Mobile HIV testing in South Africa: maximizing yield through data-guided site selection

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BACKGROUND: Mobile community HIV testing can effectively reach undiagnosed people living with HIV in southern Africa. Variable yield in HIV test positivity has been a challenge with high- and low-yield sites often being closely situated. We sought to test whether easy-to-identify, site-level characteristics were associated with HIV positivity yield in a routine mobile HIV testing program.

METHODS: We used routine testing program test data augmented with site-level characterization, either of the community or shopping site at which HIV testing was offered. Specifically, we described the local environment and interviewed key informants to gain additional information regarding the availability of HIV and other services in the locale.

RESULTS: We included 122 residential and 26 shopping sites with median HIV-positive test yields of 7.6% and 6.9%, respectively. The range for community sites was from 2 to 55% with high and low yields at geographically proximal sites. Factors related to lower income and marginalization, including informal housing and the absence of name-brand stores in shopping venues, were associated with higher HIV-positive testing yield.

CONCLUSIONS: Characterization of sites, particularly identifying factors related to marginalization, lack of services, and poverty, can aid in identifying sites with higher HIV-positive yield.

HIV diagnosis is the starting point for HIV epidemic control activities using universal test and treat (UTT) strategies. HIV testing services (HTS) have been deployed in a variety of settings, including clinic, workplaces, and through mobile units deployed in community settings – all approaches endorsed by the WHO.¹ When the goal of HTS is to support the HIV care continuum, reaching undiagnosed people with HIV (PWH) is the priority. Beyond the absolute number of new HIV diagnoses, the success of HTS activities is often measured in terms of “yield” or proportion of those testing who test HIV-positive – a measure of program efficiency. The yield of HTS varies considerably between settings, with generally higher yields of HIV-positive diagnoses made with testing in clinical settings than community settings. The reported HIV-positive yield in clinics in South Africa is as high as 41%.^{2–6} However, individuals without injury or illness, those not recognizing a value in clinic services, and those who may not feel welcome in clinical settings are more likely to be missed through clinic-based HTS.^{1,2,7,8} Alternative approaches to testing, such as

mobile community-based testing, remain important for reaching these populations.

Mobile HTS is one widely used approach to reach harder-to-test populations by delivering HTS directly in community venues, including transport hubs, parks, markets, shopping areas, sports grounds, and residential areas.^{7–10} Mobile HTS has been widely used in South Africa and elsewhere in Africa.⁷ More recently the value of mobile HTS has come into question due to concerns of cost effectiveness and pressures to pursue testing strategies with high HIV diagnosis yield and overall efficiency. Identifying approaches to increase the HIV-positive yield could shift the cost-effectiveness considerations. In order to guide deployment to maximize HTS yield, we sought to characterize higher and lower yield sites reached by mobile HTS units in our mobile HTS program in South Africa.

METHODS

Setting

This study was conducted in Ekurhuleni and Sekhukhune Districts in South Africa. Ekurhuleni is an urban and peri-urban district adjacent to the City of Johannesburg. The overall population of Ekurhuleni is 3,379,104, with a median population density of 1,609 people per km², median annual income of 29,400 South African rands (ZAR) (equivalent to 2,000 US dollars), and HIV prevalence of 15%.¹¹ Sekhukhune District is in rural Limpopo Province, and is largely rural with some mining and large-scale agriculture operations. The overall population of Sekhukhune is 1,169,762, with a median population density of 86 people per km², median annual income of ZAR14,600 (USD1,000), and HIV prevalence of 7.5%.¹¹

Three mobile HTS units were deployed in Ekurhuleni and three units were deployed in Sekhukhune during 2016. Each unit included a large van with two rooms for testing and counseling, a folding gazebo to allow for additional testing space or a shaded waiting area, folding tables, and three counsellors. In addition, mobile units had portable public address systems available for use in promotional messaging. The mobile units transported all supplies needed for rapid HIV testing. In addition, condoms and educational materials promoting male medical circumcision, HIV care, and safer sex were available and displayed on folding tables outside of the van. Incentives were usually made available and given after completion of the HTS process. Incentives were <USD1 in value (e.g., water bottle, lanyard, piece of fruit).

