



Spatial characteristics of men who have sex with men and transgender women attending HIV voluntary counselling and testing in Bangkok, Thailand, 2005–2015

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Abstract

Spatiotemporal analyses can support Human Immuno-deficiency Virus (HIV) prevention programmes by identifying locations of at-risk populations in space and time, and their proximity

to HIV testing and prevention services. We assessed residential proximity to HIV testing venues for Men who have Sex with Men (MSM) and Transgender Women (TGW) attending Voluntary Counselling and Testing (VCT) at a large urban MSM clinic in Bangkok, Thailand in the period 2005–2015. We mapped client-provided spatial data and HIV testing venues, calculating distance from residence to venues for VCT clients between i) September 2005–December 2009; ii) January 2010–September 2013; and iii) October 2013–May 2015. We assessed spatial characteristics across times, evaluating autocorrelation of HIV prevalence and visit density using Moran's *I*. Among 8,758 first-time VCT clients reporting geographic information from 2005–2015 (by period: 2737, 3917, 2104), 1329 (15.2%) lived in postal codes ≤ 5 km from the clinic. Over time, the proportion living in areas covered by Bangkok postal codes ≤ 2 km from any MSM HIV testing venue increased from 12.6% to 41.0% ($p < 0.01$). The proportion living ≤ 5 km from the clinic decreased from 16.6% to 13.0% ($p < 0.01$). HIV prevalence and clinic visit density demonstrated statistically significant non-random spatial patterning. Significant non-random patterning of prevalent infection and client visits highlighted Bangkok's urban HIV epidemic, clinic proximity to clients, and geographic reach. Clients lived closer to testing venues, yet farther from the urban MSM clinic, over time. Spatiotemporal characteristics of VCT clients can help assess service accessibility and guide targeted prevention planning.

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Introduction

Men who have Sex with Men (MSM), and Transgender Women (TGW), have a high prevalence of Human Immunodeficiency Virus (HIV) in many global settings, including Southeast Asia (Beyrer *et al.*, 2012). In Thailand's concentrated epidemic, the prevalence of HIV among MSM (9.1% in 2018; UNAIDS, 2018) is higher than the general population, and new HIV infections are primarily occurring in young MSM and TGW (van Griensven *et al.*, 2013; Sullivan *et al.*, 2015). HIV testing is a core platform for entry into HIV prevention, through strategies like Pre-Exposure Prophylaxis (PrEP) and Treatment as Prevention (TasP), including efforts to reduce viral loads to undetectable and untransmissible levels (WHO, 2014; Guadamuz *et*

al., 2015). Assessments of access to HIV testing in key populations using geospatial data provide information on whom is being served and where, as well as potential gaps in service delivery.

Spatial methods, such as the use of Geographic Information Systems (GIS), can be used to assess spatial patterns, movement, and trends in populations and identify geographic correlates that may impact health behaviours and service utilization, including HIV testing, diagnosis, and infection acquisition (Anselin *et al.*, 2010; Yao *et al.*, 2014; Hixson *et al.*, 2011). Published spatial analyses of HIV in Thailand have been limited, with most occurring in the 1990s; those analyses focused on the heterosexual epidemic and included descriptions of the distribution of support organizations, HIV seroprevalence and its correlates, and commercial sex work (Torugsa *et al.*, 2003; Sirisopana *et al.*, 1996; Del Casino, 2001; Jongsthapongpanth *et al.*, 2010). To our knowledge, few spatial analyses of HIV have focused on Bangkok or explicitly examined the geographic distribution of testing venues, individuals seeking HIV testing, or the HIV epidemic among Thai MSM and TGW.

The Silom Community Clinic (SCC), an anonymous, gay and transgender-friendly clinic in Bangkok, Thailand, providing voluntary counselling and testing (VCT) for HIV and sexually transmitted infection (STI) services, was established in 2005 by the Thailand Ministry of Public Health (MOPH) - U.S. Centers for Disease Control and Prevention (CDC) Collaboration (TUC) initially with location at the Bangkok Christian Hospital and later at the Mahidol University Hospital for Tropical Diseases (van Griensven *et al.*, 2013; Holtz *et al.*, 2012).

We aimed to assess spatial and demographic characteristics of first-time SCC clients over time to describe changes in our client population and accessibility to HIV testing venues from 2005 to 2015. Spatial patterns of clients could impact testing and prevention service utilization and may help support the design and location of future prevention programs and activities.

