis during the six-year study period. Close to two-thirds of the cases diagnosed at late-stage HIV infection did not have previous HIV tests, more than twice the proportion among those diagnosed early (29.4%). Among those who had undergone previous HIV tests prior to diagnosis, the median duration from the last negative test to HIV diagnosis was 3.8 years among cases with late-stage HIV infection, double that of those diagnosed early.

Policy makers, providers of healthcare and patients, or "the 3 P's", play an important role in addressing the barriers to HIV testing which lead to delayed diagnosis.[10] On the policy front, many initiatives to facilitate testing has been implemented in Singapore. Screening for HIV has constituted part of the routine mandatory antenatal screening package since December 2004. To encourage voluntary screening by reducing the stigma associated with seeking HIV testing, the Ministry of Health (MOH) has introduced anonymous HIV testing using oral-fluid or blood-based rapid HIV test kits at selected GP clinics and test sites run by community-based organisations since August 2007.[11] All acute hospitals have implemented the opt-out HIV screening programme for inpatients aged 21 years and older since October 2008.[12] However, the rate of inpatient HIV testing remains low.[13,14]

HIV infection has a long clinical latency period during which infected individuals may show no symptoms. Relying on symptom-based HIV diagnosis would lead to late diagnosis, missing the opportunity of early detection.[15,16] Hence, it is crucial to provide a system that can support HIV testing with minimal inconvenience, so as to encourage greater uptake of HIV screening among those who are at risk regardless of whether they are asymptomatic or symptomatic. This study demonstrated the usefulness of anonymous

testing as an avenue to facilitate early diagnosis of HIV in Singapore. Anonymous testing offers privacy and confidentiality that encourages more people to check their HIV status. Our study found that the anonymous test sites were the most popular among cases for their last negative HIV test prior to diagnosis (Fig. 3). There are now ten anonymous HIV test sites in Singapore, comprising nine GP clinics and a test site operated by Action for AIDS (AfA), a local non-governmental HIV/AIDS community-based organization.[17] To make voluntary HIV screening more accessible and convenient in Singapore, AfA launched the first Mobile Testing & Counselling Service which provides anonymous HIV and syphilis testing on wheels in December 2011.[18] The number of HIV tests conducted at anonymous test sites increased by 25% from 13,900 in 2013 to 17,400 in 2017.[19] **Error! Bookmark not defined.**At-risk individuals who go to anonymous test sites are more likely to have HIV testing on a regular basis or at a shorter inter-test interval, as reflected by the higher proportion of cases diagnosed early (79.4%) among those who were last tested negative at these test sites and the shorter median duration from the last negative test to HIV diagnosis compared with other test sites (1.5 vs 2.5 years).

As this study identified a significant proportion (63.9%) of late-stage HIV infection among HIV/AIDS cases who did not have previous HIV tests, healthcare providers should have a higher index of suspicion for HIV infection among at-risk groups, and recommend a HIV test where appropriate[10]. In a study on HIV testing behaviour among HIV-uninfected, at-risk adolescents and those who were HIV-infected in the United States, 67% of the high-risk group and 53% of the HIV-infected group cited recommendation by healthcare professionals as a reason to undergo HIV testing.[20] There is a need for physicians to be cognizant of their prejudices or prejudgments as these would influence their approach towards patients and recommendation of HIV testing.[21]

Individuals, especially those at high risk of STIs and HIV, would benefit from having better knowledge about HIV and the symptoms related to acute or advanced HIV infection,

as well as the benefits of early diagnosis and linkage to care.[10] In our study, about three-quarters of cases who had no previous HIV testing deemed that it was "not necessary to test", and the proportion was significantly higher among those with late-stage than early-stage HIV infection at diagnosis (76.3% vs. 69.1%) (Fig. 4), which likely represents a lack of knowledge of their own risk of HIV infection despite ongoing risk behaviour.

Four common risk factors were associated with no previous HIV testing in multivariable analyses in both early and late stages of HIV infection at diagnosis: older age, lower educational level, detection in the course of medical care and heterosexual transmission (Tables 2 and 3). Older persons may perceive themselves to be at lower risk of HIV infection, or may be less aware of HIV and more reluctant to undergo HIV testing. Lower educational level was an impediment in having HIV tests among men having sex with men (MSM) in some studies.[22-25] HIV testing is most likely to be initiated only during medical care due to clinical suspicion of HIV infection based on disease presentations or risk profiles.**Error! Bookmark not defined.** In a local study on men diagnosed in 1985–2007 who were infected with HIV via sexual transmission, the cumulative proportion detected during medical care surviving until the eighth year since diagnosis was 51.8%, compared to 69.1% among those diagnosed as a result of voluntary screening.[26]

Our study revealed that HIV cases infected via heterosexual transmission were less likely to have had previous testing prior to diagnosis. Similarly, in the United States, heterosexuals at high risk are known to have lower testing frequency than other groups such as MSM.[27] According to a systematic review of 19 studies that evaluated behavioural preventive interventions in low- and middle-income countries, heterosexual men remained under-represented in HIV prevention efforts.[28] This finding indicated the need to increase HIV testing rates among high-risk heterosexual men.

In a separate analysis for early-stage HIV infection, women were less likely to have previous HIV testing prior to their diagnosis. HIV/AIDS cases diagnosed in Singapore are

predominantly men with male to female ratio of 9:1. Women who believe that their sexual partners are faithful in the relationship are less likely to perceive themselves to be at risk of HIV infection. Among women diagnosed early, those of Malay ethnicity were more likely not to have had previous testing for HIV prior to diagnosis when compared with ethnic Chinese. This could be due to HIV-related stigma arising from the influence of culture and religiosity. In Malaysia, a study conducted in 2012-2013 found high HIV-related stigma, which was significantly correlated with disclosure of HIV status among Malay Muslim HIV patients.[29] Besides diagnosis of HIV in the course of medical care, women at early-stage of HIV infection detected via routine programmatic HIV screening were also more likely to have had no previous testing prior to diagnosis.

There are several limitations in this study. The cross-sectional design of our study did not allow us to make inference about the causality of having had no previous HIV testing and the associated factors. Our study used the epidemiological data collected in the National HIV Registry which was not designed to investigate determinants of previous HIV testing. Hence, not all potential confounding factors could be included in our study, and information on drivers and barriers of HIV testing was unavailable. Qualitative studies are needed to delineate the processes underlying different patterns of testing in local context[30]. As testing-related variables were ascertained based on self-reporting by HIV/AIDS cases, some extent of misclassification due to recall bias could not be avoided.

In conclusion, the proportion of cases who had never been tested for HIV prior to HIV diagnosis was 45.1%, which reflects the missed opportunities for early diagnosis and treatment. Our study findings highlight the need for concerted efforts to raise awareness of the importance of early and regular HIV testing and boost its uptake by making HIV testing more accessible and less discriminatory, particularly among the high-risk groups in Singapore.

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Contributors

LWA conceived the study, did statistical analysis and wrote the first draft of the manuscript. All authors (LWA, MPHST, ICB, CSW, SA, VJML, AC, YSL) contributed to data interpretation, revised the manuscript and approved the submission.

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None declared.

Patient consent for publication

Not applicable.

Provenance and peer review

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Data availability statement

All data relevant to the study are included in the article.

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Figure captions

Figure 1. Percentage of sexually transmitted HIV/AIDS cases who did not have HIV tests prior to diagnosis by stage of HIV infection at diagnosis in Singapore, 2012–2017

Figure 2. Histogram of time interval (in years) from last negative test to diagnosis among sexually transmitted HIV/AIDS cases who had previous HIV tests prior to diagnosis by stage of HIV infection at diagnosis in Singapore, 2012–2017

Figure 3. Distribution (%) of test sites of sexually transmitted HIV/AIDS cases for their last negative HIV test result prior to diagnosis by stage of HIV infection at diagnosis in Singapore, 2012–2017

* Other test sites include Communicable Disease Centre, blood bank and Singapore Anti-Tuberculosis Association.