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An HTS coordinator developed a monthly deployment schedule with sites selected based on requests from community organizations, the Department of Health, employers, event promoters, and the experience of the HTS coordinator. The specific spot of setting up the mobile testing was determined by consultation with community leaders or other appropriate officials. HTS was promoted by placing posters and leaving fliers in the vicinity of the planned site several days prior to the testing day and through the use of a public address system on the day or days of testing. Testing was conducted over several days at most sites. HTS was provided in accordance with the national Department of Health testing algorithm and counseling guidelines.¹² HTS at all sites was accessible to the local population: adult men and women legally able to consent to HIV testing. Black Africans were in the majority at all testing sites. There were no single-sex locations such as mining or other industrial operations, correctional facilities, or schools.

Test data collection

As part of routine service delivery and reporting, a paper register was used to register all clients and included age, sex, and test result. These registers were abstracted daily by the HTS counselors and aggregated for daily tallies of HTS completed and testing yield. It should be noted that there was no emphasis on yield made to the HTS teams throughout the study period. Specific targets, when provided, were in reference to the total number of clients tested.

Site-level data collection

A selection of sites representing high-, middle-, and low-yield testing venues from the routine program were selected for characterization. A research team member visited the site to complete a structured site assessment and a structured interview with a local community leader. The site assessment included local characteristics, including the nature of the site (e.g., shopping center, sports ground, residential area), the surrounding housing type, access to public road, sanitation facilities, access to water, presence of a school or public offices, and nature of shops in shopping centers or malls. The lowest cost housing type was based on the classification of relative quality or cost. The community leader interviews included local availability of HTS and community characteristics. We selected variables based on a potential association with testing yield (e.g., indicators of lower socio-economic status or more limited service delivery) and ease of collection for a routine use in guiding HTS unit deployment. These characteristics represented the immediate surrounding community as defined by the area within line of sight of the testing location, roughly corresponding to within 100 m.

Because HIV prevalence is higher among lower-income individuals in South Africa, we sought to characterize stores and restaurants by the target customer financial status based on whether options were aimed at lower-income or low-middle to middle-income individuals. We classified retail stores and restaurants into lowest cost and mid-cost in our sample. We categorized using the cost of a standard item or a primary meal and the study team's local knowledge. When available, we also used target market segment listed in financial reports from publically traded chain stores. Some shops, such as dry cleaners, were more likely to be associated with mid-range income, and was thus classified as mid-range. Others, such as shops selling meat for on-premises roasting, were categorized as low-cost. For retail sites, we tested the following independent variables: type of shopping center (i.e., destination vs. local shopping), accessibility to shopping

center (i.e., no cost vs. paid parking), presence of automated teller machines, presence of anchor tenants, and the type of lowest cost housing near the shopping center.

Mapping

The location of each mobile testing site and clinic were captured using a portable GPS tracker. Waypoints were then geocoded using ArcMap 10.4.1 (ESRI, Redlands, CA, USA); 'nearest distance' networking was used to estimate the distance between each testing site and the nearest clinic.

Analysis

We completed analysis separately for community and retail sites due to natural differences in these categories, leading to differences in variables describing each category. Specifically, communities were characterized by housing type, municipal services, and road access, while shopping centers were described by number and type of retail stores and restaurants. We excluded educational facilities (tertiary learning institutions), as the yield in our program was consistently low (<1%), consistent with other findings for these venues.^{6,13} Descriptive statistics were used to describe the community and shopping center venues. Binary regression analysis (*binreg* command, Stata; Stata Corp, College Station, TX, USA) was used for hypothesis testing; the primary outcome was HIV-positive testing yield. Binary regression was used to adjust for the size of the tested population, with the number testing HIV-positive as the numerator and total number of clients tested at that venue the denominator. Initially, single independent variables were assessed, followed by multivariable model building with independent variables with $P < 0.1$. For community testing, we tested the following independent variables that characterized the immediate surrounding communities: lowest cost housing type, water sources, frequency of refuse removal, public road access, energy sources for domestic purposes, distance to the clinic, and day of the week that testing occurred. Multiple variables exhibited collinearity in multivariable modeling. When we observed collinearity we kept the variable with the strongest association with testing yield (highest odds ratio) and removed collinear variables. We excluded sites from analysis that performed fewer than 15 HTS sessions.