Materials and Methods

Demographic Characteristics and HIV Testing Methods

We collected demographic and spatial information from gay, bisexual, and other MSM and TGW attending SCC for VCT from September 2005–May 2015. Postal code of residence at first visit and postal code of birth were routinely self-reported during VCT at visit registration. Participants reporting incomplete geographic data and repeat visits by the same participant were excluded from this analysis. Clients were screened for HIV-1 and HIV-2, adhering to Thai national guidelines by using a series of three rapid diagnostic tests (Determine, Abbott Laboratories, Abbott Park, IL, USA; DoubleCheck, Orgenics, Yavne, Israel, or SD Bioline, Standard Diagnostics, Kyonggi-do, South Korea; and Capillus HIV-1/2, Trinity Biotech, Carlsbad, CA, USA or HIV1/2 Core, Core Diagnostic, Birmingham, UK) (van Griensven *et al.*, 2013; van Griensven *et al.*, 2015). Beginning in 2009, we performed additional Nucleic Acid Amplification Testing (NAAT) (Aptima Genprobe, Gen-Probe, San Diego, CA, USA) and fourth generation immunoassays (AxSYM-HIV Ag/AB, Abbott Laboratories or Cobas Core, Core HIV Combi, Roche Diagnostics, Mannheim, Germany) for detection of acute HIV infection in clients who had a negative rapid HIV test result.

Data from the initial VCT visit for first-time unique individuals were described in three time frames, reflecting different periods of MSM service delivery: 1) September 1, 2005–December 31, 2009, SCC's initial years and when there was only a small number of MSM-focused venues, 2) January 1, 2010–September 30, 2013, a time frame in which the number of MSM venues nearly tripled and 3) October 1, 2013–May 31, 2015, after SCC moved to SCC @TropMed and MSM venues continued to increase in number.

Geographic Methods

Geographic shapefiles of postal codes in Thailand and the 50 districts within the city of Bangkok (Bangkok) were obtained from CDC and the Thailand Department of Provincial Administration (Samart Karuchit, personal communication). City districts could be composed of multiple postal codes, or a postal code could be comprised of areas in multiple districts. The median size of the postal codes in the city of Bangkok was 31.3 km² (mean = 63.9 km²), while the postal codes outside the city were generally larger due to the truncation down to 2 digits (*e.g.*, 97100 and 97200 both become 97000). These shapefiles were used to further categorize reported participant residence and birth postal codes as either: 1) in the city of Bangkok (referred to as Bangkok), 2) in the city's five neighbouring provinces, Nonthaburi, Nakhom Pathom, Samut Sakhon, Pathum Thani and Samut Prakan (referred to as neighbouring provinces in the Greater Bangkok Metropolitan Area [BMA]), or 3) other provinces in Thailand outside the Greater BMA area (all referred to as 'other Thailand provinces'). Postal code locations within Bangkok were further stratified by location ≤ 2 km from any public MSM HIV testing venue.

Change in location since birth was determined by comparing reported postal codes of birth and residence. Participants were classified as having: 1) moved from outside Bangkok into the city, 2) moved out of the city of Bangkok, 3) remained in the same area (*e.g.*, having been born in the city and reporting a current residence in the city), or 4) followed another pattern (*e.g.* moving from one of the five surrounding provinces in the Greater BMA to a different area of Thailand). We obtained a list of public HIV testing venues for MSM over the study period (personal communication, Prin Visavakum), and these locations were geocoded and exported to ArcGIS 10.2 (ESRI, Redlands, CA, USA).

We used postal code centroids to assess distance from the participant's postal code of residence to time-concordant venues. Polygon-based buffers were created encompassing two km and five km radii around testing venues. Clients living in postal codes which contained testing venues, or whose centroids were captured in these buffers, were respectively classified under two proximity schemes: living within 2 km of any testing venue or living within 5 km of any testing venue. GIS analysis of spatial autocorrelation measures for postal code visit density (percentage of included client visits contributed by a postal code) and HIV prevalence density (postal code client HIV prevalence). This approach used nearest neighbour weighting to create a spatial weights matrix. Choropleth maps of client residential postal code and prevalent HIV infection at first visit were created and overlaid with HIV testing venue locations.

