

# No increased HIV risk in general population near sex work sites: A nationally representative cross-sectional study in Zimbabwe

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## Funding information

Dutch AIDS Foundation

## Abstract

**Objectives:** Sex work sites have been hypothesised to be at the root of the observed heterogeneity in HIV prevalence in sub-Saharan Africa. We determined if proximity to sex work sites is associated with HIV prevalence among the general population in Zimbabwe, a country with one of the highest HIV prevalence in the world.

**Methods:** In this cross-sectional study we use a unique combination of nationally representative geolocated individual-level data from 16,121 adults (age 15–49 years) from 400 sample locations and the locations of 55 sex work sites throughout Zimbabwe; covering an estimated 95% of all female sex workers (FSWs). We calculated the shortest distance by road from each survey sample location to the nearest sex work site, for all sites and by type of sex work site, and conducted univariate and multivariate multi-level logistic regressions to determine the association between distance to sex work sites and HIV seropositivity, controlling for age, sex, male circumcision status, number of lifetime sex partners, being a FSW client or being a stable partner of an FSW client.

**Results:** We found no significant association between HIV seroprevalence and proximity to the nearest sex work site among the general population in Zimbabwe, regardless of which type of site is closest (city site adjusted odds ratio [aOR] 1.010 [95% confidence interval {CI} 0.992–1.028]; economic growth point site aOR 0.982 [95% CI 0.962–1.002]; international site aOR 0.995 [95% CI 0.979–1.012]; seasonal site aOR 0.987 [95% CI 0.968–1.006] and transport site aOR 1.007 [95% CI 0.987–1.028]). Individual-level indicators of sex work were significantly associated with HIV seropositivity: being an FSW client (aOR 1.445 [95% CI 1.188–1.745]); nine or more partners versus having one to three lifetime partners (aOR 2.072 [95% CI 1.654–2.596]).

**Conclusions:** Sex work sites do not seem to directly affect HIV prevalence among the general population in surrounding areas. Prevention and control interventions for HIV at these locations should primarily focus on sex workers and their clients, with special emphasis on including and retaining mobile sex workers and clients into services.

## KEYWORDS

commercial sex work, HIV/AIDS, HIV epidemic, HIV transmission, sub-Saharan Africa, Zimbabwe

## INTRODUCTION

About two thirds of people living with HIV worldwide reside in sub-Saharan Africa [1], with many countries still

experiencing high incidence and prevalence levels in the general population. Throughout the subcontinent, the epidemic is geographically heterogeneous with localised areas of high transmission around big cities, truck route pit-stops and locations with high levels of economic activity [2]. Sex work has often been hypothesised to be at the root of the

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observed geographical heterogeneity [3, 4], as sites where sex workers offer their services, here called ‘sex work sites’, are oftentimes also situated at locations with high economic activity. However, whether the presence of sex work sites is associated with higher HIV prevalence in the general population, and thus can directly explain the observed geographical heterogeneity in the epidemic, has never been empirically tested.

Zimbabwe is one of the countries with the highest HIV burden worldwide. Although incidence levels have decreased by 44% over the past decade [1, 5], the decline seems to have stalled in recent years [6]. HIV prevalence among female sex workers (FSWs) is over 50% according to the latest estimates (2018–2020) by the Centre for Sexual Health and HIV/AIDS Research (CeSHHAR) Zimbabwe [7], an organisation focused on HIV implementation research and responsible for running Zimbabwe’s nationally scaled healthcare program for FSWs on behalf of the Zimbabwean government ([www.ceshhar.org](http://www.ceshhar.org)). CeSHHAR runs (mobile) clinics throughout Zimbabwe, offering services at 36 sex work sites [7], and has further mapped the locations of 19 other sex work sites in the country [7]. Data on the locations and typology of sex work sites, together with nationally representative geolocated survey data from the Demographic and Health Survey (DHS) on HIV prevalence and risk behaviour in the general population [2, 8] create the unique opportunity to test whether the HIV prevalence in the general population of Zimbabwe is higher among those living in close proximity to sex work sites.

We determined if geospatial heterogeneity in HIV prevalence in the general population in Zimbabwe is associated with proximity to sex work sites. We first calculated travel distance between DHS sample locations and known sex work sites, and used univariate and multivariate logistic regression models to determine the association between distance to the nearest sex work site and HIV prevalence, controlling for demographic and sexual behavioural factors.