RESULTS

Testing yield

We included data from 152 testing sites, comprising of 126 community and 26 retail sites. We excluded four community sites because they had data for <15 HTS sessions, leaving 122 sites for analysis. Eighty-three (68%) of the community sites and 16 (62%) of the shopping center sites were in peri-urban and urban Ekurhuleni District. The remaining were in rural Sekhukhune district. The median number of tests conducted per community site was 73 (interquartile range [IQR] 42–140), representing 13,056 HTS sessions and resulting in a median of six HIV-positive test results (IQR 4–11) and a corresponding HIV-positive yield of 7.6% (IQR 5.1–10.8; range 1.5–24.1) (Table 1). A median of 87 tests (IQR 53–243) were conducted at shopping center sites resulting in a median of five identified HIV-positive clients (IQR 3–5) and a median HIV-positive yield of 6.9% (IQR 6.2–7.9; range 2.5–18) (Table 2).

Site characteristics associated with HIV-positive testing yield

When describing sites by the lowest cost housing in the vicinity, 81 (66%) sites were in areas with informal settlements or

TABLE 1 Community characteristics

	<i>n</i> (%)
Total, <i>n</i>	122
District	
Ekurhuleni	83 (68)
Sekhukhune	39 (32)
Tests per site, <i>n</i> , median [IQR]	73 [42–140]
HIV-positive yield, %, median [IQR]	7.6 [5.1–10.7]
Testing day, <i>n</i>	
Monday	67
Tuesday	65
Wednesday	69
Thursday	71
Friday	0
Saturday	63
Sunday	54
Lowest cost housing	
Informal settlements or hostels	81 (66)
Single family houses	41 (34)
Toilet type	
At home (indoor or pit)	111 (88)
Communal (chemical/bucket/pit)	15 (12)
Water source	
Communal or water truck	37 (30)
Piped to residence	54 (44)
Missing	31 (25)
Refuse removal	
No removal	33 (27)
Scheduled removal	58 (48)
Missing	31 (25)
Energy use	
Kerosene	22 (18)
Electricity	81 (66)
Missing	19 (16)
Road access	
Public roads	83 (68)
No public access	8 (6)
Missing	31 (25)
Commercial establishments	
Train station or shopping centre	55 (45)
Minibus rank or small trader market	33 (27)
No notable commercial activity	34 (28)
Distance to clinic, km, median [IQR]	1 [0.38–4.9]
<0.5	34 (28)
0.5–2	47 (38)
>2	39 (32)
Missing	2 (2)

IQR = interquartile range.

residential hostels and 41 (34%) sites were in areas of formal single-family housing. Testing sites included areas with and without access to public roads, running water, and toilet facilities for each residence. The median distance to the closest clinic was 1 km (IQR 0.38–4.9), and the median number of days that the unit was at a given site was 4 (IQR 1–6) (Table 1). Retail site testing occurred at establishments with a range of sizes and costs of retail stores and restaurants (Table 2). Venues with high and low HIV-positive yield were dispersed across the two districts, often in close proximity, especially in the urban district (Figure).