The provision of VCT services was determined to be a public health program activity by the Office of the Associate Director of Science, U.S. CDC and, as such, this analysis of public health service delivery was exempt from CDC IRB review. This activity was funded by the CDC.



Statistical Analysis Methods

Demographic and spatial characteristics were described across time frames using proportions, means, and medians, with between-time frame characteristic differences assessed using Cochran-Armitage tests of trend for binary variables and chi-square tests of association for categorical variables. Bivariate associations between factors and prevalent, non-NAAT-positive HIV infection are reported as crude prevalence Odds Ratios (cORs) with 95% Confidence Intervals (CIs). Covariates associated at a $p < 0.10$ significance level were entered into a multivariable logistic regression model. Final model results, reported as adjusted prevalence Odds Ratios (aOR) with associated 95% CIs, included variables significant at a $p < 0.05$ level after backwards elimination and assessments of collinearity and two-way interactions. Data analysis was performed in SAS 9.4 (Cary, NC, USA). Global Moran's I tests for spatial dependency (autocorrelation) and clustering for visit density and HIV prevalence density were performed in ArcGIS.

Results

From September 2005 to May 2015, 8,945 unique VCT clients visited SCC, with 8,758 (97.9%) reporting complete geographic

information. Among clients with geographic information, 2,737 (31.3%) visited during the first-time frame (Sept. 2005–Dec. 2009), 3,917 (44.7%) visited during the second time frame (Jan. 2010–Sept. 2013), and 2,104 (24.0%) visited during the third time frame (Oct. 2013–May 2015) (Table 1). A majority (64.2%) were aged between 18–29 years and 2,342 (31.1%) of those with HIV test results were HIV-seropositive (excluding acute infection) at first visit, ranging from 25.8% in the first-time frame to 33.7% and 32.6% in the latter two-time frames. Only half of first-time VCT clients had previously been tested for HIV and only 3.1% did not identify as MSM (data not shown). Around three-quarters (76.3%) of the clients resided in a Bangkok postal code, with 2,677 (30.6%) clients living in a Bangkok postal code ≤ 2 km from any public HIV testing venue during the time frame of their visit. About one in six clients (15.2%) lived in postal codes with centroids located ≤ 5 km from SCC, while nearly half (46.0%) had moved to Bangkok since birth. Postal code visit density, *i.e.* the percentage of visits contributed by residents of a postal code, is shown for the entire study time frame in Figure 1, with time frame-specific visit densities represented in Figure 2. Four HIV testing venues existed during the first-time frame, increasing to 23 venues in later time frames. An increasing proportion of clients lived in postal codes ≤ 2 km from any testing venue (12.6%, 37.5%, 41.0%, $p < 0.01$), and a decreasing proportion of clients lived in postal codes ≤ 5 km of the SCC

Table 1. Socio-demographic and behavioural factors by time frame of first VCT visit for 8,758 clients attending Silom Community Clinic and reporting valid geographic information (2005–2015).