## METHODS

### Data—CeSHHAR

CeSHHAR has registered the locations and characteristics of 55 sex work sites throughout Zimbabwe, from 2015 to 2017 [7], and GPS coordinates of each site were collected via Google Maps Coordinates [9]. Sex work sites are described as ‘hotspots’ for sex work, and one sex work site can consist of multiple venues where sex work takes place, such as bars, she-beens, streets, brothels, beer halls, sport bars, nightclubs, parking lots at border crossings, truck stops, mining areas or marketplaces. For example, the city Harare is identified as one sex work site but consists of a huge variety of sex work venues throughout the city, from parking lots to hotels. The sex work sites are originally identified based on expert opinion and reported by Fearon et al. [7]. They include 36 CeSHHAR sites, as well as 19 additional sex work locations

identified in a structured workshop with experts, based on reached consensus on the presence of each of those sex work locations per province. The identified sex work sites cover an estimated 95% of all FSWs, based on the calculations by Fearon et al. [7], who counted the numbers of FSWs at the different CeSHHAR sites during various times to calculate the proportion of FSWs among the general population at each site (using existing size population size data), which were then used to estimate the number of FSWs at non-CeSHHAR sites [7]. All 55 sex work sites were primarily identified as locations where FSWs work, but the sites might also be utilised by male and transgender sex workers. As different sex work sites might attract different types of clients with a different connection to the surrounding general population, we added a stratified analysis using five sex work site categories, based on expert opinion: city (city or regional capital), economic growth point (rural area with rapid economic growth), international (tourism, international business and border crossing), seasonal (mining, farming, fishing, university or army base) or transport (truck stop, transport hub or border crossing) [7]. Sites that fitted in multiple classifications were included in each relevant category up to a maximum of three categories per site. This way, a sex work site that was classified as, for example, truck stop and mining area was included as both a transport site and a seasonal site.

### Data—DHS

We used the 2015 DHS from Zimbabwe, which includes voluntary HIV testing in the general population, and overlaps with the timeframes in which sex work sites were identified, classified and localised. The survey was conducted using standard DHS methodology; 400 locations (primary sampling units) were randomly sampled throughout the country, weighted by the population density per area, and about 25 randomly selected households were included at each sample location. HIV status was determined in the DHS by testing a blood sample from a finger prick using enzyme-linked immunosorbent assay. GPS coordinates of sample locations were randomly displaced up to 2 km for urban and up to 5 km for rural locations, to ensure confidentiality of participants. All males and females aged 15–49 years with available HIV test results were included in our analysis.

Besides HIV status and GPS data, we included several demographic and (sexual) behavioural variables in our analyses: age, sex, male circumcision, number of lifetime sex partners, being an FSW client or being a stable partner of someone who reported to be an FSW client. FSW clients were defined based on whether a man had ever, or in the last year, paid for sexual intercourse. Men who reported to have offered gifts and goods in exchange for sex, instead of money, were not defined as FSW clients in our analysis, due to lack of coherency comparing those answers to the other FSW-related questions. Missing values for lifetime sex partners (136 values, 0.84% of all values) were imputed using multiple imputation [10].

In addition to the variables directly extracted from the DHS, we estimated the proportion of all men being an FSW client at each sample location, the proportion of all women being an FSW within 50 km radius around the sample location, and the human mobility level of people at each sample location. The proportions were determined to indicate the proportion of people directly engaging in FSW among the general population, as the relative size (i.e., number of sex workers relative to the population density of the area) is likely more important than absolute size (i.e., the estimated number of sex workers) [7, 11]. We calculated the proportion of FSW clients as the fraction of all 15- to 49-year-old men at each sample location, as proxy for utility of commercial sex work among men at the sample location. We estimated the proportion of FSWs among the female population around each DHS sample location (in a 50-km radius) by dividing the number of FSWs in the area, based on sex work site size estimates from the CeSHHAR database [7], by the total female population in the area, based on population estimates provided by the WorldPop project [12] and ZimStat [13]. The estimates are provided in Figure S1. We hypothesised that human mobility might influence the association between distance to a sex work site and HIV prevalence, as human mobility is often associated with higher HIV risk and mobile individuals might engage in sex work at different locations than where they (or their families) live long-term [3, 14, 15]. We therefore estimated the human mobility level of individuals in the DHS data based on combining three DHS variables; whether an individual was identified as being mobile in the past year through either being a seasonal worker; being away from home for at least 1 month; or being away from home more than two times in the past 12 months, with an individual being identified as ‘mobile’ when at least one out of three were answered with ‘yes’. The prevalence of human mobility was then aggregated per DHS sample location, where sample locations with a human mobility prevalence of 50% or more were marked as locations with high human mobility, and sample locations with less than 50% were marked as locations with low human mobility. More details on survey protocols and questionnaires can be found on the DHS website (<https://dhsprogram.com/>).