TABLE 2 Shopping site characteristics

	<i>n</i> (%)
Total, <i>n</i>	26
District	
Ekurhuleni	16 (62)
Sekhukhune	10 (38)
Tests per site, <i>n</i> , median [IQR]	87 [53–243]
HIV-positive yield, median [IQR]	6.9 [6.2–7.9]
Shopping centre type	
Destination shopping	6 (23)
Local shopping	20 (77)
Number of anchor stores	
None	2 (8)
1 or more	25 (92)
Dry cleaners	
No	13 (54)
Yes	11 (46)
Parking type	
Paid parking	1 (4)
No charge parking	25 (96)
Automatic teller machine	
No	1 (4)
Yes	25 (96)
Lowest income housing	
Informal or hostel	22 (85)
Formal housing	4 (15)
Adjacent to train station	
No	21 (81)
Yes	5 (19)
Restaurant cost	
Lower	12 (46)
Medium	14 (54)
Retail shop cost	
Lower	4 (15)
Medium	22 (85)

IQR = interquartile range.

In univariable analysis for community testing, testing in an area characterized by the lowest cost accommodations (including informal settlements and hostels), was associated with a higher testing yield, as were communal toilets in the residential area, use of kerosene for energy rather than electricity, and no immediate access to public roads (Table 3). In multivariable analysis, informal settlement or hostel (odds ratio [OR] 1.2, 95% confidence interval [CI] 1.9–1.5), lack of access to a public road (OR 1.4, 95% CI 1.1–1.9), and intermediate distance of 0.5–2.0 km between the test site and a public clinic were associated with higher HIV-positive test yield. To note, the association between distance from the test site to the nearest public clinic only held for Ekurhuleni. Factors for which we did not find an association with HIV-positive yield included district, day of the week of testing, nearby commercial establishments, water source, or scheduled refuse removal.

For the 26 shopping centers and malls, factors associated with a higher HIV-positive yield were all characteristics of serving a lower-income population (Table 4). These included smaller stores (lack of anchor stores), the absence of a dry cleaners, and proximity to a train station. We found that once there was at least one name-brand anchor store, the presence of additional anchor stores did not affect the yield. Thus, we created a

FIGURE HIV-positive testing yield in community sites in **A)** Ekurhuleni and **B)** Sekhukhune. The circles represent the location of testing. The size of the circles represent the HIV testing yield.

dichotomous variable of anchor store present or absent. In contrast to the community venues, HIV-positive testing yield was lower in retail establishments in rural Sekhukhune District than in Ekurhuleni District. In multivariable analysis, the association with the absence of a dry cleaners and higher HIV-positive yield lost significance, while district (OR for Sekhukhune was 0.83, 95% CI 0.70–0.99), lack of anchor tenants (OR 2.5, 95% CI 2.2–2.9), and proximity to a train station (OR 1.1, 95% CI 1.0–1.2) all retained significance. Proximity to informal settlements was not associated with test yield, nor was lower cost restaurants or shops.

DISCUSSION

Sites with the highest and lowest yield were within 500 m of each other. Specific characteristics immediately around the site and those that differentiated the site from other nearby sites were associated with yield. What distinguished sites with the highest HIV-positive yield was lower cost housing and more marginalized populations, especially areas using communal toilet facilities – also a characteristic of many informal settlements and some residential hostels. Similarly, testing at shopping areas for a lower-income consumer segment and near to a train station had a higher HIV test yield.

By determining the location of testing using GPS coding and by identifying characteristics associated with yield in the local environs, we have sought to add understanding to how best to deploy mobile HTS to maximize efficiency. To note, we have focused on the testing yield rather than the local HIV prevalence, as a high prevalence of mostly diagnosed individuals can be expected to result in a low HIV-positive testing yield during a mobile testing campaign. Our findings can help to guide community mapping activities to inform rational deployment of mobile community HTS services. Ideally, general site-level data could be collected during routine service delivery for use in continuous quality improvement efforts.