Respondent characteristics	Sep 2005–Dec 2009 (N=2,737) N (%)	Jan 2010–Sep 2013 (N=3,917) N (%)	Oct 2013–May 2015 (N=2,104) N (%)	Total (N=8,758) N (%)	p value**
Age at entry (years)					< 0.01 ^a
<18	40 (1.5)	40 (1.0)	29 (1.4)	109 (1.2)	
18–24	921 (33.6)	1,205 (30.8)	807 (38.4)	2,933 (33.5)	
25–29	829 (30.3)	1,156 (29.5)	593 (28.2)	2,578 (29.4)	
≥ 30	947 (34.6)	1,516 (38.7)	675 (32.1)	3,138 (35.8)	
Human immunodeficiency virus infection ^c					< 0.01 ^b
Antibody-positive	554 (25.8)	1,149 (33.7)	639 (32.6)	2,342 (31.1)	
Postal code of birthplace ^d					< 0.01 ^a
Bangkok	896 (37.4)	1,347 (34.6)	681 (32.4)	2,924 (34.9)	
Neighbouring provinces in Greater BMA ⁺⁺	144 (6.0)	266 (6.8)	166 (7.9)	576 (6.9)	
Other provinces in Thailand	1,356 (56.6)	2,278 (58.5)	1,255 (59.7)	4,889 (58.3)	
Distance from residence at first visit to any testing venue					< 0.01 ^a
Bangkok postal code ≤ 2 km from testing venue	344 (12.6)	1,470 (37.5)	863 (41.0)	2,677 (30.6)	
Bangkok postal code > 2 km from testing venue ⁺	1,805 (65.9)	1,541 (39.3)	657 (31.2)	4,003 (45.7)	
Neighboring provinces in Greater BMA ⁺⁺	353 (12.9)	577 (14.7)	379 (18.0)	1,309 (14.9)	
All other Thailand provinces	235 (8.6)	329 (8.4)	205 (9.7)	769 (8.8)	
Distance to SCC location at first visit					< 0.01 ^b
Postal code residence ≤ 2 km of SCC location	132 (4.8)	139 (3.5)	185 (8.8)	456 (5.2)	< 0.01 ^b
Postal code residence ≤ 5 km of SCC location	454 (16.6)	601 (15.3)	274 (13.0)	1,329 (15.2)	< 0.01 ^b
Location since birth ^d					< 0.01 ^a
Change from outside Bangkok to Bangkok	1,076 (44.9)	1,832 (47.1)	948 (45.1)	3,856 (46.0)	
Change from Bangkok to outside Bangkok	98 (4.1)	188 (4.8)	111 (5.3)	397 (4.7)	
Stayed in same geographic area classification	1,093 (45.6)	1,641 (42.2)	861 (41.0)	3,595 (42.9)	
Other movement pattern	129 (5.4)	230 (5.9)	182 (8.7)	541 (6.4)	

* Individual categories sum down columns, total column sums values across rows; ** p value is association between time frame and characteristic, using either Chi square test of association or Cochran-Armitage Trend test; ⁺ Bangkok postal codes > 2 km from a testing venue exclude venues located in neighboring provinces in the Greater BMA; ⁺⁺ Greater BMA = Greater Bangkok Metropolitan Area (Includes the city of Bangkok and neighboring provinces of Nonthaburi, Nakhom Pathom, Samut Sakhon, Pathum Thani, Samut Prakan provinces); ^c Chi-square test of association; ^b Cochran-Armitage Trend Test; ^d Denominator is 7,519, excludes 41 individuals with NAAT-positive and serology-negative test results and 1,198 individuals without antibody testing results; ^e 369 missing values; Bangkok = City of Bangkok; VCT = Voluntary Counselling and Testing; SCC = Silom Community Clinic.