## Statistical analysis

We applied Ordinary Kriging to predict and visualise geospatial heterogeneity in HIV prevalence among adults throughout Zimbabwe. This is a commonly used geospatial method that could be used to estimate the best linear unbiased prediction of HIV prevalence at unsampled locations, based on HIV prevalence levels from known data points, which in our study were the sample locations from the DHS data [16]. Using this method, an HIV prevalence estimate was predicted for every 5-by-5 km grid cell in Zimbabwe. The method is described in more detail elsewhere [2].

Next, we determined the distance between DHS sample locations and sex work sites, calculated as the shortest distance from each DHS sample location to the nearest sex work site via paved and unpaved roads in kilometres (roads available via Open Street Map [17]). We applied these distances to each individual in the DHS data based on their sample location. The proximity calculation is illustrated in Figure S2.

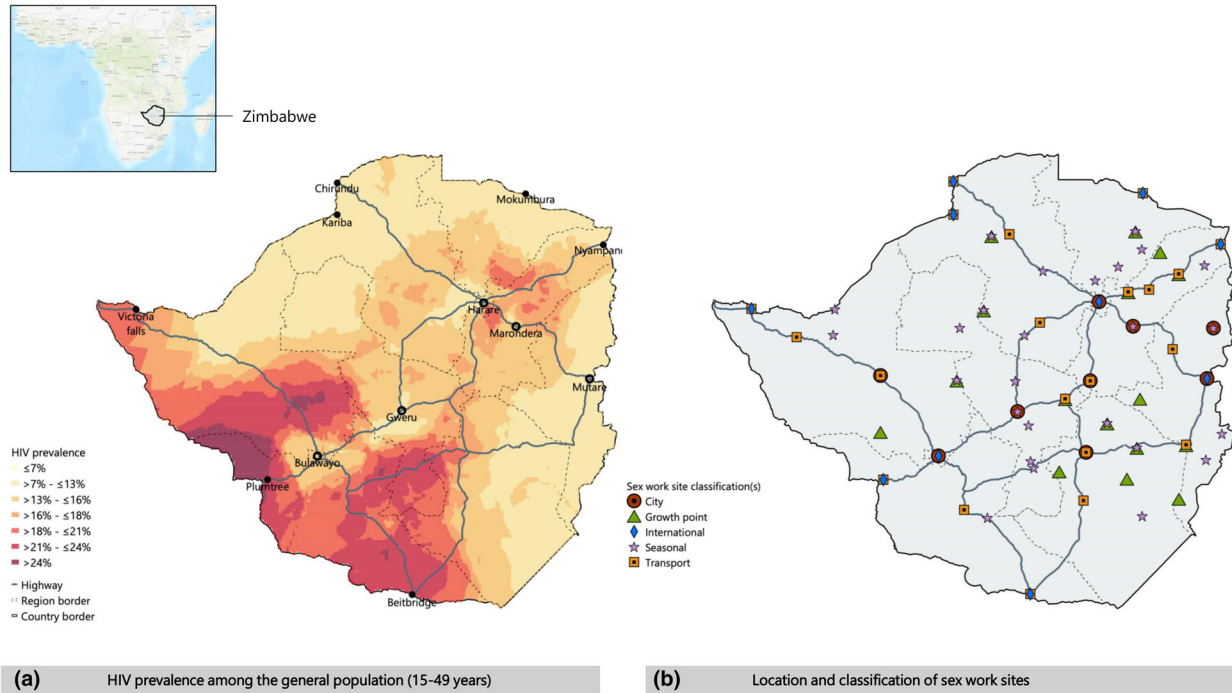
To determine the association between HIV prevalence among the general population and proximity to sex work sites, we performed individual-level and multilevel logistic regression analyses with HIV status (positive or negative) as dependent variable and the proximity to the nearest sex work site (distance to any sex work site as well as by type of site, e.g., distance to the nearest city site and distance to the nearest economic growth point site) as independent variables.

We first plotted the untransformed association between travel distance to sex work site, and both HIV prevalence at each sample location, and proportion of men reporting being FSW clients at each sample location. We then tested the univariate association between general population HIV status and proximity to sex work sites using logistic regression using a square root transformed proximity variable as the variable most closely resembled a normal distribution using this transformation. However, we also explored associations with categorical, untransformed continuous, and log-transformed proximity variables (Figure S3). The associations between HIV status and all demographic and sexual behavioural variables included in this study were also first assessed univariately.

