Population size estimation of men who have sex with men using Google Trends search data.

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Submitted to: JMIR Public Health and Surveillance
on: March 20, 2024

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Abstract

Background: Population size estimation (PSE) for key populations is needed to inform HIV programming and policy. We examined the potential utility of applying a recently proposed method using Google Trend (GT) internet search data to generate PSE (GTPSE) for men who have sex with men (MSM) in 54 countries in Africa, Asia, the Americas, and Europe.

Objective: To examine the utility and plausibility of using Google Trends data to generate PSE in 54 LMICs.

Methods: Applying a newly proposed PSE method, we examined GT relative search volumes (RSV, representing the relative internet search frequency of specific search terms) for “porn” and, as a comparator term, “gay porn” for the year 2020. We assumed the term “porn” represents “men” (denominator) while “gay porn” represents a subset of “MSM” (numerator) in each county, resulting in a proportional size estimate for MSM. We multiplied the proportional GTPSE values with countries’ male adult population (15-49 years) to obtain absolute size estimates. Separately, we produced subnational MSM PSE limited to countries’ (commercial) capitals. Using linear regression analysis, we examined the effect of countries’ level of urbanization, internet penetration, criminalization of homosexuality, and stigma on national GTPSE results. We examined key assumptions of the proposed model. Further, we conducted a sensitivity analysis in a subset of countries (n=14) examining the effect of alternative English search terms, different language search terms (Spanish, French, Swahili), and alternative search years (2019, 2021).

Results: One country was excluded from our analysis as no GT data could be obtained. Of the remaining 53 countries, all national GTPSE values exceeded the World Health Organization’s (WHO) recommended minimum PSE threshold of 1% (range: 1.2%-7.5%). For 44/49 (89.8%) of countries, GTPSE results were higher than UNAIDS KP Atlas values but largely consistent with the regional UNAIDS Global AIDS Monitoring results. Substantial heterogeneity across same-region countries was evident in GTPSE although smaller than those based on KP Atlas data. Subnational GTPSE values could be obtained in 51/53 (96%) countries; all subnational GTPSE values exceeded 1% but often did not match or exceed the corresponding countries’ national estimates. None of the covariates examined had a substantial effect on the GTPSE values (R2 values 0.01-0.28). Alternative (English) search terms in 12/14 (85%) countries produced GTPSE >1%. Using non-English language terms often produced markedly lower same-country GTPSE values compared to English with 10/14 (71%) countries showing national GTPSE exceeding 1%. GTPSE using 2019 and 2021 search data produced similar results as the reference year 2020. Due to lack of absolute search volume data, credibility intervals could not be computed. The validity of key assumptions, especially who (males, females) searches for porn and gay porn, could not be assessed.

Conclusions: GT-based PSE for MSM provides a simple, fast, virtually cost-free method. Limitations include the lack of validation of key assumptions, and inability to assign credibility intervals. GTPSE for MSM may provide an additional data source, especially for estimating national-level PSE.

(JMIR Preprints 20/03/2024:58630)
DOI: https://doi.org/10.2196/preprints.58630

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Conclusion: GTPSE for MSM provides a simple, fast, virtually cost-free method. Limitations that impact the certainty of our estimates include lack of validation of key assumptions and inability to assign credibility intervals. GTPSE for MSM may provide an additional data source, especially for estimating national-level PSE.

Key words: Population size estimation, men who have sex with men, MSM, PSE, Google Trends

Introduction

The Joint United Nations Programme on HIV/AIDS (UNAIDS) estimated that in 2022, about 39 million people were living with HIV (PLHIV) worldwide.[1] HIV burden is higher among men who have sex with men (MSM), people who inject drugs (PWID), sex workers (SW), and transgender

persons (TG), which together are often described as key populations (KP).[1] KPs and their paying or non-paying sexual partners may account for 70% of new HIV infections worldwide, with an estimated 80% of new HIV infections outside sub-Saharan Africa (SSA) and 55% of all new infections within SSA.[1, 2]

Key population size estimation (PSE) is needed to estimate the number of individuals belonging to a KP in a given geographical area.[3, 4] PSEs provide the denominator values to inform KP programming and policy.[5] However, PSE is a difficult field and its methods often lack rigor in design or implementation, and the many methods available reflect the lack of an acceptable gold standard.[3, 6] Challenges to PSE include lack of sampling frames, mobility, and non-disclosure of KP defining behaviors.[3, 4] Further, most PSE methods produce local estimates whereas national PSE estimates are often obtained through “expert opinion”, simple projection, or modeling and less often through national-level empirical data such as direct survey questions or the network scale-up method, both used in general population based surveys.[6, 7] Direct survey questions about KP-defining traits suffer from reporting bias and require a major effort unless they can be added to an already planned general population survey. The frequent lack of reliable national-level PSE constitutes an even larger challenge compared to the availability of local PSE and complicates national, regional, and global HIV estimation work.[3, 8-10]

The rise of the internet facilitates virtual activities to improve public health, including in the field of digital epidemiology and *infoveillance*.[11] Recently, a new PSE method using Google Trends (GT) internet search data was proposed in a proof of concept paper by Card et al.[12] GT is a free cloud-based application that displays the relative frequency of user-specified Google search terms as trends across time and user-selected geographical areas.[12-14] Card et al. used GT and Canadian census data to estimate local PSE of MSM in urban and rural locations throughout Canada.[12] Card et al. related search terms presumed to be representative of MSM (*gay porn*) to that presumed to be representative of the general (male) population (*porn*).[12] By relating these two sets of values, Card et al. estimated the relative size of MSM in these Canadian towns.[12] To date, no other published PSE exist using this method.