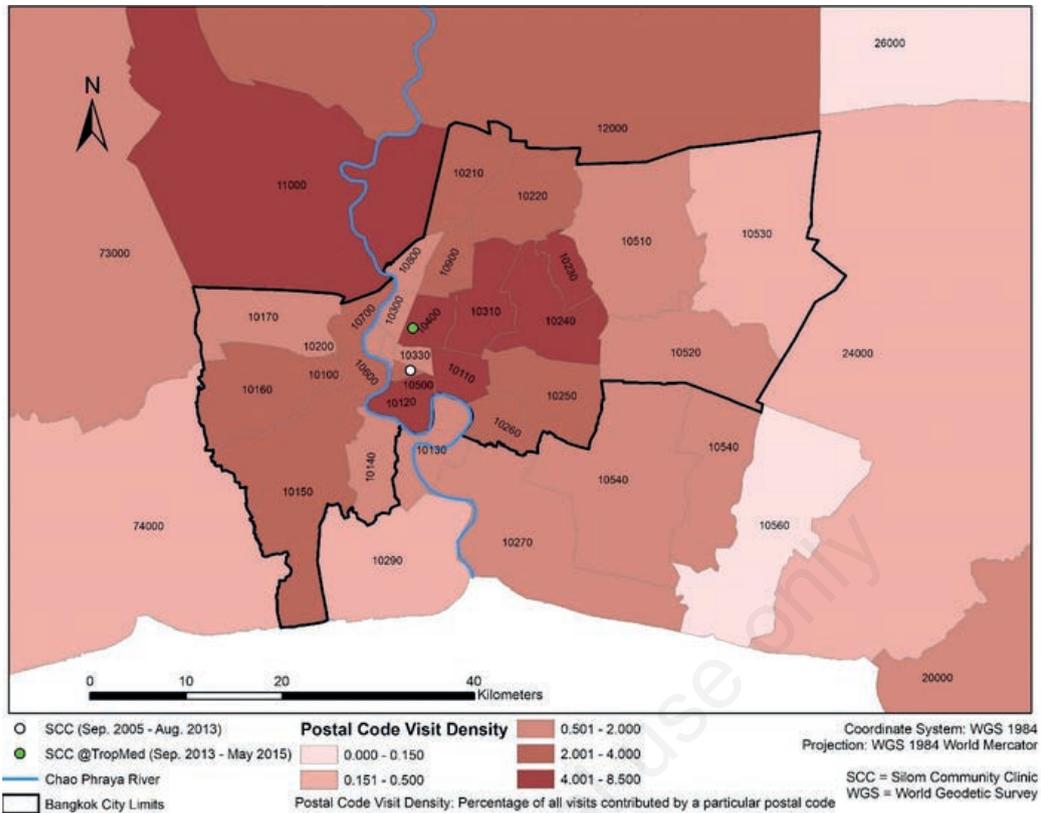


Figure 1. Downtown Bangkok postal codes covered by SCC, 2005–2015.

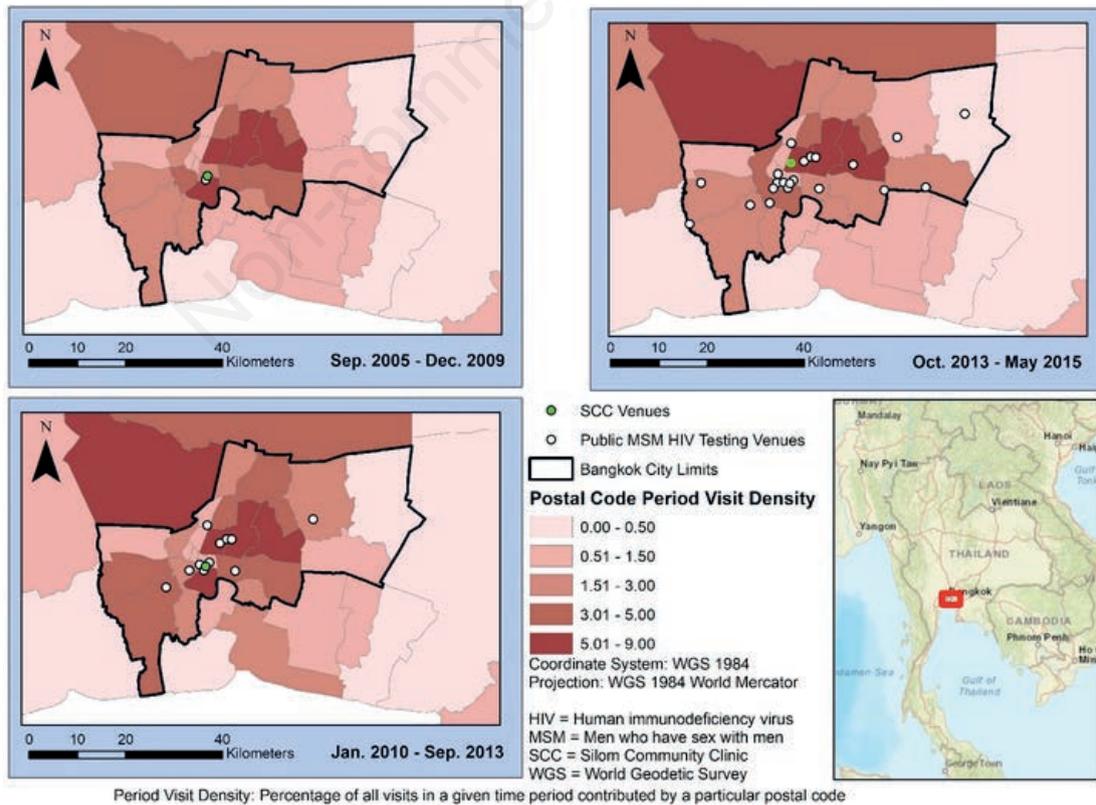


Figure 2. Increasing numbers of HIV testing venues for Thai MSM, but similar client distribution, during three time frames.



location open during that time frame (16.6%, 15.3%, 13.0%, $p < 0.01$).