Figure 4. Distribution (%) of reasons for no previous HIV test prior to diagnosis among sexually transmitted HIV cases by stage of HIV infection at diagnosis in Singapore, 2012–2017

* Other reasons include concern about confidentiality of test result and fear of needles.

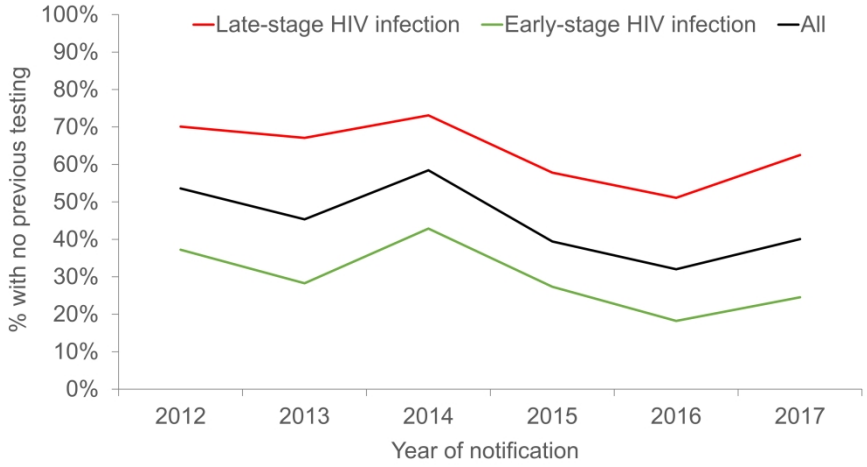

Figure 1. Percentage of sexually transmitted HIV/AIDS cases who did not have HIV tests prior to diagnosis by stage of HIV infection at diagnosis in Singapore, 2012–2017.

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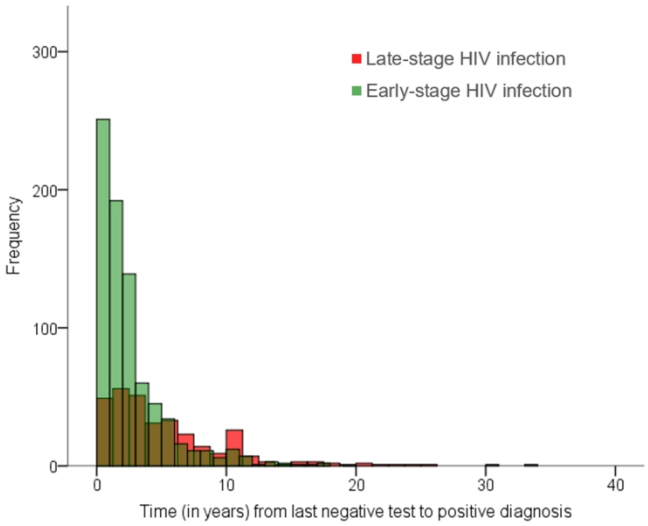

Figure 2. Histogram of time interval (in years) from last negative test to diagnosis among sexually transmitted HIV/AIDS cases who had previous HIV tests prior to diagnosis by stage of HIV infection at diagnosis in Singapore, 2012–2017.

338x190mm (300 x 300 DPI)

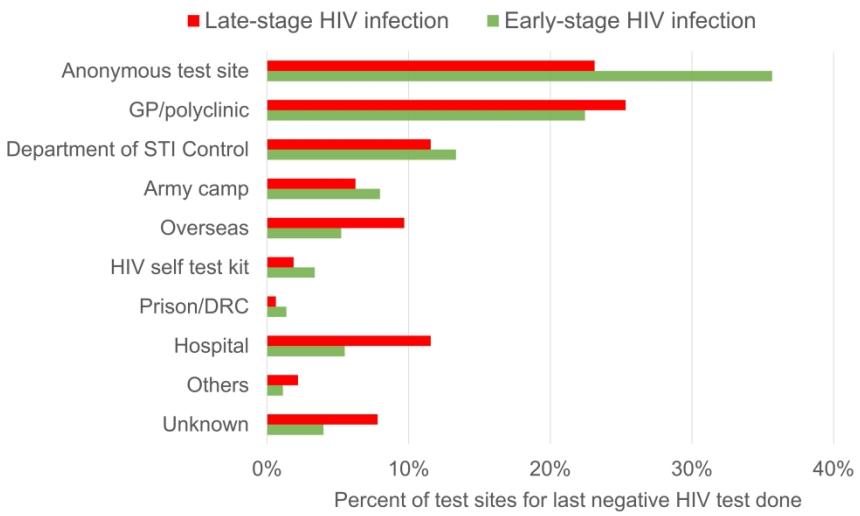

Figure 3. Distribution (%) of test sites of sexually transmitted HIV/AIDS cases for their last negative HIV test result prior to diagnosis by stage of HIV infection at diagnosis in Singapore, 2012–2017.

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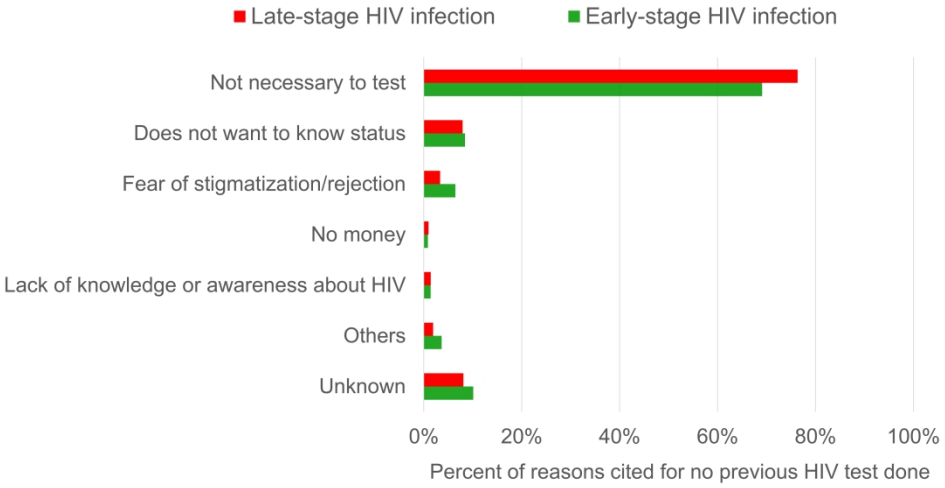

Figure 4. Distribution (%) of reasons for no previous HIV test prior to diagnosis among sexually transmitted HIV cases by stage of HIV infection at diagnosis in Singapore, 2012–2017.

338x190mm (300 x 300 DPI)

Missed opportunities for early HIV diagnosis: Epidemiological factors associated with the absence of previous HIV testing among HIV-infected persons in Singapore, 2012 to 2017

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	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	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	6
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
Bias	9	Describe any efforts to address potential sources of bias	-
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7

		(*c*) Explain how missing data were addressed	7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	-
		(*e*) Describe any sensitivity analyses	-
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	7-8
		(b) Give reasons for non-participation at each stage	-
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	9-10
Outcome data	15*	Report numbers of outcome events or summary measures	9-11
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	11-14
		(*b*) Report category boundaries when continuous variables were categorized	9,12-13
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	-
Discussion			
Key results	18	Summarise key results with reference to study objectives	15
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	18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15-18
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	-

*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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Epidemiological factors associated with the absence of previous HIV testing among HIV-positive persons in Singapore, 2012 to 2017

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Epidemiological factors associated with the absence of previous HIV testing among HIV-positive persons in Singapore, 2012 to 2017

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ABSTRACT

Objective: To assess temporal trend and identify risk factors associated with the absence of previous HIV testing prior to their diagnosis among HIV-positive persons in Singapore.