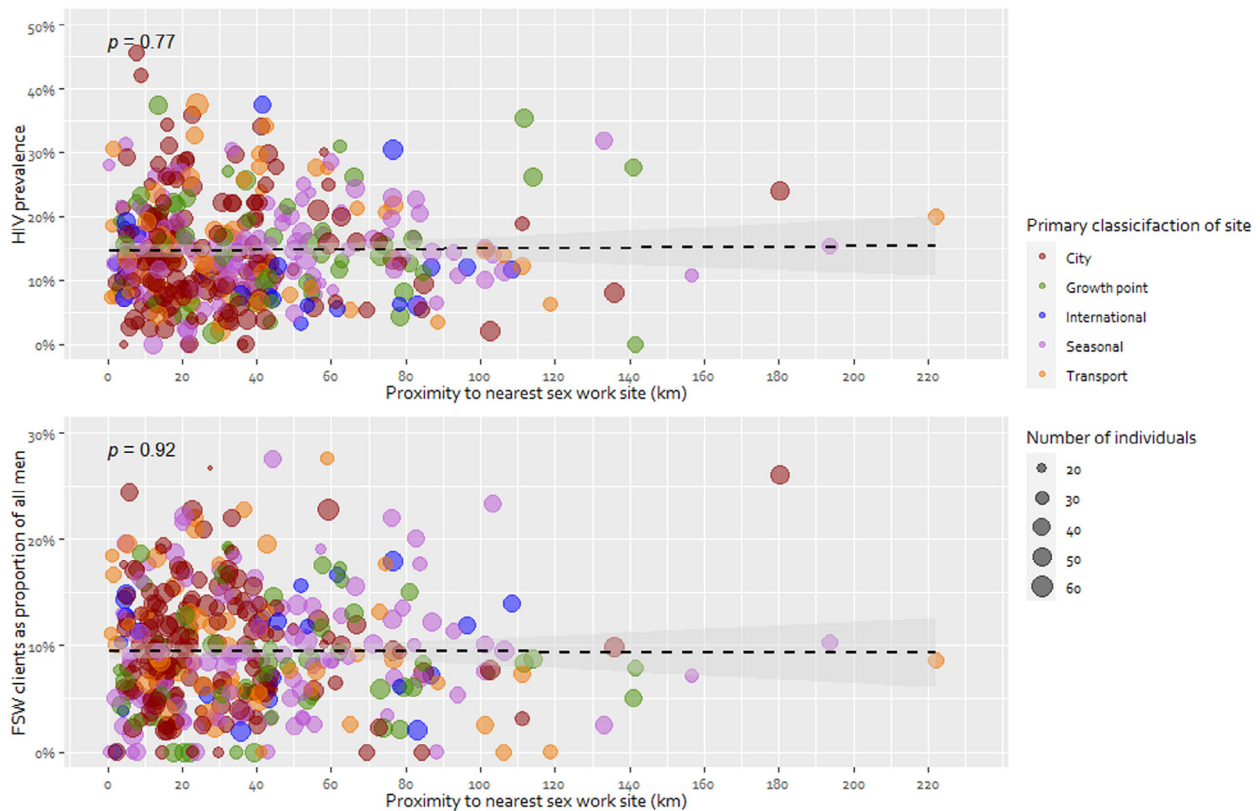
In the multivariate analysis, the association between travel distance to sex work sites and HIV status was adjusted for individual-level and sample location-level demographic and sexual behavioural risk factors related to FSW: age, sex, male circumcision, lifetime sex partners and being identified as an FSW client, estimated proportion of FSWs at each sample location, urban or rural classification of each sample location, and population mobility score of each sample location. The DHS sample location was included as a random effect. The final multilevel multivariate model was developed using a backward selection procedure, where all variables that did not significantly improve the model fit (tested using likelihood tests,  $p > 0.05$ ) were excluded. Finally, we separately fitted univariate and multivariate models stratified by sample location mobility score and urban/rural classification to examine potential effect modification. We used R software version 4.0.1 and ArcGIS Pro version 2.3 to perform the analyses.

## Ethics approval

Ethics approval was arranged by USAID (<https://dhsprogram.com/Methodology/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm>). No separate consent was required to use the anonymised data.



**FIGURE 1** HIV prevalence among the general population in Zimbabwe (panel (a)) and sex work sites in Zimbabwe by type (panel (b)). HIV prevalence estimates are acquired using Ordinary Kriging (shown by  $5 \text{ km}^2$ ) and are based on the Zimbabwe 2015 DHS data of males and females (aged 15–49 years). DHS data obtained through <https://dhsprogram.com/>. Sex work site sites are obtained via CeSHHAR Zimbabwe (<http://ceshhar.org/>). Twenty-one sites were identified as transport sites, 32 as seasonal sites, 10 as international sites, 9 as city sites and 9 as economic growth point sites. DHS, Demographic and Health Survey.