Tests of spatial autocorrelation for both 1) postal code visit density, and 2) prevalent HIV infection density were significant by the Global Moran's I statistic ($I = 0.23$ and $p < 0.01$, $I = 0.19$ and $p < 0.01$, respectively). Birth in a Bangkok postal code (cOR = 0.64, 95% CI, 0.58–0.72), current residence in a postal code in Bangkok ≤ 5 km from an SCC location (cOR = 0.81, 95% CI, 0.70–0.93) and age below 18 (cOR = 0.48, 95% CI, 0.28–0.84) were all significantly associated with reduced odds of prevalent HIV infection in bivariate analyses (Table 1). Additionally, a first visit to SCC in a later time frame (Jan 2010–Sep 2013 cOR = 1.47, 95% CI, 1.30–1.65; Oct 2013–May 2015 cOR = 1.40, 95% CI, 1.22–1.60), movement into Bangkok (cOR = 1.53, 95% CI, 1.38–1.70) and age greater than 18–24 years (aged 25–29 years cOR = 1.33, 95% CI, 1.18–1.50; ≥ 30 years cOR = 1.35, 95% CI, 1.20–1.52) were significantly associated with increased odds of prevalent HIV infection in bivariate analyses.

In multivariable logistic regression analysis, movement into Bangkok (aOR = 1.52, 95% CI, 1.37–1.69) was significantly associated with increased odds of prevalent HIV infection. HIV seropositive infection was less likely among clients living ≤ 5 km from SCC (aOR = 0.80, 95% CI, 0.69–0.92) (Table 2). More recent clients had greater odds of being HIV seropositive (Jan 2010–Sep 2013 aOR = 1.37, 95% CI, 1.21–1.55; Oct. 2013–May 2015 aOR = 1.33, 95% CI, 1.16–1.53). Increased age was also associated with increased odds of prevalent infection (25–29 cOR = 1.34, 95% CI, 1.18–1.52; ≥ 30 cOR = 1.39, 95% CI, 1.23–1.57). Postal code at birth was removed from the multivariable model due to issues of collinearity with postal code of residence. No two-way interaction terms were significant.

Discussion

This analysis describes spatiotemporal characteristics of Thai MSM and TGW attending SCC over a 10-year period. We found that first-time clients had varied spatial characteristics over time, with evidence that clients lived closer to HIV testing and prevention services. Overall, we see this as a positive trend for access to services for these key populations. Geographic attributes, including movement and distance to HIV testing venues, were significant predictors of prevalent HIV infection, and there was significant spatial patterning of residential locations of all and HIV-positive VCT clients. Describing spatiotemporal characteristics of populations at risk for HIV can support tailored HIV prevention interventions. An increased number of testing sites may not result in increased testing among Thai MSM, however, as factors such as risk perception and venue environment might affect testing uptake.

This analysis expands on previous Thai HIV spatial research, yet is the first to focus on the key populations of MSM and TGW. A previous study of more than 400,000 Royal Thai Army recruits demonstrated a wide geographic distribution of the HIV epidemic (Torugsa *et al.*, 2003). Geographic correlates, namely residence in a high-seroprevalence region (Sirisopana *et al.*, 1996) and commercial sex work concentration (Jongsthapongpanth *et al.*, 2010) were associated with prevalent HIV infection. These assessments in Thailand primarily occurred in the 1990s–2000s and focused on the heterosexual HIV epidemic. Since this time, there has been a shift of the HIV epidemic to key populations of MSM and TGW (National AIDS Committee, 2015).

To date, there have been no spatiotemporal assessments of MSM and TGW in Thailand, and this descriptive analysis could serve as a foundation for more advanced or targeted research. As

Table 2. Crude and adjusted prevalence odds ratios and 95% confidence intervals for correlates of being HIV seropositive at first VCT visit, SCC (2005–2015). (Adjusted Model N=7,228).