We found overall factors associated with yield at community sites and shopping venues were relatively consistent. One difference was a lack of association with the district in the multivariable analysis of community testing when controlling for other associations with yield, which contrasts with the lower yield in Sekhukhune District in shopping site testing. The lower HIV-positive yield in shopping sites may reflect the overall lower prevalence of HIV in Sekhukhune, where the overall HIV prevalence is half of that in Ekurhuleni (7.5% vs. 15%).¹⁴ The lack of an association between the district and yield at the community sites may be a result of more effective deployment of mobile units to more marginalized communities with anticipated higher HIV testing

TABLE 3 Associations between community HIV testing venue characteristics and HIV yield

Characteristic	n/N	Univariable OR (95% CI)	P value	Multivariable aOR (95% CI)	P value
District					
Ekurhuleni	938/10,589	Reference		Reference	
Sekhukhune	186/2,467	0.85 (0.69–1.0)	0.1	0.97 (0.76–1.2)	0.8
Housing					
Tract housing, house	333/4,374	Reference		Reference	
Informal settlement, hostel	791/8,682	1.2 (1.0–1.5)	0.02	1.2 (1.0–1.4)	0.05
Toilets					
Household	764/9,359	Reference			
Communal	260/2,316	1.5 (1.2–1.8)	0.001		
Water source for domestic use					
Piped to residence	543/6,186	Reference			
Communal or trucked in	423/4,652	1.3 (1.0–1.7)	0.02		
Refuse removal					
Scheduled removal	780/8,447	Reference			
No removal	186/2,391	1.1 (0.86–1.5)	0.4		
Energy source					
Electricity	707/8,530	Reference			
Kerosene	317/3,145	1.5 (1.1–2.0)	0.01		
Missing	100/1,381				
Adjacent commercial facilities					
Shops or train station	625/7,251	Reference			
Informal market or minibus station	324/3,264	1.2 (0.95–1.5)	0.1		
No commercial activity	175/2,541	0.78 (0.62–0.97)	0.02		
Public road access					
Access	854/9,900	Reference		Reference	
None	112/928	1.4 (1.1–1.9)	0.01	1.5 (1.1–2.0)	0.01
Missing	158/2,218	0.80 (0.65–0.98)	0.03		
Distance to nearest clinic, km					
<0.5	381/4,660	Reference		Reference	
0.5–2.0	494/4,937	1.2 (1.0–1.6)	0.06	1.2 (1.0–1.5)	0.06
>2.0	240/3,324	0.87 (0.69–1.1)	0.2	0.87 (0.69–1.1)	0.2
Missing	9/135	0.81 (0.46–1.4)	0.5	0.84 (0.53–1.3)	0.4

OR = odds ratio; CI = confidence interval; aOR = adjusted OR.

yield. We hypothesize that the association with train stations and HIV-positive yield is because lower-income workers use municipal commuter trains in South Africa.

Geospatial mapping has long been a tool to guide public health measures, including prevention and HIV treatment services.^{15,16} Geospatial mapping has been used to provide a birds-eye overview of HIV prevalence for sub-Saharan Africa.^{17–20} Geospatial mapping has also been used to target specific services such as response to a local epidemic and geographical descriptions of HIV incidence and geospatial associations, including distance from transport routes, population density, and available health services.^{15,16} Less effort has gone into understanding how to use geospatial data to deploy available resources to be most efficient. One study, also from South Africa, assessed location of mobile testing and distance between venue and residence of clients.⁶ This study similarly found considerable variation in HIV yield by site, with sites close to minibus hubs having the highest yield.

Our study had the following strengths: focused community-level data collection within a larger routine mobile HTS service, and a large number of venues with substantial heterogeneity across the two study districts. This study also had some limitations. These include potential poorer quality data as rou-

tine data were used, and selecting and correctly characterizing the most appropriate local site characteristics. We also lacked data on new diagnoses because self-report of HIV testing is unreliable and there is no national registry of HIV testing in South Africa, and data on new diagnoses vs. retesting. It is possible that some proportion of those testing HIV-positive may have had a prior positive test result. However, we do not believe that this varied substantially by test site characteristic, limiting bias in our results.