The literature on pornography consumption by sex and sexual orientation is limited and often the MSM population is not represented. However, a major porn website reported that about a third of its visitors globally in 2021 were reportedly women.[15, 16] Further, women, regardless of sexual orientation, may also watch gay porn, possibly in substantial numbers.[17] Beyond this, we found no meaningful grey literature or peer-reviewed articles about internet pornography consumption in low middle income countries (LMICs) or pornography consumption by MSM in LMICs. We are also not aware of (grey) literature about the proportion of heterosexual and homosexual men searching Google for (gay) porn in LMIC.

We expanded the literature search to include high income settings. A study conducted in the United States, reported that more men than women consume pornography (92%:68%, respectively) over the span of a year.[18] The study did not report the type of pornography consumed or disaggregate male respondents by sexual orientation or practice.[18] A separate study from Norway with a sample of

some 2,300 male and female participants suggested that more men than women consume some pornography (94% of men, 68% of women).[19] However, only 5% (n=106) of participants identified as gay/lesbian/bisexual, no breakdown of sexual orientation by sex was given, and no information on the type of pornography consumed by participants was available.[19]

The aim of this study was to examine the potential utility of using GT data to obtain MSM PSE in selected low- and middle-income countries.

Methods

Preliminary literature search

A non-systematic literature search was conducted to better understand the behavior of pornography consumption of the general population and sexual minorities, by sex, as well as the relative frequencies with which these populations search for (gay) porn in general (via Google) or by directly accessing specific porn sites.

Selection of countries

We analyzed GT data for a selected set of 54 countries that receive support from the United States (US) President's Emergency Plan for AIDS Relief (PEPFAR), the US Government's initiative to support global HIV responses, for which information on MSM PSE has been sought.[20, 21] These countries are located in sub-Saharan Africa (SSA, n=29), Asia (n=13), the Americas (n=11), and Ukraine (Table 1A and 1B).

GT-based population size estimation

GT provides results based on exact search terms or topic searches. Our search was modeled after Card et al and used exact search terms *porn* and *gay porn* without quotations marks. GT does not provide absolute search frequency values; instead, GT offers *Relative Search Volume* (RSV) values across time (e.g., 52 weeks) in a specified space (e.g., Kenya), i.e., it normalizes search frequencies for specific search terms (e.g., *porn*) to a range from 0-100, where a search term's maximum frequency (for the specified geographic area and during the specified time frame) is set at 100 and 0 reflects no search for that term.[11, 13, 14] Importantly, GT allows users to add "comparator" terms (e.g., *gay porn*) next to the main term (e.g., *porn*); the RSV values for such comparator terms are normalized against the main term's RSV values.[13, 22] For the purpose of PSE calculation, the main term *porn* may represent all men whereas the comparator term *gay porn* may be viewed as a subset men who represent the subpopulation of gay men or MSM. To generate an MSM PSE from the RSV values we divide the comparator RSV value (*gay porn*) by the larger same-time, same-place RSV value (*porn)*.

National size estimates

PSE data collection was carried through Google Trend's application.[13] We applied this analytic approach for the year 2020 using *porn* and *gay porn* as the main and comparator search terms to each of the 54 countries. The time period for data collection was set as the year 2020, the most recent year

for which we could obtain all necessary data for this analysis. A single calendar year was chosen for the analysis because PSE changes over time and because of the perceived large search volumes for *porn* and *gay porn.* Weekly RSV values for *porn* and *gay porn* for the year 2020 were exported, summed, and proportional size estimates obtained. For example, for Botswana, the average of the weekly RSV values for *porn* was 78.3, the corresponding average for *gay porn* was 1.66 and the proportional PSE was therefore calculated as 1.66/78.3=2.1%. This was repeated for all countries. We then calculated the absolute GT PSE (GTPSE) by multiplying the proportional GTPSE by the total male population aged 15-49 in each country, the most used age range for key populations. The sizes for countries' 15-49 year-old male general population in 2020 were obtained through Spectrum (version 6.1, Avenir Health).[23]

Local size estimates

GT data can be restricted to subnational areas. Separately from national estimates, for each country we also attempted to obtain local GTPSE for the political (or, if different, commercial) capital city. Where data were unavailable for the political or commercial capital city, we used data from the district that contained the capital city. The calculation to obtain relative GTPSE was then the same as for the national level. We did not produce absolute subnational GTPSE.

Consistency of GTPSE results with WHO-recommended minimum estimate

We assessed whether the GTPSE results met the World Health Organization (WHO) and UNAIDS recommendation that national MSM PSE should represent at least 1% of the general adult male population.[24, 25]

Comparability

We compared the country-level GTPSE against two reference data sources used by UNAIDS: the *KP Atlas* database and the *Global AIDS Monitoring* system (GAM).[24, 26, 27] The *KP Atlas* database stores countries' self-reported absolute MSM size estimates using a wide range of PSE methods, often projected up to national scale from local estimates, with primary data collected over different periods of time. Proportional KP Atlas PSE values were computed by dividing the absolute MSM PSE values from the KP Atlas over the male general population (15-49 years). UNAIDS' GAM is a global data warehousing system to inform policy and facilitate monitoring, including key population size estimates. Using GAM data, UNAIDS curated a table with regional relative MSM PSE (median and interquartile ranges, IQR) deemed reasonable.

Covariates potentially affecting GTPSE

We examined the potential effect of select covariates on the relative GTPSE values by performing regression analysis for each covariate. The country-specific covariates we examined included internet penetration, urbanization, stigma, and criminalization of homosexuality. The covariate data are provided in Supplementary Table 1; these data were not used to adjust GTPSE values.