**FIGURE 2** HIV prevalence among the general population (age 15–49 years) (panel (a)) and the proportion of all men who ever visited a FSW (panel (b)) in relation to proximity to the nearest sex work site, by DHS sample location. Colours represent the primary classification of the sex work site. Sizes of the bubbles represent the number of individuals in each DHS sample location, numbers shown in legend are approximations. Dashed lines represent smoothed generalised logistic regression fits for the associations, for all types of sex work sites together. DHS, Demographic and Health Survey; FSW, female sex worker.

**TABLE 1** Univariate and multivariate multilevel logistic regression analysis of HIV status among Zimbabwean males and females age 15–49. Both univariate and multivariate models are adjusted for DHS sample location random effects.

Covariate	N	HIV prevalence	Univariate analysis		Multivariate analysis			
			OR [95% CI]	p Value	aOR [95% CI]	p Value		
Proximity to the nearest female sex work site (km, square root transformed)								
All sites	16,121	14.7%	0.995 [0.976–1.013]	0.563	–			
Proximity to the nearest female sex work site (km, square root transformed) by type								
City	6481 <sup>a</sup>	14.5%	0.998 [0.986–1.009]	0.692	1.010 [0.992–1.028]	0.290		
Economic growth point	2325 <sup>a</sup>	15.5%	0.984 [0.968–1.000]	0.050	* 0.982 [0.962–1.003]	0.088		
International	999 <sup>a</sup>	12.2%	1.001 [0.990–1.012]	0.884	0.995 [0.979–1.012]	0.564		
Seasonal	4124 <sup>a</sup>	15.3%	0.988 [0.974–1.003]	0.124	0.987 [0.968–1.006]	0.176		
Transport	2192 <sup>a</sup>	14.5%	1.006 [0.990–1.023]	0.462	1.007 [0.986–1.028]	0.500		
Percentage of FSW clients as proportion of all men in survey at sample location								
<5%	3493	12.8%	1	–	–			
5%–15%	10,125	15.1%	1.208 [1.022–1.426]	0.026	* –			
≥15%	2503	15.8%	1.259 [1.012–1.567]	0.039	* –			
Percentage of FSWs as proportion of the female population in 50 km radius around sample location								
<5%	7378	14.0%	1		1			
5%–15%	4964	16.0%	1.173 [1.008–1.365]	0.039	* 1.155 [0.986–1.353]	0.075		
≥15%	1483	14.2%	1.017 [0.804–1.286]	0.889	1.118 [0.874–1.431]	0.375		
Sex								
Male	7069	11.2%	1		1			
Female	9052	17.5%	1.684 [1.535–1.849]	<0.001	*** 2.540 [2.202–2.930]	<0.001	***	
Age								
15–24 years	6739	5.1%	1		1			
25–34 years	4922	16.7%	3.848 [3.368–4.397]	<0.001	*** 2.454 [2.085–2.890]	<0.001	***	
34+ years	4460	27.0%	7.324 [6.437–8.335]	<0.001	*** 5.001 [4.261–5.868]	<0.001	***	
Sex work client ever (males only)								
Yes	1529	20.5%	2.710 [2.312–3.177]	<0.001	*** 1.440 [1.188–1.745]	<0.001	***	
No	5540	8.6%	1		1			
Sex work client in the last year (males only)								
Yes	822	19.7%	2.101 [1.728–2.553]	<0.001	*** –			
No	6247	10.1%	1		–			
Partner of FSW client (females only)								
Yes	787	19.7%	1.147 [0.949–1.386]	0.157	–			
No	8265	17.3%	1		–			
Lifetime number of sex partners								
None	3309	3.4%	0.172 [0.141–0.211]	<0.001	*** 0.519 [0.407–0.662]	<0.001	***	
1–3	9651	16.0%	1		1			
4–9	2251	22.8%	1.501 [1.337–1.685]	<0.001	*** 1.999 [1.713–2.332]	<0.001	***	
9+	910	23.2%	1.538 [1.300–1.818]	<0.001	*** 2.072 [1.654–2.596]	<0.001	***	
Circumcised (males only)								
Yes	1150	7.4%	0.558 [0.440–0.708]	<0.001	*** 0.654 [0.495–0.865]	0.003	**	
No	5916	11.9%	1		1			
Sample location-level human mobility prevalence								
High	6334	13.4%	1.088 [0.995–1.190]	0.064	–			
Low	9787	15.6%	1		–			

(Continues)

TABLE 1 (Continued)

Covariate	N	HIV prevalence	Univariate analysis		Multivariate analysis	
			OR [95% CI]	p Value	aOR [95% CI]	p Value
Type of place of residence						
Urban	6737	19.9%	1.087 [0.996–1.187]	0.063	-	
Rural	9384	11.0%	1		-	

Note: Significance codes: 0 “\*\*\*\*” 0.001 “\*\*\*” 0.01 “\*\*” 0.05 “.” 0.1 “.” 1.