We believe that mobile HTS continues to have an important role in HIV testing and diagnosis. Our findings indicate that mobile HTS services have the potential to achieve high yield, with deliberate optimal selection of sites to maximize yield. To maintain or increase the relevance of mobile HTS, testing programs should systematically select sites based on factors in the immediate vicinity of the potential site. In our setting, these were more likely to be marginalized areas or commercial areas geared to lower-income individuals. One of the challenges with mobile HTS is to ensure that there is good coordination so that testing services are provided in places where people need them. If we deploy mobile HTS in areas with local characteristics suggesting likely higher yield, as indicated by our study findings, mobile HTS can play an important role in identifying individuals living with HIV, espe-

TABLE 4 Associations between commercial shopping venue characteristics and positive HIV testing yield

Characteristic	n/N	Univariable OR (95% CI)	P value	Multivariable aOR (95% CI)	P value
District					
Ekurhuleni	335/4,574	Reference		Reference	
Sekhukhune	46/770	0.80 (0.68–0.95)	0.01	0.83 (0.70–0.99)	0.04
Shopping type					
Destination	112/1,676	Reference			
Local	269/3,668	1.1 (0.89–1.4)	0.4		
Parking					
Pay	15/243	Reference			
No cost parking	366/5,101	1.2 (1.1–1.3)	<0.001		
“Anchor” tenants					
0	13/84	2.4 (2.0–2.9)	<0.001	2.5 (2.2–2.9)	<0.001
1 or more	368/5,260	Reference		Reference	
Dry cleaner present					
No	254/3,478	1.2 (1.0–1.3)	0.02		
Yes	60/953	Reference			
Restaurant cost					
Lower	163/2,159	1.1 (0.94–1.3)	0.2		
Medium	218/3,185	Reference			
Retail shop cost					
Lower	53/649	1.2 (0.82–1.7)	0.4		
Medium	328/4,695	Reference			
Adjacent housing					
Tract housing–house	364/5,087	Reference			
Informal settlement–hostel	17/257	1.1 (0.9–1.3)	0.4		
Adjacent to train station					
No	272/3,920	Reference		Reference	
Yes	109/1,424	1.1 (1.0–1.2)	0.04	1.1 (1.0–1.2)	0.03

OR = odds ratio; CI = confidence interval; aOR = adjusted OR.

cially those less likely to visit clinics, and engaging them in the care continuum.

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CONTEXTE : Le dépistage communautaire mobile du VIH est un moyen efficace pour atteindre les personnes vivant avec le VIH non diagnostiquées en Afrique australe. Les taux de positivité variables aux tests de dépistage du VIH constituent un défi puisque certains sites aux taux de positivité élevés sont souvent géographiquement proches de sites dont les taux de positivité sont faibles. Nous avons cherché à tester si certaines caractéristiques faciles à identifier et propres aux sites étaient associées aux taux de positivité des tests de dépistage du VIH dans un programme de dépistage du VIH mobile systématique.

MÉTHODES : Nous avons utilisé les données des tests du programme de dépistage systématique et procédé à une caractérisation des sites, soit de la communauté soit de la zone commerciale où le dépistage du VIH était proposé. Plus précisément, nous avons décrit l'environnement local et interrogé des informateurs

clés afin d'obtenir des informations supplémentaires sur la disponibilité de services anti-VIH et autres dans cette zone.

RÉSULTATS : Nous avons inclus 122 résidents et 26 zones commerciales avec un taux médian de positivité aux tests de dépistage du VIH de 7,6% et 6,9%, respectivement. L'étendue allait de 2% à 55% pour les sites communautaires, avec des taux de positivité faibles ou élevés dans des sites géographiquement proches. Les facteurs liés à de faibles revenus et à une marginalisation (par ex., logement informel et absence de magasins de marque dans les zones commerciales) étaient associés à de plus forts taux de positivité aux tests de dépistage du VIH.

CONCLUSIONS : La caractérisation des sites, notamment l'identification des facteurs liés à la marginalisation, au manque de services et à la pauvreté, peut aider à identifier les sites où les taux de positivité aux tests de dépistage du VIH sont plus élevés.