Internet penetration and urbanization. Internet penetration data were extracted from the *World Development Indicators* database through the World Bank and the *Internet World Statistics* database, indicating the percent of each country's total population with access to the internet. Urbanization

data were obtained from the *World Development Indicators* database through the World Bank, indicating the percent of the total population in each country considered urban. [28, 29]

Stigma

Country-level stigma values were extracted from the *Global Acceptance Index* (GAI).[30] This index was developed using computer modeling informed by responses to questions that measure attitudes toward lesbian, gay, bisexual, transgender, and/or intersex (LGBTI) people from 11 different global surveys to create a stigma score in 175 countries toward LGBTI persons. The system scores countries on a scale of 1 to 10; higher scores indicate less stigma.[30]

Criminalization. The *State-sponsored Homophobia International Lesbian, Gay, Bisexual, Trans and Intersex Association* report was used to evaluate the effects of criminalization of homosexual orientation or behavior on GTPSE.[30] The report classifies countries based on their level of legal protections or criminalization of sexual orientation and same-sex sexual acts. These classifications, ranging from most severe to most protected, include: the death penalty, up to lifelong imprisonment, up to eight years imprisonment, de facto criminalization, no criminalization or legal protections, limited protections, employment protections, broad protections, and constitutional protections. We converted these classifications into a quantitative ranking ranging from +4 to -4. The most severe classification (death penalty) was assigned the rank value "+4" and descended to the least severe/most protective classification (constitutional protection) with a rank value "-4."

Sensitivity analysis

Using a subset (n=14) of the 53 countries we performed three sensitivity analyses at the national level. The 14 countries were randomly selected among countries with prominent languages being French, Spanish, or Swahili. The first sensitivity analysis probed the effect of select non-English search languages. The 14 countries comprised 4 using Swahili (Kenya, Tanzania, Uganda, Democratic Republic of Congo [DRC]), 5 using French (Cote d'Ivoire, Senegal, Cameroon, Mali, Haiti), and 5 using Spanish (Dominican Republic, Panama, El Salvador, Nicaragua, Honduras) as their national/dominant language. We generated GTPSE using search terms in Swahili ("*ngono*", *"ngono za mashoga"*), French (*porno, porno gay*), and Spanish (*porno, porno gay*) and compared them to the original relative GTPSE values. Using the same 14 countries, the second sensitivity analysis probed the effect of different search terms in English on GTPSE, i.e., *sex, gay sex* as well as *sex, anal sex* and compared them to the original GTPSE (*porn, gay porn*). The third sensitivity analysis probed the effect of using different calendar years, i.e., (2019 [pre-COVID] and 2021) and compared them to the original 2020 GTPSE values, using the original English language search terms.

Results

GTPSE and comparability

Of the 54 countries examined, one (South Sudan), was omitted for lack of RSV values. All remaining 53 countries had GTPSE exceeding 1% (Table 1A), similar to GAM values (all exceeding 1% as well) and compared to KP Atlas values where 24/53 (45%) countries showed values above 1%. GTPSE ranged from 1.16% to 7.46% (median: 1.99%, interquartile range (IQR): 1.54-3.48%),

compared to 0.06% to 6.04% (median: 0.99%, IQR: 0.34%-1.93%) in the KP Atlas, and 1.38% to 2.82% in GAM regions. In 48/53 (91%) countries, relative GTPSE exceeded estimates in the KP Atlas values; KP Atlas values were larger in 5 countries (DRC, Liberia, Lao People's Democratic Republic [PDR], Thailand, and Jamaica). Absolute differences between GTPSE and KP Atlas ranged from -312,900 (Thailand) to 6,221,800 (India). Table 1B displays regional median GTPSE, ranging from 1.64% (East Africa) to 5.26% (Central/South America), larger in all regions than the corresponding KP Atlas values and largely similar to GAM values in most regions. Table 1A also displays the ratios between the largest and smallest country-level %PSE for each region, separately for GT and KP Atlas values. While substantial variability is seen in all regions and for both data sources (GT and KP Atlas), in all regions the observed heterogeneity was consistently higher for KP Atlas values compared to GT values.

Table 1A: National MSM PSE for PEPFAR supported countries (n=53) using Google Trends (GT) data for the year 2020.

Region	Country	GT (# of MSM) (N=53)	GT (N=53)	UNAIDS GAM Regional (N=7)	UNAIDS KP Atlas (N=49)
East Africa	Burundi	48500	1.77%	1.67%	0.34%
	Ethiopia	365000	1.28%		-
	Kenya	276000	1.99%		0.24%
	Rwanda	51300	1.54%		0.15%
	Tanzania	243000	1.73%		0.35%
	Uganda	154000	1.47%		0.23%
	Max:Min ratio:	-	1.6	-	2.3
Southern Africa	Angola	106000	1.44%	1.67%	-
	Botswana	13000	2.12%		0.43%
	Eswatini	4500	1.57%		1.38%
	Lesotho	10000	1.71%		1.05%
	Malawi	52500	1.16%		0.94%
	Mozambique	134000	1.87%		0.22%
	Namibia	16500	2.60%		-
	South Africa	393000	2.46%		1.94%
	Zambia	51800	1.18%		0.15%
	Zimbabwe	53000	1.64%		0.71%
	Max:Min ratio:	-	2.2	-	12.9
West Central Africa	Benin	34000	1.18%	1.28% (IQR:0.45 %-1.50%)	0.20%
	Burkina Faso	88000	1.80%		0.07%
	Cameroon	148000	2.29%		0.11%
	Cote d'Ivoire	166000	2.68%		0.90%
	DRC	33000	1.66%		0.98%