Abbreviations: aOR, adjusted odds ratio; CI, confidence interval; N, number of observations; N/A, not applicable; ‘-’, covariate not present in multivariate regression model.

<sup>a</sup>Number of individuals per type was calculated based on the primary classification of the sex work site that was closest to that individual. However, sex work sites could have up to three classifications assigned to them.

## RESULTS

A total of 16,121 individuals from the DHS data were included in our study (Table S1). The overall HIV prevalence in the study population was 14.7% (11.2% among men; 17.5% among women). Over one in five men (21.6%,  $N = 1529$ ) reported to have ever visited an FSW, and about half of them (11.6%,  $N = 822$ ) reported to have visited an FSW during the past year. HIV prevalence among men who ever visited an FSW was 20.5% versus 8.6% for men who never did. Less than half of the study population (41.8%) lived in urban areas, where HIV prevalence was higher as compared to rural areas: 19.9% vs. 11.0%. HIV prevalence was comparable between people with low and high mobility scores (14.5% vs. 15.0%, respectively). HIV prevalence levels for the general population and by subpopulation, that is, men, women and young people (15–24 years), stable partners of FSW clients, FSW clients and FSWs, are shown in Figure S4.

The geographical spread of HIV among the general population was highly heterogeneous (Figure 1a). Prevalence varied from just below 7% in north Zimbabwe and the eastern and north-western borders, to over 21% and 24% at border crossings with South Africa and Botswana respectively. Prevalence was also high (above 18%) in the Victoria Falls area, north of Harare (mining), and in the surrounding areas of Bulawayo (mining area, transport route).

The geographical locations and primary classification of the 55 sex work sites as registered by CeSHHAR are shown in Figure 1b. The nine city sites were located in or close to Harare, Zimbabwe’s capital, and in or close to the other four bigger cities: Bulawayo and Gweru in central Zimbabwe; and Mutare, and Marondera in northeast Zimbabwe. The nine economic growth point sites and 32 seasonal sites were mostly located in the rural areas of the country. Ten international sites were located at border crossings with Botswana (Plumtree), Mozambique (Mokumbura and Nyampanda), South Africa (Beitbridge), and Zambia (Chirundu and Kariba) and around tourist locations (Victoria falls) and the large cities. Twenty-one transport sites were mostly located on the national truck routes throughout the country as well as at the international border crossings.

Figure 2a shows the association between sample location-level HIV prevalence and untransformed distance to the nearest sex work site. There was a large variation in both general population HIV prevalence per sample location, ranging from 0% to 55%, and proximity to nearest sex work site, ranging from 360 m to 220 km, yet there was no statistically significant association between the two variables ( $p = 0.77$ ). Similarly, Figure 2b shows that there was no significant association between the proportion of FSW clients at a sample location, ranging from 0% to 28%, and proximity to nearest sex work site ( $p = 0.92$ ). Scatterplots of the association between HIV prevalence and square root-transformed proximity to the nearest sex work site by type of site are shown in Figure S5.

Table 1 shows the univariate and multivariate associations between square root transformed proximity to sex work sites and demographic and behavioural covariates, and individual HIV status. Univariately, proximity to the nearest sex work site overall was not associated with HIV prevalence (odds ratio [OR] = 0.995 [95% confidence interval {CI} 0.976–1.013],  $p = 0.563$ ). When stratified by type of sex work site, only distance to economic growth point sites was borderline significantly associated with HIV status (OR = 0.984 [0.968–1.000];  $p = 0.050$ ), with increasing distance being associated with lower HIV prevalence.