Study design: Cross-sectional.

Setting and participants: We analyzed data of HIV-positive persons infected via sexual transmission, who were notified to the National HIV Registry in 2012–2017.

Outcomes: Epidemiological factors associated with the absence of HIV testing prior to diagnosis were determined separately for two groups of HIV-positive persons: early and late stages of HIV infection at diagnosis.

Results: 2,188 HIV-positive persons with information on HIV testing history and CD4 cell count were included in the study. The median age at HIV diagnosis was 40 years (interquartile range [IQR], 30–51). Nearly half (45.1%) had never been tested for HIV prior to their diagnosis. The most common reason cited for no previous HIV testing was “not necessary to test” (73.7%). The proportion diagnosed at late-stage HIV infection was significantly higher among HIV-positive persons who had never been tested for HIV (63.9%) compared with those who had undergone previous HIV tests (29.0%). Common risk factors associated with no previous HIV testing in multivariable logistic regression analysis stratified by stage of HIV infection were: older age at HIV diagnosis, lower educational level, detection via medical care, and HIV infection via heterosexual transmission. In the stratified analysis for persons diagnosed at early-stage of HIV infection, in addition to the four risk factors, women and those of Malay ethnicity were also less likely to have previous HIV testing prior to their diagnosis.

Conclusion: Targeted prevention efforts and strategies are needed to raise the level of awareness of HIV/AIDS and to encourage early and regular screening among the at-risk groups by making HIV testing more accessible.

(Word count: 279)

Keywords: late-stage, HIV testing; risk factors, screening

ARTICLE SUMMARY

Strengths and limitations of this study

- We were able to use the epidemiological data collected in the National HIV Registry in Singapore, which improves the generalisability of the findings.
- Not all potential confounding factors associated with absence of prior HIV testing prior to HIV diagnosis could be included in our study, and information on drivers and barriers of HIV testing was unavailable.
- As testing-related variables were ascertained based on self-reporting by HIV/AIDS cases, some extent of misclassification due to recall bias could not be avoided.

INTRODUCTION

Regular HIV testing among at-risk individuals is paramount as a preventive strategy in the programmatic response to HIVAIDS epidemic. The Joint United Nations Programme on HIV/AIDS (UNAIDS) and partners launched the 90–90–90 targets in 2014, which called for 90% of all people living with HIV (PLHIV) to be aware of their status, 90% of those diagnosed to receive antiretroviral therapy (ART), and 90% of those on ART to achieve viral suppression by 2020.[1] The corresponding estimates for PLHIV in Singapore were 80%, 91% and 91% in 2018.[2] Regular and frequent HIV testing provides an essential gateway to serostatus awareness and early diagnosis, thereby enhancing the effectiveness of all subsequent steps in the cascade of HIV care including provision of ART and counselling on behaviour. The risk of onward transmission by persons who are unaware of their HIV infection and premature deaths is also reduced with diagnosis of HIV infection at an early stage.

As of end-2019, there were 8,618 Singapore residents diagnosed with HIV infection, of whom 2,097 had died.[3] Despite the widespread availability and accessibility of HIV testing in Singapore, late diagnosis in the course of HIV infection continues to be a barrier in tackling HIV.[4] A local study revealed that over half (54%) of HIV-positive persons infected via sexual transmission in 1996–2009 had late-stage disease at diagnosis.[5] The higher short-term mortality of persons diagnosed with late-stage HIV infection underscores the importance of testing and detection at the earliest opportunity.[6] Another local study found that the median survival of HIV-positive persons diagnosed late was 5 years, whereas the cumulative proportion of those diagnosed early surviving until the fifth year since diagnosis was 80%.[7]

This study seeks to elucidate epidemiological factors associated with the absence of previous HIV testing prior to their diagnosis separately for HIV-positive persons diagnosed at early and late stages of HIV infection. The findings provide insights into reviewing and tailoring public health preventive and interventional

strategies to increase the uptake of HIV testing in at-risk groups, so as to facilitate early diagnosis and timely initiation of ART for HIV-infected persons.

MATERIALS AND METHODS

Study population

Notification of HIV/AIDS diagnosis is mandatory under the Infectious Diseases Act in Singapore[8]. Information collected in the National HIV Registry is protected under the law, and includes socio-demographic characteristics, CD4 cell count, mode of detection and exposure factors such as the mode of transmission and the type of sexual partners.

Information on risk factors and current and previous HIV testing behaviour is obtained from review of medical case notes and interviews with persons who are diagnosed with HIV. The mode of HIV transmission consists of sexual contact (heterosexual, homosexual, or bisexual), intravenous drug use, blood transfusion, renal transplant overseas, perinatal (mother to child), and uncertain/others. The mode of detection consists of voluntary screening (own request), medical care for HIV related symptoms and non-HIV care, routine programmatic HIV screening (includes screening programmes for those with sexually transmitted infections [STIs], hospital inpatients and those identified through contact tracing), and other reasons for current HIV testing such as health screening for life insurance application. We classified the type of sexual partners into mutually exclusive categories (regular only; regular and casual only; sex workers and social escorts) based on the following groups: casual; regular; spouse / girlfriend / boyfriend; sex worker (brothel-based), sex worker (non-brothel) / social escort; ex-spouse / ex-girlfriend / ex-boyfriend.

Data on self-reported history of HIV testing has been collected since 2010, and the proportion of missing data dropped from 39% in 2010 to below 20% since 2012. The majority (95.1%) of HIV-positive persons reported in 1985–2017 were

infected via sexual transmission, hence we restricted the analyses to those infected via sexual transmission to allow for a more homogenous group. The study population were sexually transmitted HIV-positive persons diagnosed and notified to the National HIV Registry in 2012–2017. Approval for this study was provided by the Ministry of Health, Singapore. As the data was collected under the Infectious Diseases Act and analyses were performed on an anonymized dataset, informed consent was not required for this study.

The analyses were stratified by stage of HIV infection at diagnosis (early or late), hence HIV-positive persons with either unknown HIV testing history or missing CD4 count at diagnosis were excluded. Factors associated with no previous HIV testing were deemed to differ depending on the stage of infection at diagnosis, hence separate analysis was conducted for HIV-positive persons diagnosed at early and late stages of infection. Late-stage HIV infection was defined as having either a CD4 count <200 cells/mm^3 at the time of diagnosis, or an AIDS-defining illness at diagnosis or within one year of HIV diagnosis.[5] To ensure accuracy in classifying late-stage HIV infection based on CD4 count <200 cells/mm^3, efforts were taken to exclude acute infection through the process of contact tracing interviews, which include questions about previous HIV tests. Recency assays to document or confirm acute infections were not done routinely or universally for all persons newly-diagnosed with HIV. We excluded HIV-positive persons whose first available date of CD4 count was more than 90 days after their HIV diagnosis date as they would most likely to have started treatment on their first date of CD4 count, hence whether these individuals had late-stage infection or not was unknown.

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of the study results.