	Ghana	112000	1.40%		0.69%
	Liberia	22600	1.83%		6.04%
	Mali	70500	1.55%		0.09%
	Nigeria	614000	1.26%		0.49%
	Senegal	73600	1.94%		1.38%
	Sierra Leone	27000	1.36%		0.16%
	Togo	53100	2.65%		0.30%
	Max:Min ratio:	-	2.3	-	86.3
Asia	Burma	664000	4.53%	1.63% (IQR: 0.26%-3.10%)	1.72%
	Cambodia	258000	5.67%		1.93%
	India	6460000	1.18%		0.06%
	Indonesia	1180000	1.61%		1.03%
	Kazakhstan	137000	2.99%		1.35%
	Kyrgyz Rep.	53000	3.10%		0.99%
	Lao PDR	53000	2.73%		2.96%
	Nepal	83000	1.19%		0.86%
	PNG	31000	1.30%		1.58%
	Tajikistan	52000	2.14%		0
	Thailand	215000	1.25%		3.08%
	Philippines	1260000	4.27%		2.33%
	Viet Nam	1953000	7.46 %		0.98%
	Max:Min ratio:	-	6.3	-	51.3
Europe	Ukraine	366000	3.48%	2.11% (IQR: 1.75%-2.49%)	1.71%
Caribbean	Dominican Rep.	124000	4.26%	2.71%	4.90%
	Guyana	8200	3.60%		1.45%
	Haiti	108000	3.60%		1.03%
	Jamaica	24000	2.91%		5.15%
	Trinidad and Tobago	11000	3.04%		-
	Max:Min ratio:	-	1.5	-	5
Central & South America	Brazil	2960000	5.18%	3.37%	3.50%
	El Salvador	85000	5.20%		3.31%
	Guatemala	245000	5.09%		2.42%
	Honduras	147000	5.32%		1.48%
	Nicaragua	114000	6.32%		1.97%
	Panama	81000	7.23%		2.65%
	Max:Min	-	1.2	-	2.4

	ratio:				

Note: These estimates are for descriptive purposes only, to examine issues related to the potential utility of the method proposed by Card, et al. They represent the men who have sex with men population national population size estimates (% of MSM) during the year 2020. The % of MSM was calculated by taking the average Relative Search Volume score produced by Google Trends for *Gay Porn* and dividing it by the average Relative Search Volume score produced by Google Trends for *Porn*. Men who have sex with men population size estimate (# of MSM) was calculated by taking the % Men who have sex with men population size estimate and dividing it by the total male population (age 15-49). Key Populations Atlas % Men who have sex with men population size estimate was calculated by dividing the absolute Men who have sex with men population size estimate taken from the UNAIDS Key Populations Atlas Dashboard, dividing it by the total adult male population (age 15-49), and then multiplying by 100. The absolute value difference was calculated by subtracting the Google Trends absolute Men who have sex with men population size estimate value from the Key Populations Atlas Men who have sex with men population size estimate absolute value. All absolute values under 10,000 are rounded to the nearest 100. All other absolute values are rounded to the nearest 1000. UNAIDS GAM values are regional values transcribed from the UNAIDS open-source Spectrum 6 guide. Interquartile range (IQR) values were included for available regions. Regions without an interquartile range listed did not have one available. The countries used to create these regions and respective values may not be in full alignment with the countries included in the population size estimate analysis, therefore direct 1:1 comparisons should not be made. Data points with a "- "instead of a percentage indicates missing data for that country. Max:Min ratio: The ratio based on the largest and smallest %PSE value in each region.

Table 1B: Regional median GTPSE, USAID GAM, and KP Atlas for MSM population for the year 2020.

Region	Median regional %MSM PSE		
	GT	UNAIDS GAM	UNAIDS KP Atlas
Eastern Africa	1.64%	1.67%	0.24%
Southern Africa	1.68%	1.67%	0.83%
West Central Africa	1.73%	1.28%	0.40%
Asia	2.86%	1.63%	-
Europe	2.86%	2.11%	1.47%
Caribbean	3.60%	2.71%	3.17%
Central & South America	5.26%	3.37%	2.54%

Note: GTPSE refers to Google Trends Population Size Estimate and MSM refers to men who have sex with men. Google Trends and KP Atlas regional estimates only include estimates from include countries with available data (see Table 1). UNAIDS GAM data separates regions differently and includes countries that vary from our GT or the KP Atlas regional Data: UNAIDS GAM includes eastern and southern Africa in one estimate and separates Asia and Europe into two estimates (1.63% for Asia and the Pacific, 2.11% for Eastern Europe and Central Asia). Region names were not adjusted in above table to align with GAM data.

Local GTPSE pertaining to political or commercial capitals or the larger sub-national areas encompassing these are displayed in Table 2 We could obtain local estimates for 51/53 (96%) countries' capital cities; GT did not provide data for Nairobi (Kenya) and Kathmandu (Nepal). Among the 51 cities with estimates, the GTPSE ranged from 0% to 13% (median 2.2%); most cities' estimates (86%, n=44) exceeded 1%. Five cities yielded non-credible GTPSE values of 0.0%, including Bujumbura (Burundi), Dodoma (encompassing Dar es Salaam, Tanzania), Ouagadougou (Burkina Faso), Monrovia (Liberia), and Vientiane (Laos PDR). Of the 44 subnational GTPSE with values >1%, 18 (41%) were below the same-country national GTPSE.

Table 2: Reported local MSM GTPSE, N=53, in the year 2020.