When controlling for demographic and behavioural variables in the multivariate models, proximity to sex work sites remained not significantly associated with HIV seropositivity in the general population for any sex work site type: city site adjusted odds ratio (aOR) = 1.010 [95% CI 0.992–1.028],  $p = 0.290$ ; economic growth point site aOR = 0.982 [95% CI 0.962–1.002],  $p = 0.088$ ; international site aOR = 0.995 [95% CI 0.979–1.012],  $p = 0.564$ ; seasonal site aOR = 0.987 [95% CI 0.968–1.006],  $p = 0.176$  and transport site aOR = 1.007 [95% CI 0.987–1.028],  $p = 0.500$ . In contrast, individual-level covariates indicative of high-risk behaviour and engaging in commercial sex were significantly associated with HIV prevalence. Reported to have ever engaged in transactional sex (men only) showed a 44% increase in the odds of living with HIV (aOR = 1.445 [95% CI 1.188–1.745],  $p < 0.001$ ). Similarly, reporting nine or more lifetime sexual partners were associated with an over twofold increase in the odds of living with HIV compared to

reporting 1–3 lifetime partners (aOR = 2.072 [95% CI 1.654–2.596],  $p < 0.001$ ). Being circumcised showed a 35% decrease in odds of living with HIV (aOR = 0.654 [95% CI 0.495–0.865],  $p = 0.003$ ).

Multivariate logistic regression models stratified by rural/urban classification or stratified by mobility score of the DHS sample locations showed similar outcomes on the associations between proximity to sex work sites and HIV seropositivity (Tables S2 and S3). Only for the urban sample, proximity to economic growth points was significantly associated with HIV seropositivity in the multilevel model (aOR 0.953 [95% CI 0.925–0.981],  $p = 0.001$ ).

## DISCUSSION

Our analysis of 55 sex work sites and 16,121 individuals from 400 DHS sample locations across Zimbabwe showed no apparent association between proximity to the nearest sex work site and HIV seropositivity among the general population, regardless of which type of sex work site was closest. In contrast, individual-level indicators of FSW and high-risk behaviour were significantly associated with HIV seropositivity, with ever having been an FSW client being associated with a 1½ times increase in the odds of living with HIV, and having nine or more lifetime partners being associated with a more than two-fold increase in the odds of living with HIV compared to reporting one to three lifetime partners.

Geospatial analyses are increasingly being used to illustrate and explain the heterogeneous spread of HIV [2, 8, 18]. For example, Palk and Blower showed that the heterogeneous spread of HIV in Malawi is associated with having a high number of lifetime sex partners [18]. Likewise, in a previous study across seven countries in East and Southern Africa, we showed that the large geographic heterogeneity in HIV prevalence among young adults could be linked to areas of high economic activity [2]. In these and other studies, FSW was univocally hypothesised as an important underlying driver of the geospatial HIV heterogeneity [2, 18–20]. However, this hypothesis was never tested empirically due to the lack of suitable data on locations of sex work sites, FSWs, and FSW clients in areas with nationally representative survey data available. In household surveys such as the DHS, FSWs are often not identifiable as being a sex worker [21]. Clients are identifiable, although reliant on self-reported behaviour. Using our unique combination of geolocated individual-level survey data on HIV seropositivity and risk in the general population, and the mapped locations of over 95% of all sex work sites in Zimbabwe, we showed that the hypothesised direct link between proximity to sex work site locations and heterogeneity in HIV prevalence among the general population does not hold for the situation in Zimbabwe.

It is important to note that our results do not refute the well-grounded notion that FSW is a major driver of HIV transmission in Zimbabwe and other settings with generalised epidemics [20, 22]. On the contrary, our findings clearly

demonstrate that at an individual level, indicators of practising commercial sex as a client are significantly associated with increased risks for HIV. The lack of a geospatial association between sex work sites and HIV prevalence could be explained by a combination of mobility of both FSWs and clients [14, 23, 24], and maturity of the HIV epidemic [22]. Historically, HIV prevalence has been associated with proximity to busy transport routes, truck drivers and migrant mining labour [25–34], which are often locations for sex work sites [35]. However, as epidemics mature, HIV increasingly spreads from transmission hotspots to other areas through bridging populations, diluting the measurable association between HIV prevalence and distance to the hotspots. Furthermore, population mobility is a known key factor among both sex workers and their clients, and the places where they engage in sex are often not equal to places where they live [36]. A previous study on FSWs in Zimbabwe found that around 20% of FSWs travelled at least a couple of times a year over smaller distances, and 10% travelled long-distance while staying away from home for weeks or sometimes months [14]. Clients also do not usually visit FSWs close to where they live, but rather visit FSWs when they spend some time away from home [22]. This is also supported by our study, where we found a clear association between proximity to sex work sites and the prevalence of FSW clients among the general population.