Statistical analysis

Changes in proportions over time were analysed using the Chi-square test for trend. The Chi-square test or Fisher's exact test, where appropriate, was used for comparison of categorical variables. The Mann-Whitney U test was used to assess differences between any two groups for continuous variables. For variables with missing data proportion less than 10%, we used missForest (version 1.4), an iterative non-parametric method, to impute the missing values.[9]

The main outcome was whether the HIV-positive person had previous HIV tests prior to diagnosis. Crude odds ratios (OR) and adjusted odds ratio (aOR) along with 95% confidence interval (CI) were calculated based on logistic regression models. Multivariable analysis was conducted to determine factors independently associated with no previous HIV testing. Variables with p <0.10 in the univariable regression analyses were considered for inclusion in a backward selection process, and retained in the final multivariable model only when p <0.05. We performed separate logistic regression analyses for two groups: early and late stages of HIV infection at diagnosis.

All p values reported were 2-sided and statistical significance was taken as p <0.05. Statistical analyses were performed using SPSS version 24 (IBM, USA) and R version 3.5.0 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

A total of 2,579 newly-diagnosed HIV-positive persons infected via sexual transmission were notified to the National HIV Registry in 2012–2017. We excluded 391 cases from this study; 282 had unknown HIV testing history and another 109 did not have CD4 cell counts measured at diagnosis. Among the 2,188 HIV-positive persons included in the study, 45.1% had no previous HIV testing prior to diagnosis.

There was a significant decline in the annual proportion of HIV-positive persons with no previous HIV testing; from 53.6% in 2012 to 40.1% in 2017 ($p < 0.0005$) (Fig. 1). The annual proportion without previous HIV testing was consistently higher in persons diagnosed at late-stage than early-stage of HIV infection.

The median age of the 2,188 HIV-positive persons was 40 years (interquartile range [IQR], 30–51). About 93.5% were men, 71.8% were Chinese, 68.8% had never been married, 67.0% had attained post-secondary education or diploma levels (67.0%), and 62.5% worked in professional/managerial positions or administrative/service sectors (Table 1). About 45.7% of the HIV-positive persons were detected during the course of medical care wherein HIV testing was performed as part of the diagnostic evaluation for their presenting symptoms, while 28.1% were detected via routine programmatic HIV screening. Over half of the HIV-positive persons were infected via homosexual/bisexual route of transmission (58.8%), had regular and casual sexual partners only (62.0%), were diagnosed at early-stage of HIV infection (55.3%), and did not have any self-reported history of STIs (76.2%).

Characteristics of HIV-positive persons with and without previous HIV testing

Compared with HIV-positive persons who had previous HIV testing, a significantly higher proportion of those without previous testing were aged 45 years or older at HIV diagnosis (59.7% vs. 21.0%), women (10.6% vs. 3.2%), had ever been married (48.9% vs. 16.6%), had a secondary education or below (29.3% vs. 11.2%), and were blue-collar workers (23.0% vs. 4.8%) or unemployed (4.4% vs. 2.2%) (Table 1). A significantly higher proportion of HIV-positive persons without previous HIV tests were diagnosed in the course of medical care (65.5% vs. 29.5%), infected via heterosexual transmission (64.1% vs. 22.4%), and had sex workers and social escorts as sexual partners (39.0% vs. 15.9%). The proportion without any self-reported history of STIs was significantly higher among HIV-positive persons without

previous tests than in those who had ever been tested for HIV prior to diagnosis (81.0% vs. 72.3%). The proportion of late-stage HIV infection among HIV-positive persons without previous tests was about two times that of those with previous HIV tests (63.9% vs. 29.0%).

Table 1. Characteristics (%) of sexually transmitted HIV-positive persons by history of HIV testing prior to diagnosis in Singapore, 2012–2017.

Characteristic	Total (N=2,188)	No previous HIV tests (N=986)	Had previous HIV tests (N=1,202)	*P*-value
	n (%)	n (%)	n (%)	
Age group (years)				<0.0005
15–24	231 (10.6)	59 (6.0)	172 (14.3)	
25–34	548 (25.0)	138 (14.0)	410 (34.1)	
35–44	567 (25.9)	200 (20.3)	367 (30.5)	
45–54	487 (22.3)	303 (30.7)	184 (15.3)	
55–64	274 (12.5)	211 (21.4)	63 (5.2)	
≥65	81 (3.7)	75 (7.6)	6 (0.5)	
Gender				<0.0005
Male	2045 (93.5)	881 (89.4)	1164 (96.8)	
Female	143 (6.5)	105 (10.6)	38 (3.2)	
Ethnic group				0.092
Chinese	1571 (71.8)	700 (71.0)	871 (72.5)	
Malay	413 (18.9)	193 (19.6)	220 (18.3)	
Indian	122 (5.6)	64 (6.5)	58 (4.8)	
Others	82 (3.7)	29 (2.9)	53 (4.4)	
Marital status				<0.0005
Never married	1506 (68.8)	504 (51.1)	1002 (83.4)	
Married	469 (21.4)	326 (33.1)	143 (11.9)	
Separated/Divorced/Widowed	213 (9.7)	156 (15.8)	57 (4.7)	
Educational level				<0.0005
No formal / Primary	161 (7.4)	129 (13.1)	32 (2.7)	
Secondary	263 (12.0)	160 (16.2)	103 (8.6)	
Post-secondary / Diploma	1466 (67.0)	630 (63.9)	836 (69.6)	
University degree or higher	290 (13.3)	63 (6.4)	227 (18.9)	
Unknown	8 (0.4)	4 (0.4)	4 (0.3)	
Occupational type				<0.0005
Professional / executive	463 (21.2)	155 (15.7)	308 (25.6)	
Administrative / service	904 (41.3)	380 (38.5)	524 (43.6)	
Blue-collar worker	285 (13.0)	227 (23.0)	58 (4.8)	
Unemployed	69 (3.2)	43 (4.4)	26 (2.2)	
Others	302 (13.8)	112 (11.4)	190 (15.8)	
Unknown	165 (7.5)	69 (7.0)	96 (8.0)	
Mode of detection				<0.0005
Voluntary screening	452 (20.7)	69 (7.0)	383 (31.9)	
Medical care	1001 (45.7)	646 (65.5)	355 (29.5)	
Routine programmatic HIV screening‡	615 (28.1)	241 (24.4)	374 (31.1)	
Others	120 (5.5)	30 (3.0)	90 (7.5)	
Mode of HIV transmission				<0.0005

Characteristic	Total (N=2,188)	No previous HIV tests (N=986)	Had previous HIV tests (N=1,202)	*P*-value
Homosexual/bisexual	1287 (58.8)	354 (35.9)	933 (77.6)	
Heterosexual	901 (41.2)	632 (64.1)	269 (22.4)	
Type of sexual partners				<0.0005
Regular only	246 (11.2)	126 (12.8)	120 (10.0)	
Regular and casual only	1357 (62.0)	471 (47.8)	886 (73.7)	
Sex workers and social escorts	576 (26.3)	385 (39.0)	191 (15.9)	
Unknown	9 (0.4)	4 (0.4)	5 (0.4)	
Self-reported history of STIs				<0.0005
No	1668 (76.2)	799 (81.0)	869 (72.3)	
Yes	520 (23.8)	187 (19.0)	333 (27.7)	
Stage of HIV infection				<0.0005
Early	1210 (55.3)	356 (36.1)	854 (71.0)	
Late	978 (44.7)	630 (63.9)	348 (29.0)	

STIs, sexually transmitted infections.

‡ Routine programmatic HIV screening includes screening programmes for those with STIs, hospital inpatients and those identified through contact tracing.

There was a significant decreasing trend in the age-specific proportion having prior test(s) before HIV diagnosis; this proportion declined from 74.5% in age group of 15-24 years to 23.0% in those aged 55-64 years and 7.4% in elderly persons aged 65 years or older (*p* for trend <0.0005).