Region	Country	Local area	Relative national GTPSE	Relative local GTPSE	Absolute % difference national and local GTPSE
East Africa	Burundi	Bujumbura	1.77%	0.00%	-1.77%
	Ethiopia	Addis Ababa	1.28%	1.30%	0.02%
	Kenya	Nairobi	1.99%	-	-
	Rwanda	Kigali	1.54%	1.70%	0.16%
	Tanzania	Dodoma	1.73%	0.00%	-1.73%
	Uganda	Kampala	1.47%	1.60%	0.13%
Southern Africa	Angola	Luanda	1.44%	2.04%	0.60%
	Botswana	Gaborone	2.12%	0.00%	-2.12%
	Eswatini	Mbabane	1.57%	1.48%	-0.09%
	Lesotho	Maseru	1.71%	1.01%	-0.70%
	Malawi	Lilongwe	1.16%	2.24%	1.08%
	Mozambique	Maputo	1.87%	2.04%	0.17%
	Namibia	Windhoek	2.60%	2.53%	-0.07%
	South Africa	Johannesburg (Gauteng)	2.46%	0.99%	-1.47%

	Zambia	Lusaka	1.18%	1.56%	0.38%
	Zimbabwe	Harare	1.64%	1.56%	-0.08%
West Central Africa	Benin	Littoral (Cotonou)	1.18%	4.11%	2.93%
	Burkina Faso	Centre (Ouagadougou)	1.80%	0.00%	-1.80%
	Cameroon	Littoral (Douala)	2.29%	2.47%	0.18%
	Cote d'Ivoire	Abidjan	2.68%	1.01%	-1.67%
	DRC	Kinshasa	1.66%	2.04%	0.38%
	Ghana	Accra	1.40%	1.42%	0.02%
	Liberia	Monrovia	1.83%	0.00%	-1.83%
	Mali	Bamako	1.55%	2.93%	1.38%
	Nigeria	Abuja (Federal Capital Terriorty)	1.26%	1.44%	0.18%
	Senegal	Dakar	1.94%	2.85%	0.91%
	Sierra Leone	Freetown	1.36%	1.01%	-0.35%
	Togo	Lome	2.65%	2.04%	-0.61%
Asia	Burma	Yangon (Yangon Region)	4.53%	4.79%	0.26%
	Cambodia	Phnom Penh	5.67%	5.43%	-0.24%
	India	New Delhi (Uttar Pradesh)	1.18%	1.15%	-0.03%
	Indonesia	Jakarta	1.61%	2.20%	0.59%
	Kazakhstan	Almaty (Almaty Region)	2.99%	5.52%	2.53%
	Kyrgyz Rep.	Bishkek	3.10%	3.09%	-0.01%
	Lao PDR	Vientiane	2.73%	0.00%	-2.73%
	Nepal	Katmandu/ Kantipur	1.19%	-	-
	PNG	Port Moresby	1.30%	1.01%	-0.29%
	Tajikistan	Dushanbe	2.14%	1.01%	-1.13%
	Thailand	Bangkok	1.25%	3.24%	1.99%
	Philippines	Manila	4.27%	5.51%	1.24%
	Viet Nam	Hanoi	7.46%	4.56%	-2.90%
Europe	Ukraine	Kyiv	3.48%	4.14%	0.66%
Caribbean	Dominican Rep.	Santo Domingo	4.26%	3.99%	-0.27%
	Guyana	Georgetown	3.60%	3.09%	-0.51%
	Haiti	Port-au-Prince	3.60%	3.09%	-0.51%
	Jamaica	Kingston (St. Andrew Parish)	2.91%	3.38%	0.47%
	Trinidad and Tobago	Port of Spain	3.04%	13.00%	9.96%

Central & South America	Brazil	São Paulo (State of São Paulo)	5.18%	5.92%	0.74%
	El Salvador	San Salvador	5.20%	5.73%	0.53%
	Guatemala	Guatemala City (Guatemala Department)	5.09%	4.91%	-0.18%
	Honduras	Tegucigalpa (Comayagua)	5.32%	8.13%	2.81%
	Nicaragua	Managua	6.32%	5.31%	-1.01%
	Panama	Panama City	7.23%	7.44%	0.21%

Note: GTPSE refers to Google Trends Population Size Estimate and MSM refers to men who have sex with men. Local MSM GTPSE for 53 countries for the year 2020 were calculated by restricting the geographic entity to the desired capital city or commercial hub. Where Google Trends did not provide data for a given city, we substituted the place name with the largest city by population or by district that had data available in Google Trends. This is noted by listing what was available in Google Trends in parenthesis next to the capital city. Kenya and Nepal were excluded from this analysis due insufficient regional data available in Google Trends. Data points with a "- "instead of a percentage indicates missing data for that country.

Effect of covariates

Figure 1A-D displays the correlations between national-level GTPSE and urbanization, internet penetration, stigma, and criminalization. Coefficients ranged from 0.01 (criminalization) to 0.28 (internet penetration).

Sensitivity analysis

Table 3A displays how the GTPSE generated from the alternative search terms compares to the original search term GTPSE. In most countries *Porn/Gay Porn* produced higher PSE values compared to *Sex/Anal Sex* (13/14, 93%) as well as compared to *Sex/Gay Sex* (12/14, 86%). For *Sex/ Gay Sex*, all 14 countries produced estimates exceeding 1%. For S*ex/Anal Sex* 3/14 (21%) countries did not produce estimates reaching the 1% threshold, including Mali for which zero search results were reported for *Anal Sex*.

Table 3A: Sensitivity Analysis Using Alternative Search Terms in Google Trends to Calculate National PSEs for Select PEPFAR Countries, N=53 in 2020

	Original GT PSE	**SA Alternate Search Term GT PSE**			
Country	Porn/Gay Porn PSE	Sex/Gay Sex PSE	Absolute % Difference	Sex/ Anal Sex PSE	Absolute % Difference

Kenya	1.99%	1.37%	0.62%	1.37%	0.62%
Tanzania	1.73%	1.46%	0.27%	3.54%	-1.81%
Uganda	1.47%	1.38%	0.09%	1.26%	0.21%
DRC	1.66%	1.55%	0.11%	1.15%	0.51%
Cameroon	2.29%	1.28%	1.01%	0.90%	1.39%
Mali	1.55%	1.65%	-0.10%	0.00%	1.55%
Cote d'Ivoire	2.68%	1.90%	0.78%	1.74%	0.94%
Senegal	1.94%	1.50%	0.44%	0.88%	1.06%
Haiti	3.60%	2.60%	1.00%	2.83%	0.77%
Dominican Rep.	4.26%	3.36%	0.90%	1.83%	2.43%
Panama	7.23%	5.17%	2.06%	3.71%	3.52%
El Salvador	5.20%	5.34%	-0.14%	4.19%	1.01%
Nicaragua	6.32%	7.10%	-0.78%	4.82%	1.50%
Honduras	5.32%	4.85%	0.47%	2.96%	2.36%
Median	2.49%	1.78%	0.45%	1.79%	1.03%
25th Quartile	1.78%	1.47%	0.10%	1.18%	0.66%
75th Quartile	4.97%	4.48%	0.87%	3.40%	1.54%

Note: Alternative search terms were chosen based on words that represented the general male population and MSM subset population in each country (n=53) in the year 2020.