Characteristic	Prevalent HIV infection	
	Crude Odds Ratio (95% CI)	Adjusted Odds Ratio (95% CI)
Age at entry (years)		
<18	0.48 (0.28–0.84)	0.53 (0.30–0.94)
18–24	Referent	Referent
25–29	1.33 (1.18–1.50)	1.34 (1.18–1.52)
≥ 30	1.35 (1.20–1.52)	1.39 (1.23–1.57)
Postal code of birthplace		
Bangkok	0.64 (0.58–0.72)	Removed for Collinearity
Neighboring provinces in Greater BMA	0.83 (0.68–1.02)	Removed for Collinearity
Other provinces in Thailand	Referent	Removed for Collinearity
Postal code residence ≤ 5 km of SCC location	0.81 (0.70–0.93)	0.80 (0.69–0.92)
Time frame of first visit		
Sep 2005–Dec 2009	Referent	Referent
Jan 2010–Sep 2013	1.47 (1.30–1.65)	1.37 (1.21–1.55)
Oct 2013–May 2015	1.40 (1.22–1.60)	1.33 (1.16–1.53)
Location since birth		
Change from outside Bangkok to Bangkok	1.53 (1.38–1.70)	1.52 (1.37–1.69)
Change from Bangkok to outside Bangkok	1.11 (0.87–1.42)	1.08 (0.85–1.38)
Stayed in same geographic area classification	Referent	Referent
Other movement pattern	1.29 (1.04–1.59)	1.22 (0.98–1.51)

CI = Confidence Interval; Bangkok = City of Bangkok; Greater BMA = Greater Bangkok Metropolitan Area (Includes the city of Bangkok and neighboring provinces of Nonthaburi, Nakhom Pathom, Samut Sakhon, Pathum Thani, Samut Prakan provinces); VCT = voluntary counseling and testing; SCC = Silom Community Clinic.

governments and other stakeholders are working to get to no new HIV infections, geospatial assessments can identify where to target efforts and programs. Further spatial information on sexual networks, which are a key determinant of HIV risk among MSM, to inform network-level interventions can help improve service accessibility and address risk behaviours (Amirkhanian, 2014). Although not representative of all MSM and TGW, clients attending SCC VCT clinics that have served MSM for over a decade provide a large, geographically diverse MSM client population to assess service accessibility in the absence of true population-based representative samples. Routine collection of geographic information on all HIV VCT clients in Bangkok could further this understanding. Our study found that an increasing proportion of first-time clients attending SCC lived ≤ 2 km from any public MSM testing venue over time, rising significantly from 12.6% to 41.0% by the last time frames. Two km represented a reasonable walking distance for clients and staff, and five km represented a reasonable motorbike or taxi distance. This suggests that HIV testing venues for MSM and TGW seeking VCT have become more accessible over time in Bangkok, Thailand. The community recognized the MSM/TGW HIV epidemic in the early 2000s, and, subsequently, Thailand has made efforts to increase service delivery to MSM/TGW, including geographic and numeric expansion of MSM-friendly HIV testing. These vary in environment, cost to the client, operating hours, and types of services provided, but this is a positive step in addressing the HIV epidemic in Thailand.

Accessibility to HIV testing is a key factor that can influence the likelihood of being tested for HIV; more testing venues and sites, and an increase of self-testing and mobile testing efforts, can boost testing rates among those at risk (Yao *et al.*, 2014; Khumalo-Sakutukwa *et al.*, 2008; Kawichai *et al.*, 2012). An Atlanta-based analysis of linkage to HIV care and viral suppression highlighted the interaction between where one lives and social factors, such as poverty, that can drive access issues potentially leading to onward HIV transmission (Goswami *et al.*, 2016). Greater access to testing for key populations can enable utilization of HIV-related services, supporting both HIV prevention and HIV care and treatment (WHO, 2014). Service delivery, including hours of operation, cost, environment, ease of use, and types of services offered, can also influence and support HIV testing and HIV prevention efforts (Kawichai *et al.*, 2012). Evaluation of location, and proximity of HIV testing venues to MSM and TGW, can support optimal HIV testing services.

Although there was an increase in the number of first-time MSM client visits at SCC during the study's entire time frame, other settings in Bangkok did not meet HIV testing targets for MSM and other at-risk key populations (National AIDS Committee, 2015). MSM face potential stigma, violence, discrimination, and criminalization, which are associated with fear of seeking care and lower rates of service utilization (Baral *et al.*, 2014). A study of UN country reports showed that only about a third of Thai MSM had been tested for HIV, while only a quarter of South and Southeast Asian MSM were reached by HIV prevention programs (Adam *et al.*, 2009). Expanding access to care, beginning with testing, and convenience of care locations could contribute to better engagement in care. In addition, venues need to consider their service delivery model for key populations to ensure protection and safety and ease of use and comfort. More efforts may be needed to consider a centre of excellence model for service delivery to key populations in Southeast Asia.