Comparison of HIV-positive persons included and excluded from the study

Compared with the 391 sexually transmitted HIV-positive persons excluded from the analyses, a significantly higher proportion of those included in this study were aged between 15–34 years at HIV diagnosis (35.6% vs. 26.1%), never married (68.8% vs. 61.6%), had university degree or higher (13.3% vs. 7.2%), were detected via voluntary screening (20.7% vs. 11.8%), and infected via homosexual/bisexual transmission (58.8% vs. 48.8%) (all *p* <0.01) (Supplementary table). The proportion with unknown occupational type and type of sexual partners was significantly different between these two groups.

Duration from last test to HIV diagnosis, type of test sites, and reasons cited by HIV-positive persons without previous HIV test before diagnosis

Among the 1,202 HIV-positive persons who had previous HIV tests, 1,122 (93.3%) reported a negative result for the last test prior to diagnosis and their median duration from the last negative test to HIV diagnosis was 2.1 years (IQR 1.0–4.4). This interval was significantly longer at 3.8 years (IQR 2.0–7.3) among the 320 HIV-positive persons diagnosed at late-stage HIV infection compared with 1.7 years (IQR 0.8–3.2) among the 802 cases diagnosed early ($p < 0.0005$).

Of the remaining 80 HIV-positive persons who had previous HIV tests but last test prior to diagnosis was not negative, 59 reported positive result (24 tested overseas, 23 tested at anonymous test sites, 4 at other places and 8 were unknown) and 21 reported indeterminate results (no information on the test site). Of the 59 HIV-positive persons with previous positive test result for HIV, 30 (50.8%) were detected via voluntary screening, 17 (28.8%) via medical care, 8 (13.6%) via routine programmatic HIV screening and 4 (6.8%) via other modes. The median duration from the first positive test to HIV diagnosis was 1.1 years (IQR 0.2–5.9).

Popular test sites for HIV-positive persons with previous HIV tests were anonymous test sites (32.1%), primary care clinics (23.3%) and the Department of STI Control (DSC) Clinic, a specialist outpatient clinic for the diagnosis, treatment and control of STIs (12.8%). The median duration from the last negative test to HIV diagnosis was 1.5 years (IQR 0.7–2.9) at anonymous test sites, compared with 2.5 years (IQR 1.2–5.2) at other test sites ($p<0.0005$).

About 49.4% of the 360 HIV-positive persons who previously tested negative at anonymous test sites were subsequently diagnosed with HIV via voluntary outpatient screening, while the rest were diagnosed via medical care or routine programmatic HIV screening. About 79.4% of these persons were diagnosed at early-stage of HIV infection. The proportion last tested negative at anonymous test sites was significantly higher in HIV-positive persons diagnosed at early-stage of HIV infection than those diagnosed at late-stage (35.7% vs 23.1%) ($p<0.0005$) (Fig. 2).

The most common reason cited by HIV-positive who did not have any previous HIV testing prior to diagnosis was “not necessary to test” (73.7%), followed by “does not want to know status” (8.1%) and “fear of stigmatisation / rejection” (4.5%). There was a significantly higher proportion of HIV-positive diagnosed at late-stage of HIV infection (76.3%) who cited “not necessary to test” compared with those diagnosed early (69.1%) (p=0.01) (Fig. 3).

Factors associated with no previous HIV testing

Four factors were independently associated with no previous HIV testing among HIV-positive persons diagnosed at late-stage of infection: older age at HIV diagnosis (≥55 years vs 15–24 years), lower educational level (vs university degree or higher), detection via medical care (vs voluntary screening), and HIV infection via heterosexual transmission (vs homosexual/bisexual transmission) (Table 2). The following six factors were independently associated with no previous HIV testing among HIV-positive persons diagnosed at early-stage: older age at HIV diagnosis (≥45 years vs 15–24 years), women, Malays (vs Chinese), lower educational level (vs university degree or higher), detection via medical care and routine programmatic HIV screening (vs voluntary screening), and HIV infection via heterosexual transmission (vs homosexual/bisexual transmission) (Table 3).

Table 2. Proportion and odds ratios of absence of previous HIV testing in sexually transmitted HIV-positive persons cases diagnosed at late-stage HIV infection in Singapore, 2012–2017.

Characteristic	% without previous HIV testing	Univariable model			Multivariable model		
		cOR	(95% CI)	*p* value	aOR	(95% CI)	*p* value
Age at diagnosis (years)				<0.0005			<0.0005
15–24	44.4	1.00	Referent		1.00	Referent	
25–34	38.4	0.78	(0.34–1.78)	0.552	0.76	(0.31–1.85)	0.546
35–44	49.6	1.23	(0.55–2.73)	0.610	0.89	(0.38–2.11)	0.794
45–54	73.6	3.48	(1.56–7.76)	0.002	1.97	(0.83–4.68)	0.126
55–64	83.6	6.37	(2.72–14.92)	<0.0005	2.71	(1.07–6.85)	0.035
≥65	93.4	17.81	(5.02–63.20)	<0.0005	6.14	(1.60–23.50)	0.008
Gender							
Male	62.8	1.00	Referent				
Female	83.1	2.91	(1.58–5.37)	0.001			
Ethnic group				0.087			
Chinese	65.6	1.00	Referent				
Malay	60.3	0.80	(0.57–1.12)	0.194			
Indian	73.3	1.44	(0.73–2.84)	0.290			
Others	50.0	0.52	(0.27–1.01)	0.053			
Marital status				<0.0005			
Single	51.7	1.00	Referent				
Married	82.2	4.30	(3.02–6.13)	<0.0005			
Divorced/ separated/ widowed	81.3	4.05	(2.58–6.35)	<0.0005			
Educational level†				<0.0005			0.039
No formal / Primary	88.9	14.45	(6.87–30.39)	<0.0005	3.23	(1.40–7.46)	0.006
Secondary	66.9	3.65	(2.09–6.37)	<0.0005	1.51	(0.81–2.84)	0.195
Post-secondary / Diploma	63.6	3.16	(1.98–5.04)	<0.0005	1.75	(1.03–2.96)	0.038
University degree or higher	35.6	1.00	Referent		1.00	Referent	
Occupational type†				<0.0005			
Professional / executive	49.0	1.00	Referent				
Administrative / service	58.7	1.48	(1.05–2.07)	0.023			
Blue-collar worker	84.5	5.66	(3.58–8.95)	<0.0005			
Unemployed	80.4	4.27	(2.03–8.98)	<0.0005			
Others	68.2	2.23	(1.31–3.81)	0.003			
Mode of detection				<0.0005			<0.0005
Voluntary screening	26.7	1.00	Referent		1.00	Referent	
Medical care	72.7	7.30	(4.40–12.10)	<0.0005	4.15	(2.35–7.33)	<0.0005
Routine programmatic HIV screening‡	54.1	3.23	(1.82–5.71)	<0.0005	1.90	(0.99–3.65)	0.054

Characteristic	% without previous HIV testing	Univariable model			Multivariable model		
		cOR	(95% CI)	*p* value	aOR	(95% CI)	*p* value
Others	36.4	1.57	(0.67–3.68)	0.304	0.89	(0.34–2.34)	0.819
Mode of sexual transmission							
Homosexual/bisexual	43.1	1.00	Referent		1.00	Referent	
Heterosexual	81.3	5.76	(4.32–7.67)	<0.0005	3.46	(2.50–4.80)	<0.0005
Type of sexual partners†				<0.0005			
Regular only	74.5	1.00	Referent				
Regular and casual only	52.9	0.39	(0.24–0.63)	<0.0005			
Sex workers and social escorts	78.8	1.27	(0.75–2.14)	0.369			
History of STIs							
Yes	57.7	1.00	Referent				
No	65.8	1.41	(1.00–1.98)	0.048			

cOR, crude odds ratio; aOR, adjusted odds ratio; STIs, sexually transmitted infections.