Table 3B shows how GTPSE generated using alternative language terms compared to the original GT search terms. For Swahili, only one country yielded a PSE in that language. All countries using French (n=5), or Spanish (n=5) search terms yielded estimates, all exceeding 1%. All alternative language estimates were lower than the original *Porn/Gay Porn* PSE values.

Table 3B: Sensitivity Analysis Using Alternate National Language Searches in Google Trends to Calculate National PSE for Select PEPFAR Countries, N=14 in 2020.

Language	**Country**	**Original GT PSE (English)**	**Alternate Language Term GT PSE**	**Absolute % Difference**
Swahili	Kenya	1.99%	0.00%	1.99%
	Tanzania	1.73%	0.52%	1.21%
	Uganda	1.47%	0.00%	1.47%
	DRC	1.66%	0.00%	1.66%
French	Cameroon	2.29%	1.36%	0.93%

	Mali	1.55%	1.07%	0.48%
	Cote d'Ivoire	2.68%	1.35%	1.33%
	Senegal	1.94%	1.28%	0.66%
	Haiti	3.60%	2.23%	1.37%
Spanish	Dominican Rep.	4.26%	2.56%	1.70%
	Panama	7.23%	5.14%	2.09%
	El Salvador	5.20%	4.36%	0.84%
	Nicaragua	6.32%	4.13%	2.19%
	Honduras	5.32%	4.07%	1.25%
Note: Alternative language search terms included *ngono/ngono za mashoga* (Swahili), *Porno/Porno Gay*(French), *Porno/Porno Gay* (Spanish)				

Table 3C displays how GTPSE generated for alternative years (2019 and 2021) compared to the original 2020 GT searches. All 14 countries in both years produced estimates exceeding 1%. No large discrepancies in PSE between the years were observed; 13 out of 14 in 2019 values were larger than the 2020 values whereas the 2021 values were largely similar to the 2020 values.

Table 3C: Sensitivity Analysis for MSM Population Size Estimates for select PEPFAR Supported Countries (N=14) using Google Trends Data in Years 2019 and 2021 compared to year 2020.

	2019 PSE%	2020 PSE %	2021 PSE%
Kenya	2.37%	1.99%	1.99%
Tanzania	1.96%	1.73%	1.85%
Uganda	1.73%	1.47%	1.69%
DRC	1.95%	1.66%	1.60%
Cameroon	2.70%	2.29%	2.25%
Mali	2.30%	1.55%	2.17%
Cote d'Ivoire	2.52%	2.68%	2.23%
Senegal	2.54%	1.94%	1.90%
Haiti	4.33%	3.60%	2.92%
Dominican Republic	4.91%	4.26%	4.34%
Panama	9.36%	7.23%	6.74%
El Salvador	6.19%	5.20%	4.77%
Nicaragua	7.31%	6.32%	4.93%
Honduras	6.79%	5.32%	5.51%

Note: 2019 and 2021 values were computed in the same way as the reference 2020 estimates.

Discussion

Our analysis suggests that national-level MSM GTPSE are feasible in almost all countries.

Importantly, all estimates appeared plausible, i.e., exceeded the WHO/UNAIDS suggested minimum threshold of 1%. Heterogeneity of GT PSE across same-region countries was pronounced within all regions yet smaller than the ratios based on the UNAIDS KP Atlas values which contained numerous PSE values well below the 1% threshold.

Our analysis draws on several strengths. We successfully applied the GTPSE method to many low and middle-income countries, suggesting that GTPSE appears to have wide geographic applicability. We compared the values against two PSE data sources at UNAIDS, assessed the potential effect of various covariates on GTPSE values, and conducted a sensitivity analysis with varying English search terms, non-English search languages, and different calendar years. Google is the dominant search engine in all countries covered in this analysis, with a market share ranging between 84% and 99% (data shown in supplementary table).[29] Although no absolute search volume data was available to us, searches for *porn* globally was among the top 20 search terms in 2023 with about 65 million searches globally each month according to one source[31] although this is still well behind the largest porn site-specific searches. GTPSE may emerge as another example for digital public health and epidemiology that include real-time surveillance of disease outbreaks[32], assessing the impact of global public health days[33], informing health and health policy research[34] or understanding spatiotemporal patterns of dry eye disease[35].

While most local estimates were plausible (>1%), 14% (n=7) did not reach the WHO/UNAIDS minimum threshold, and two more locations did not produce a GTPSE value at all due to lack of GT data and how GT organized the subnational data despite some of the affected cities' large population sizes. This is not an uncommon finding, as other PSE methods in active use typically do not meet the WHO/UNAIDS minimum threshold. For a few other country or commercial capital cities with no direct GT data available, such as Johannesburg (South Africa), we could obtain a subnational estimate using the larger district or province within which the city (e.g., Johannesburg and Pretoria) are located. This may limit the utility and comparability of such local estimates. About one-third of the local (relative) estimates did not reach or exceed the same country national level estimates, somewhat contrary to our expectation that rural-to-urban migration among MSM may be more pronounced than that of other men and so yielding higher GTPSE values.[9] In Card et al.'s study on Canadian towns and cities the estimates ranged from 2-4% compared to 0-13% among the local estimates, whereas the Canadian national estimate was 2.8% compared to 1.2-7.5% across all countries we examined.[12] While not a limitation, it is worth noting that weekly RSV data varied widely (data not shown), confirming the recommendation to use GT data for size estimation only over longer time periods, such as a full calendar year.