Our findings show that effective programmatic planning of the HIV response cannot solely depend on the observed geospatial heterogeneity in HIV prevalence, as previously suggested [2, 8, 18]. While planning testing and treatment services based on geospatial distribution of HIV prevalence within the general population would still suffice, allocating services for key populations requires careful mapping of hotspots and sites independent of general population HIV prevalence levels [7, 14]. It is essential to better understand what other factors drive the observed geospatial heterogeneity in HIV prevalence—for example, clustering of cultural, geographical or socio-economic factors, or heterogeneities in access to and uptake of interventions—so that interventions can be tailored accordingly.

The lack of a spill-over effect of HIV to the general population in areas surrounding FSW sites emphasises that interventions at these areas should primarily be focused on FSWs and clients, preferably through people-centred HIV services specifically for FSWs and clients at the sex work site, with peer-outreach as a central aspect of implementation [37]. Including sex workers in the design of such interventions and hiring them as staff members is recommended to improve the effectiveness and acceptability by ensuring that services are sensitive and acceptable to the target population [37]. Given the often-high mobility levels of these subpopulations, good accessibility of services is crucial, especially since FSWs and clients might prefer to access HIV clinics at places away from home or utilise several different clinics depending on where they work and engage in commercial sex. Finally, the increased HIV risk among stable partners of FSW clients highlights the need of focused

interventions for this specific subpopulation. Reaching partners of FSW clients might be challenging, as the FSW-visiting partner might be not open to disclose information on engagement in commercial sex to the stable partner. Nevertheless, targeted HIV services for FSW clients could, for example, include their stable partners or include discussing condom use with stable partners.

Our study had some limitations. While the overall number of respondents in the DHS between 15 and 49 years accepting HIV testing was relatively high at 85% [38], male respondents were slightly lower; 81% compared to 88% among women. It is often hypothesised that those who decline have higher HIV risk [39]. However, younger people (15–34 years), often at higher risk of acquiring HIV, were somewhat more likely to participate in the HIV testing in the 2015 DHS. Also in rural areas, with often higher proportions of clients, response rates were generally higher. We therefore do not expect selective non-response to have influenced our findings substantially. Furthermore, the sex work sites from the CeSHHAR data were determined based on clinic data collected between 2015 and 2017 as well as locations identified through expert opinion [7], and it is perceivable that some sex work sites in Zimbabwe may not have been captured in our data. Since the DHS are cross-sectional data containing HIV status with no information on lag-time since seropositive status, we cannot make definite claims about causal effects between proximity to sex work sites and HIV risk. Next, there can be underreporting of the amount of FSW visits, or selective non-response from the people who visit FSW, but it is very unlikely that this potential bias negates the qualitative interference from our study findings, as we did find that reported FSW visiting was associated with increased HIV prevalence. Finally, it is important to note that this work was focused on FSWs and their clients only, because there were no data available on sex workers who identify as cisgender male, transgender women and transgender men, their clients, and their sex work sites. This does not mean these groups do not exist in Zimbabwe. For example, male sex work in Zimbabwe was described by Tsang et al. [40]. It is perceivable that most of these sex workers would work at, or close by, the sex work sites for FSWs, and it is therefore unlikely that knowing the locations of non-cisgender FSWs would alter the qualitative inference of our results.

## CONCLUSIONS

We found no evidence of an association between the proximity of sex work sites and HIV prevalence in Zimbabwe. Programmatic planning of (key population) interventions to curb HIV transmission can therefore not be taken merely based on geospatial heterogeneity of the epidemic, but requires careful mapping and considerations of transmission dynamics related to key populations implicitly. The absence of a geospatial association can be explained by the mobile nature of both FSWs and their clients, as individual-level

indicators of FSW were still significantly associated with HIV. Given that spill-over of HIV into the general population surrounding sex work sites seems limited, prevention and control interventions for HIV at these sites should primarily focus on sex workers and clients, with special emphasis on including and retaining mobile sex workers and their clients into services.

## ACKNOWLEDGEMENTS

The authors would like to express our gratitude to all the Centre for Sexual Health and HIV/AIDS Research (CeSHHAR) staff and contributors and sex workers who took part in the data collection. MK and JH were supported by the Dutch AIDS Foundation (P-29702). The corresponding author had full access to all study data and final responsibility for the decision to submit for publication.

## DATA AVAILABILITY STATEMENT

The data from the USAID Demographic and Health Surveys are openly available via <https://dhsprogram.com/>. The data from the Centre for Sexual Health and HIV/AIDS Research (CeSHHAR) are available upon request.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

**How to cite this article:** Kloek M, Bulstra CA, Chabata ST, Fearon E, Taramusi I, de Vlas SJ, et al. No increased HIV risk in general population near sex work sites: A nationally representative cross-sectional study in Zimbabwe. *Trop Med Int Health*. 2022. <https://doi.org/10.1111/tmi.13791>