‡ Routine programmatic HIV screening includes screening programmes for those with STIs, hospital inpatients and those identified through contact tracing.

† Missing data were imputed.

Table 3. Proportion and odds ratios of absence of previous HIV testing in sexually transmitted HIV-positive persons diagnosed at early-stage HIV infection in Singapore, 2012–2017.

Characteristic	% without previous HIV testing	Univariable model			Multivariable model		
		cOR	(95% CI)	*p* value	aOR	(95% CI)	*p* value
Age at diagnosis (years)				<0.0005			<0.0005
15–24	23.0	1.00	Referent		1.00	Referent	
25–34	20.4	0.86	(0.57–1.29)	0.453	1.07	(0.69–1.67)	0.758
35–44	23.5	1.02	(0.67–1.56)	0.909	1.07	(0.67–1.71)	0.769
45–54	44.1	2.64	(1.71–4.08)	<0.0005	2.26	(1.38–3.73)	0.001
55–64	62.4	5.53	(3.20–9.56)	<0.0005	3.18	(1.70–5.96)	<0.0005
≥65	90.0	30.06	(6.73–134.30)	<0.0005	13.17	(2.80–62.03)	0.001
Gender							
Male	27.5	1.00	Referent		1.00	Referent	
Female	62.1	4.32	(2.58–7.22)	<0.0005	2.07	(1.13–3.78)	0.018
Ethnic group				0.002			0.004
Chinese	26.7	1.00	Referent		1.00	Referent	
Malay	36.8	1.60	(1.18–2.17)	0.002	1.76	(1.24–2.50)	0.002
Indian	40.3	1.85	(1.14–2.99)	0.012	1.21	(0.70–2.08)	0.499
Others	22.7	0.81	(0.39–1.66)	0.561	0.53	(0.24–1.18)	0.119
Marital status				<0.0005			

Characteristic	% without previous HIV testing	Univariable model			Multivariable model		
		cOR	(95% CI)	*p* value	aOR	(95% CI)	*p* value
Single	22.5	1.00	Referent				
Married	52.5	3.80	(2.77–5.22)	<0.0005			
Divorced/ separated/ widowed	56.5	4.47	(2.71–7.37)	<0.0005			
Educational level*				<0.0005			<0.0005
No formal / Primary	63.0	8.81	(4.52–17.15)	<0.0005	2.22	(1.04–4.75)	0.040
Secondary	53.0	5.85	(3.47–9.87)	<0.0005	2.80	(1.56–5.04)	0.001
Post-secondary / Diploma	27.2	1.94	(1.30–2.90)	0.001	1.15	(0.74–1.79)	0.538
University degree or higher	16.2	1.00	Referent		1.00	Referent	
Occupational type†				<0.0005			
Professional / executive	21.4	1.00	Referent				
Administrative / service	28.0	1.43	(1.02–2.00)	0.038			
Blue-collar worker	61.6	5.88	(3.67–9.43)	<0.0005			
Unemployed	36.8	2.14	(1.05–4.37)	0.037			
Others	26.0	1.29	(0.86–1.93)	0.223			
Mode of detection				<0.0005			<0.0005
Voluntary screening	12.6	1.00	Referent		1.00	Referent	
Medical care	45.5	5.81	(3.96–8.53)	<0.0005	3.66	(2.39–5.59)	<0.0005
Routine programmatic HIV screening‡	34.0	3.58	(2.49–5.16)	<0.0005	2.66	(1.79–3.95)	<0.0005
Others	20.7	1.81	(0.99–3.32)	0.053	1.41	(0.74–2.70)	0.294
Mode of sexual transmission							
Homosexual/bisexual	19.6	1.00	Referent		1.00	Referent	
Heterosexual	53.0	4.60	(3.52–6.02)	<0.0005	2.17	(1.55–3.04)	<0.0005
Type of sexual partners†				<0.0005			
Regular only	36.0	1.00	Referent				
Regular and casual only	23.3	0.54	(0.37–0.78)	0.001			
Sex workers and social escorts	47.8	1.63	(1.06–2.48)	0.025			
History of STIs							
Yes	25.6	1.00	Referent				
No	31.0	1.31	(0.99–1.73)	0.060			

cOR, crude odds ratio; aOR, adjusted odds ratio; STIs, sexually transmitted infections.

‡ Routine programmatic HIV screening includes screening programmes for those with STIs, hospital inpatients and those identified through contact tracing.

† Missing data were imputed.

DISCUSSION

This study found that slightly less than half of the sexually-transmitted HIV-positive persons reported no previous HIV test prior to diagnosis. Close to two-thirds of the HIV-positive persons diagnosed at late-stage HIV infection did not have previous HIV tests, more than twice the proportion among those diagnosed early (29.4%). The median duration from the last negative test to HIV diagnosis was 3.8 years among HIV-positive persons with late-stage HIV infection, double that of those diagnosed early. These findings highlight the importance of regular HIV testing for early diagnosis so as to secure optimal outcomes in the HIV care cascade.

Anonymous test sites were the most popular among HIV-positive persons for their last negative HIV test prior to diagnosis (Fig. 2). At-risk individuals who go to anonymous test sites are more likely to have HIV testing on a regular basis or at a shorter inter-test interval, as reflected by the higher proportion of HIV-positive persons diagnosed early (79.4%) among those who were last tested negative at these test sites and the shorter median duration from the last negative test to HIV diagnosis compared with other test sites (1.5 vs 2.5 years). To encourage voluntary outpatient screening by reducing the stigma associated with seeking HIV testing, the Ministry of Health introduced anonymous HIV testing using oral-fluid or blood-based rapid HIV test kits at selected GP clinics and test sites run by community-based organisations in August 2007.[10] Anonymous testing offers privacy and confidentiality that encourages more people to check their HIV status. There are now ten anonymous HIV test sites in Singapore, comprising nine GP clinics and a test site operated by Action for AIDS (AfA), a local non-governmental HIV/AIDS community-based organization.[11] To make voluntary HIV screening more accessible and convenient in Singapore, AfA launched the first Mobile Testing & Counselling Service which provides anonymous HIV and syphilis testing on wheels in December 2011.[12] The number of HIV

tests conducted at anonymous test sites increased by 25% from 13,900 in 2013 to 17,400 in 2017.[13]

Four common risk factors were associated with no previous HIV testing in multivariable analyses in both early and late stages of HIV infection at diagnosis: older age, lower educational level, detection in the course of medical care and heterosexual transmission (Tables 2 and 3). Older persons may perceive themselves to be at lower risk of HIV infection, or may be less aware of HIV and more reluctant to undergo HIV testing. Lower educational level was an impediment in having HIV tests among men having sex with men (MSM) in some studies.[14-17] HIV testing is most likely to be initiated only during medical care due to clinical suspicion of HIV infection based on disease presentations or risk profiles.**Error! Bookmark not defined.** In a local study of HIV-positive men, those of older age (≥30 years) at diagnosis and infected via heterosexual transmission were more likely to be detected through medical care as opposed to voluntary screening.[18] Our finding indicated the need to increase HIV testing rates among persons at high risk of HIV infection with these epidemiological risk factors.