Like most PSE methods, GTPSE has limitations. In particular, the assumptions underlying the GTPSE method deserve close scrutiny: search term *porn* represents men, search term *gay porn* represents gay men, straight men only search for *porn*, MSM only search for *gay porn*, MSM and straight men search for *(gay) porn* in equal proportions, and women don't search for *(gay) porn* at all or do not affect the generated GTPSE for MSM. Violations of these assumptions will result in bias if they affect RSV for *porn* and *gay porn* to differing extents, hence altering the proportion of porn searches that are directed at *gay porn*. There is additional risk of bias as women and gay men may search for porn using just *porn* as a search term. While the literature from LMIC settings on this topic is very sparse, reports and literature from high income settings suggest that *gay porn* is also

consumed by heterosexual men and women, suggesting that some bias may be present. Complicating speculations about magnitude and direction of bias is the fact that specific porn websites' user statistics may not accurately reflect searches for *(gay) porn* on Google. Women's search behavior on Google regarding *gay porn* may increase or decrease the GTPSE estimates depending on the frequency relative to searches for just *porn*.

Regrettably, Google does not provide access to its algorithm generating the RSV data nor can users filter Google Trend searches by age or gender. An inherent limitation in using GT data include the lack of de-duplication in the search data (although repeated searches by the same user within a short time period are not counted multiple times by Google), the lack of absolute search volume data. Not having access to the absolute search volume data impedes the computation of uncertainty intervals (which in most national settings may be expected to be small due to the large search volumes involved). However, absolute search volume information may eventually be made available by Google and is already offered to some extent by select third party companies. Absolute search volume data may also inform the choice of search language and even search terms and may facilitate composite GTPSE metrics by incorporating multiple GTPSE metrics stemming from different languages search terms. Restricting GTPSE-relevant data to male users may further refine GTPSE values by excluding female users, a limitation our analysis could not overcome. VPN (virtual private network) too has the potential to introduce error if users select a virtual country other than their place of residence. The adoption of VPN may vary considerably across time and by country, and, among PEPFAR countries. According to one industry website in 2020, VPN was highest in Ukraine (7.9%) and lowest in Kenya (0.5%).[36] Taken together, these limitations constitute a major source of uncertainty about the bias and precision of GTPSE. For that reason, GPTSE should be regarded as approximate reference values. Clearly, they do not attain the rigor or transparency as statistically principled estimation from accurately measured data, which the currently best available PSE methods do offer. Additionally, GTPSE may not be feasible for a few countries, perhaps due to poor or little data availability on search terms and frequencies.

GTPSE seems infeasible for size estimation among transgender persons, sex workers, or people who inject drugs. Unlike (*gay) porn*, where the search is about a web-based product (visual depictions of *porn*), searches for sex work or clients, transgenderism, or injecting drug use are not directly tied to the internet, may exhibit a more variable search terminology, and may lack fitting "denominator" search terms (analogous to *porn*).

Overall, the GTPSEs often were substantially higher than the KP Atlas estimates but were more closely aligned with the reported GAM regional estimates. The KP Atlas estimates are based on a broad range of PSE methods typically generating local PSE that may or may not be projected to national scale, or summed or averaged across multiple localities, and may refer to various time points (calendar years) and various age ranges. Many KP Atlas based MSM PSE were implausibly low (<1%), suggesting that substantial differences to GTPSE may often be due to KP Atlas underestimates. The regional GAM estimates are based on a more curated data base of PSE after excluding estimates with subpar quality and hence of perhaps more trustworthy quality.[24] However, GAM regions do not exactly overlap with the regions we used for GTPSE and the KP Atlas estimates.

The national MSM GTPSE values were robust against varying levels of urbanization, internet penetration, stigma, and criminalization/protection of homosexuality, negating the need for adjustment and increasing comparability across different settings. The largest influence was seen with internet penetration which can be expected to increase over time. In the sensitivity analysis, the largest differences to the original GTPSE values were seen using alternate English language search

terms. Among the 14 examined countries, almost half (43%) of the alternate estimates were below 1% and hence considered implausibly low. This indicates that search term selection is important, especially for comparison across time and space. Further exploration may be warranted to evaluate if country or region-specific English or Non-English slang terms may produce plausible estimates; however, the limited sensitivity analysis suggests that *Porn/Gay Porn* may be dependable and consistently produces plausible values. The use of similar search terms in French, Spanish, and Swahili yielded universally lower results; Swahili, not a nationally dominant language in most countries, appears particularly unsuitable as it frequently produced 0% PSE values. As most countries display prominent non-English language use, countries may want to consider using the predominant language (used for web searches) when applying this method while considering any language's geographic scope in-country. The results also appeared robust across time (two years affected by the COVID pandemic plus one-year pre-COVID) as the two adjacent years produced plausible and (same country) consistent results. The lack of uncertainty intervals however impeded a more meaningful interpretation of the results from the sensitivity analyses.

Conclusions

Generating national-level population size estimations for key populations is challenging for many countries. GTPSE is a simple method with the potential to address this problem efficiently without the need of additional resources. However, the lack of validation of key assumptions and inability to generate credibility intervals suggest important uncertainty regarding accuracy and precision of the estimates. Additional research, such as expanding or building on our sensitivity and covariate analysis, to address or better understand these limitations may further improve the quality and utility of GTPSE for MSM in LMIC.