Spatial analysis can describe geographic variation and cluster-

ing, as well as risk factors, of infectious diseases, including HIV (Wand *et al.*, 2015; Zulu *et al.*, 2014). Recent work in China has described the county-level distribution of HIV cases, analysing the national case registry through spatial regression to detect disease clustering and correlates of prevalence (Qin *et al.*, 2017). Our study found there was significant global autocorrelation, or non-random patterning, for prevalent HIV infection and client visit density, manifesting as, respectively, neighbouring postal codes with similar prevalence of HIV-positive VCT clients and overall VCT clients. This finding reflects the urban location of both SCC clinics as well as the urban nature of the HIV epidemic in Thai MSM (van Griensven *et al.*, 2013; Sullivan *et al.*, 2015).

Notably, only 15% of SCC clients came from postal codes within 5 km, highlighting the wide geographic reach of a long-established clinic. This may indicate that SCC model for service delivery, including evening operating hours, well-trained staff, focus on confidentiality and client protections, engagement with the community, and no-cost services are attracting MSM from outside their immediate residential areas. Loyalty to this clinic model may translate to interest in follow-up and retention in care, augmenting the initial first visit with repeat prevention messages and opportunities. There may also be a lack of awareness of more conveniently located MSM testing venues. It is unknown whether Thai MSM living near MSM HIV testing clinics are more likely to test elsewhere as a result of potential stigma or unwanted disclosure of sexual orientation associated with visiting a nearby MSM clinic. It is also unknown whether these clients may have also received HIV testing at other closer venues. Future assessments of the location of MSM populations in Bangkok with more granular geo-mapping information, such as that provided by a mobile phone or other application, and service provision across venues could evaluate whether there may be unidentified gaps in service delivery for MSM testing.

This study has several limitations. Our assessment only evaluated first visits of clients attending SCC and this sample may not be representative of all MSM in Bangkok. Given that SCC was one of the largest, and only, HIV service providers during these time frames, it may offer insight on access to care; we are not aware of any representative samples of Bangkok MSM with geocoding data available (van Griensven *et al.*, 2013). SCC moved to a different, urban location in downtown Bangkok at the beginning of the third time frame. Evaluation of HIV testing and access by postal code may be subject to the ecological fallacy of applying larger characteristics to an individual level, as postal codes may not necessarily reflect underlying population distribution, and different spatial units could lead to different conclusions (Piantadosi *et al.*, 1988; Grubestic *et al.*, 2006). Further integration of other measures of service access and utilization, such as the collection of more granular location data or reasons for accessing a particular service location would enhance the robustness of these findings. Additionally, centroid-based distance analysis and lack of residential point data might obscure individual-level accessibility trends; a postal code of residence may not correlate perfectly with areas where key populations are spending most of their time or exhibiting risk behaviours.

Considering the limitations of ecologic and centroid-based analyses, these spatial findings are best used for exploratory assessment and hypothesis generation, rather than as concrete explanations of individual-level risks. The collection of more local, disaggregated data, such as sub-district-level or even specific GIS coordinates of home, work, and social environments, may



help us better understand spatial patterns beyond those seen at a postal code level. Future spatial assessments that include all MSM in Bangkok, rather than those attending a single venue, can better characterize key population locations as well as the availability of HIV prevention and care services. This could include evaluations using GIS in smartphone applications to assess questions such as the impact of geography accessibility on uptake of HIV prevention and care services to key populations. A large systematic review found that more than three-quarters of studies identified that greater distance or travel time to care was associated with worse health outcomes (Kelly *et al.*, 2016). Recent studies have identified spatial access as a key predictor of willingness to use HIV PrEP (Ojikutu *et al.*, 2019) and loss-to-follow-up from HIV care (Bilinski *et al.*, 2017). Targeted prevention and care efforts and programs, including focusing on geographic hotspots, may benefit from the findings of basic and more advanced geospatial analyses using individual and aggregated data. Characterization of the demographics, location, and movement of persons at risk for HIV can help identify the best locations and methods for health services to support HIV prevention in the community. Regular collection and analysis of spatial data from HIV prevention programs, both clinic-based and mobile, is needed and can help determine whether greater proximity to HIV testing venues can improve testing rates and service utilization in Thai MSM. The use of spatial techniques and data visualization can serve to support public health programs and policies, but can also serve as a tool for effective communication to stakeholders and policymakers about the local context of the epidemic (Torugsa *et al.*, 2003).

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