The proportion of persons infected with HIV via heterosexual transmission with no previous HIV test prior to diagnosis (70.1%) was about 2.5 times that of those infected via homosexual/bisexual transmission (27.5%). Hence they were also less likely to have recent HIV infection (RHI) at diagnosis, as shown in a local study in which the proportion of RHI was significantly lower in heterosexual men than in men who have sex with men (MSM) (11.1% vs. 23.4%).[19] Similarly, in the United States, heterosexuals at high risk are known to have lower testing frequency than other groups such as MSM.[20] According to a systematic review of 19 studies that evaluated behavioural preventive interventions in low- and middle-income countries, heterosexual men remained under-represented in HIV prevention efforts.[21] In Singapore, the outreach programme run by AfA includes edutainment shows, regular condom and collateral distributions to heterosexuals who

engage in high-risk sexual activities at venues they frequent, so as to increase their knowledge about HIV/STIs and preventive methods, and encourage more voluntary testing.[22]

In a separate analysis among cases diagnosed at early-stage HIV infection, women were less likely to have previous HIV testing prior to their diagnosis. HIV/AIDS cases diagnosed in Singapore are predominantly men with male to female ratio of 9:1. Women who believe that their sexual partners are faithful in the relationship are less likely to perceive themselves to be at risk of HIV infection. Among HIV-positive persons who had been diagnosed early, those of Malay ethnicity were more likely not to have had previous testing for HIV prior to diagnosis when compared with ethnic Chinese. This could be due to HIV-related stigma arising from the influence of culture and religiosity. In Malaysia, a study conducted in 2012-2013 found that Malay Muslim HIV patients who disclosed their illness had significantly higher total stigma level than the non-disclosure group.[23]

As this study identified a significant proportion of late-stage HIV infection (63.9%) among HIV-positive persons who did not have previous HIV tests, healthcare providers should have a higher index of suspicion for HIV infection among at-risk groups, and recommend a HIV test where appropriate[24]. In a study on HIV testing behaviour among HIV-uninfected, at-risk adolescents and those who were HIV-infected in the United States, 67% of the high-risk group and 53% of the HIV-infected group cited recommendation by healthcare professionals as a reason to undergo HIV testing.[25] In a study among heterosexuals at high risk of HIV infection in New York City, facilitators of past-year HIV testing common to both genders included STI testing or STI diagnosis, peer norms supporting HIV testing, and HIV testing access.[26] Independent factors associated with regular HIV testing behavior among MSM in China included perceived risk, greater knowledge of HIV testing and having a STI test in the past year.[27] Individuals, especially those at high risk of STIs and HIV, would benefit from having better knowledge about HIV

and the symptoms related to acute or advanced HIV infection, as well as the benefits of early diagnosis and linkage to care.[24]

HIV infection has a long clinical latency period during which infected individuals may show no symptoms. Relying on symptom-based HIV diagnosis would lead to late diagnosis, missing the opportunity of early detection.[28,29] Hence, it is crucial to provide a system that can support HIV testing with minimal inconvenience, so as to encourage greater uptake of HIV screening among those who are at risk regardless of whether they are asymptomatic or symptomatic. In our study, about three-quarters of HIV-positive who had no previous HIV testing deemed that it was “not necessary to test”, and the proportion was significantly higher among those with late-stage than early-stage HIV infection at diagnosis (76.3% vs. 69.1%) (Fig. 3), which likely represents a lack of knowledge of their own risk of HIV infection despite ongoing risk behaviour. The Singapore Health Promotion Board has been working with partner organisations to conduct programmes and campaigns targeted at high-risk individuals to urge them to go for early and regular HIV testing.[30] Various educational programmes on HIV prevention and management are conducted using a lifestyle approach in order to reach out to at-risk individuals through social settings.

There are several limitations in this study. Our study used the epidemiological data collected in the National HIV Registry which was not designed to investigate determinants of previous HIV testing. Hence, not all potential confounding factors could be included in our study, and information on drivers and barriers of HIV testing was unavailable. Qualitative studies are needed to delineate the processes underlying different patterns of testing in local context[31]. As testing-related variables were ascertained based on self-reporting by HIV/AIDS cases, some extent of misclassification due to recall bias could not be avoided.

In conclusion, the proportion of cases who had never been tested for HIV prior to HIV diagnosis was 45.1%. Our study findings highlight the need for concerted efforts to raise awareness of the importance of early and regular HIV testing and boost its uptake by making HIV testing more accessible and less discriminatory, particularly among the high-risk groups in Singapore.

Acknowledgments

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Contributors

LWA conceived the study, did statistical analysis and wrote the first draft of the manuscript. All authors (LWA, MPHST, ICB, CSW, SA, VJML, AC, YSL) contributed to data interpretation, revised the manuscript and approved the submission.

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Competing interests

None declared.

Patient consent for publication

Not applicable.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data availability statement

All data relevant to the study are included in the article.

Ethics statement

Research approval for this study was provided by the Ministry of Health, Singapore. As the data was collected under the Infectious Diseases Act and analyses were performed on an anonymized dataset, informed consent was not required for this study.

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Figure captions

Figure 1. Percentage of sexually transmitted HIV-positive persons who did not have HIV tests prior to diagnosis by stage of HIV infection at diagnosis in Singapore, 2012–2017

Figure 2. Distribution (%) of test sites of sexually transmitted HIV-positive persons for their last negative HIV test result prior to diagnosis by stage of HIV infection at diagnosis in Singapore, 2012–2017
DRC: Drug rehabilitation centre; DSC: Department of STI Control

Figure 3. Distribution (%) of reasons for no previous HIV test prior to diagnosis among sexually transmitted HIV-positive persons by stage of HIV infection at diagnosis in Singapore, 2012–2017

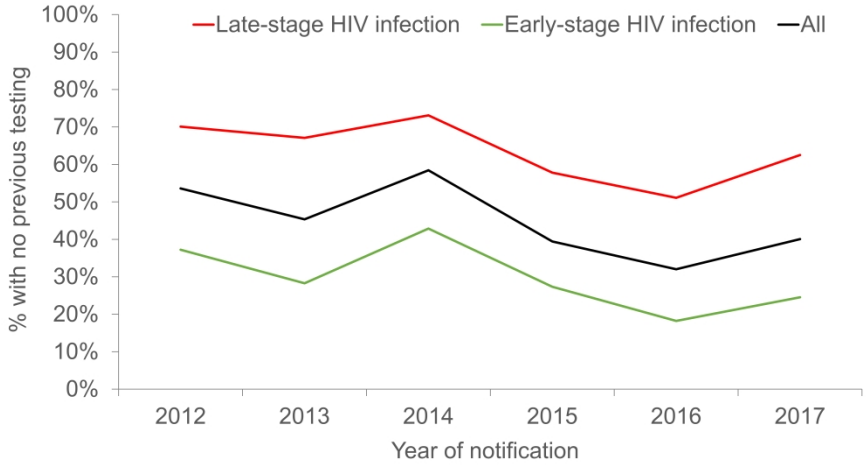

Figure 1. Percentage of sexually transmitted HIV/AIDS cases who did not have HIV tests prior to diagnosis by stage of HIV infection at diagnosis in Singapore, 2012–2017.

338x190mm (600 x 600 DPI)

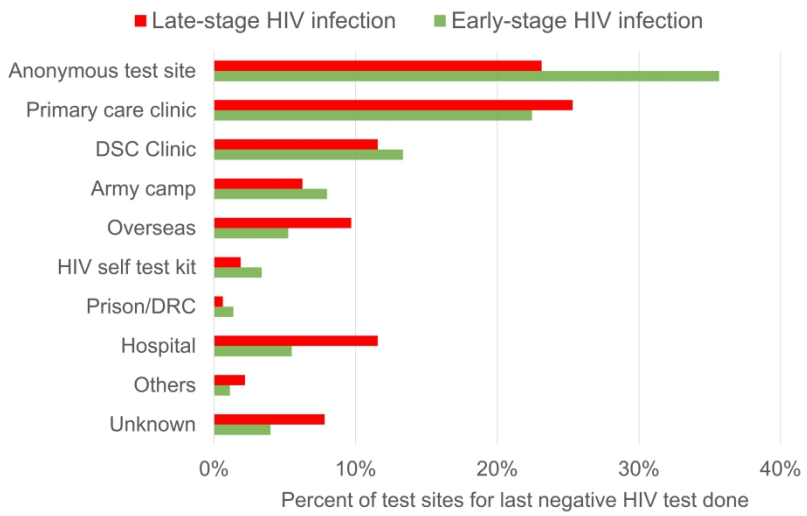

Figure 2. Distribution (%) of test sites of sexually transmitted HIV-positive persons for their last negative HIV test result prior to diagnosis by stage of HIV infection at diagnosis in Singapore, 2012–2017

338x190mm (300 x 300 DPI)

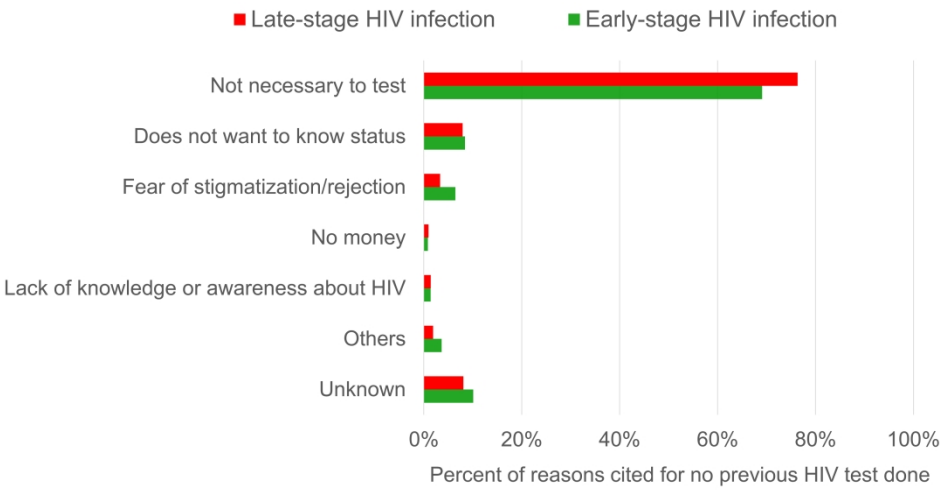

Figure 3. Distribution (%) of reasons for no previous HIV test prior to diagnosis among sexually transmitted HIV-positive persons by stage of HIV infection at diagnosis in Singapore, 2012–2017

338x190mm (300 x 300 DPI)

Epidemiological factors associated with the absence of previous HIV testing among HIV-positive persons in Singapore, 2012 to 2017

Li Wei Ang, Matthias Paul Han Sim Toh, Irving Charles Boudville, Chen Seong Wong, Sophia Archuleta, Vernon Jian Ming Lee, Angela Chow, Yee Sin Leo

Supplementary Table. Characteristics (%) of sexually transmitted HIV-positive persons who were included and excluded from the study, 2012–2017.

Characteristic	All (n=2,579)	Included (n=2,188)	Excluded (n=391)	*P*-value
Age group (years)				<0.0005
15–24	262 (10.2)	231 (10.6)	31 (7.9)	
25–34	619 (24.0)	548 (25.0)	71 (18.2)	
35–44	678 (26.3)	567 (25.9)	111 (28.4)	
45–54	573 (22.2)	487 (22.3)	86 (22.0)	
55–64	335 (13.0)	274 (12.5)	61 (15.6)	
≥65	112 (4.3)	81 (3.7)	31 (7.9)	
Gender				0.659
Male	2,408 (93.4)	2,045 (93.5)	363 (92.8)	
Female	171 (6.6)	143 (6.5)	28 (7.2)	
Ethnic group				0.109
Chinese	1,837 (71.2)	1,571 (71.8)	266 (68.0)	
Malay	486 (18.8)	413 (18.9)	73 (18.7)	
Indian	152 (5.9)	122 (5.6)	30 (7.7)	
Others	104 (4.0)	82 (3.7)	22 (5.6)	
Marital status				0.020
Never married	1,747 (67.7)	1,506 (68.8)	241 (61.6)	
Married	572 (22.2)	469 (21.4)	103 (26.3)	
Separated/Divorced/Widowed	260 (10.1)	213 (9.7)	47 (12.0)	
Educational level				0.005
No formal / Primary	189 (7.3)	161 (7.4)	28 (7.2)	
Secondary	305 (11.8)	263 (12.0)	42 (10.7)	
Post-secondary / Diploma	1,759 (68.2)	1,466 (67.0)	293 (74.9)	
University degree or higher	318 (12.3)	290 (13.3)	28 (7.2)	
Unknown	8 (0.3)	8 (0.4)	0 (0.0)	
Occupational type				<0.0005
Professional / executive	531 (20.6)	463 (21.2)	68 (17.4)	
Administrative / service	1,044 (40.5)	904 (41.3)	140 (35.8)	
Blue-collar worker	337 (13.1)	285 (13.0)	52 (13.3)	
Unemployed	89 (3.5)	69 (3.2)	20 (5.1)	
Others	354 (13.7)	302 (13.8)	52 (13.3)	
Unknown	224 (8.7)	165 (7.5)	59 (15.1)	

(Continued)

Characteristic	All (n=2,579)	Included (n=2,188)	Excluded (n=391)	*P*-value
Mode of detection				<0.0005
Voluntary screening	498 (19.3)	452 (20.7)	46 (11.8)	
Medical care	1,189 (46.1)	1,001 (45.7)	188 (48.1)	
Routine programmatic HIV screening‡	724 (28.1)	615 (28.1)	109 (27.9)	
Others	168 (6.5)	120 (5.5)	48 (12.3)	
Mode of HIV transmission				<0.0005
Homosexual/bisexual	1,478 (57.3)	1,287 (58.8)	191 (48.8)	
Heterosexual	1,101 (42.7)	901 (41.2)	200 (51.2)	
Type of sexual partners				<0.0005
Regular only	301 (11.7)	246 (11.2)	55 (14.1)	
Regular and casual only	1,583 (61.4)	1357 (62.0)	226 (57.8)	
Sex workers and social escorts	677 (26.3)	576 (26.3)	101 (25.8)	
Unknown	18 (0.7)	9 (0.4)	9 (2.3)	
Self-reported history of STIs				0.898
No	1,965 (76.2)	1,668 (76.2)	297 (76.0)	
Yes	614 (23.8)	520 (23.8)	94 (24.0)	

STIs, sexually transmitted infections.

‡ Routine programmatic HIV screening includes screening programmes for those with STIs, hospital inpatients and those identified through contact tracing.

Epidemiological factors associated with the absence of previous HIV testing among HIV-positive persons in Singapore, 2012 to 2017

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	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
Methods			
Study design	4	Present key elements of study design early in the paper	6-7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6-7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
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	6-7
Bias	9	Describe any efforts to address potential sources of bias	-
Study size	10	Explain how the study size was arrived at	8
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	8

		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	-
		(*e*) Describe any sensitivity analyses	-
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	8
		(b) Give reasons for non-participation at each stage	-
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-11
		(b) Indicate number of participants with missing data for each variable of interest	9-11
Outcome data	15*	Report numbers of outcome events or summary measures	9-11
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	11-14
		(*b*) Report category boundaries when continuous variables were categorized	14-16
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	-
Discussion			
Key results	18	Summarise key results with reference to study objectives	17
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	20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17
Generalisability	21	Discuss the generalisability (external validity) of the study results	17-20
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	-

*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.