Acknowledgements: We wish to acknowledge all authors who contributed to this paper. WH and AA contributed to study concept and design. All authors substantially contributed to the study's conduct, or to data analysis and interpretation. All authors contributed to writing, reviewing, or editing, of the manuscript. We also wish to acknowledge all colleagues within the Center for Disease Control and Prevention who offered insights and alternative perspectives during the analysis and writing of this paper.

Data Availability: All data generated or analyzed during this study are publicly accessible data. With the exception that only aggregate data can be obtained through Google Trends. Links to where the data can be accessed are included in this published article and its supplementary information files. Further, all RSV data points can be reproduced through Google Trends.

Conflicts of interest: The corresponding author had full access to all study data and final responsibility for the decision to submit this manuscript for publication. All authors declare that they have no conflicts of interest.

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the funding agencies. This research publication has been supported by the President's Emergency Plan for AIDS Relief (PEPFAR) through the Centers for Disease Control and Prevention (CDC) under the terms of project number: 0900f3eb820619c0. This publication was also supported by Cooperative Agreement No.: NU2GGH002093 between the Centers for Disease Control and Prevention and the Public Health Institute.

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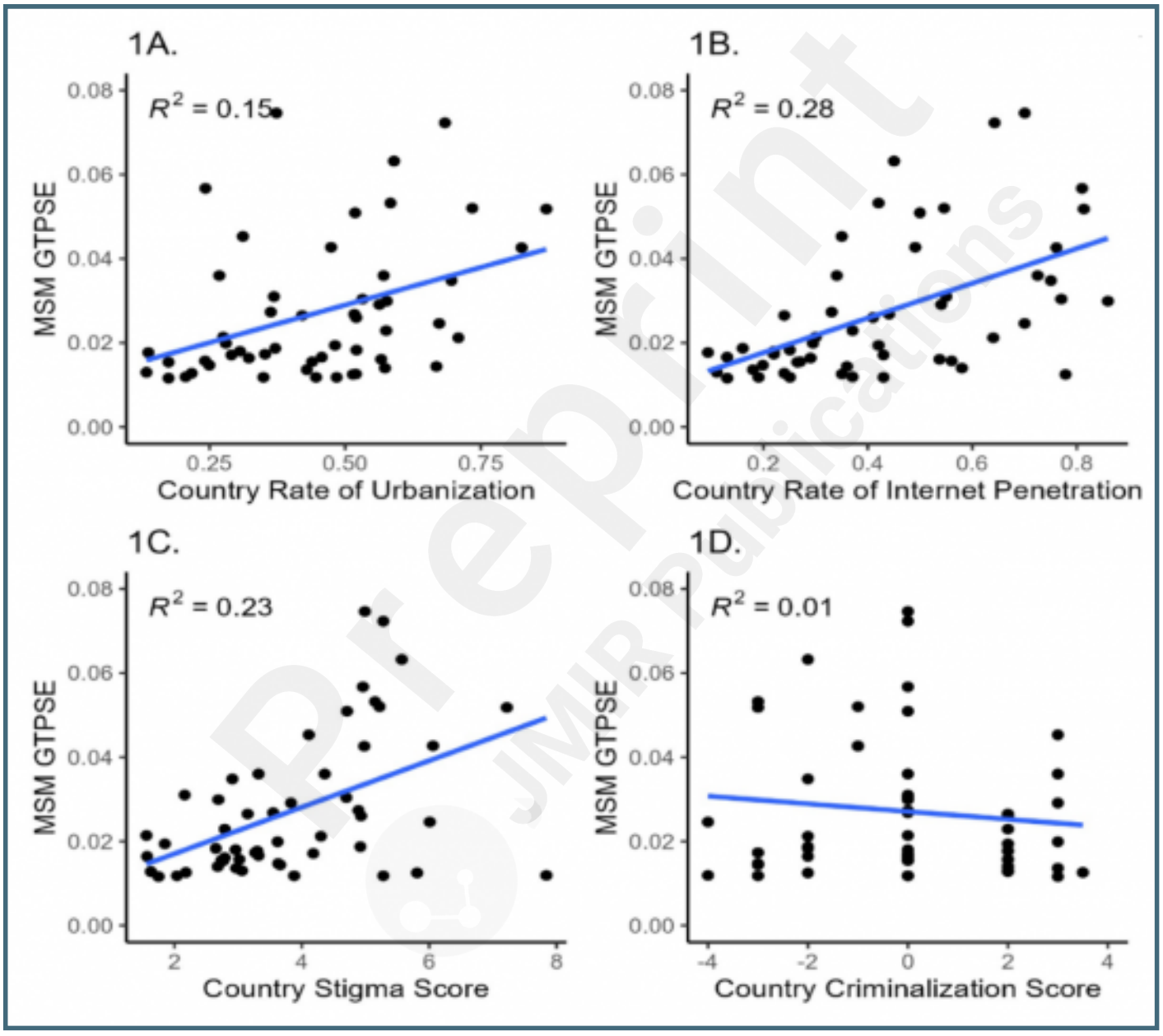
Abbreviations	
KP	Key population
PSE	Population size estimation
MSM	Men who have sex with men
GT	Google Trend(s)
GTPSE	Google Trend Population Size Estimate
RSV	Relative Search Volume
GAM	Global AIDS Monitoring system
WHO	World Health Organization
UNAIDS	United Nations Programme on HIV/AIDS
PEPFAR	United States President's Emergency Plan for AIDS Relief

Supplementary Files

Figures

Note: 1A depicts the linear relationship between the Google Trends national population size estimates and the rate of urbanization in each country (N=53). 1B depicts the linear relationship between the Google Trends national population size estimates and the rate of urbanization in each country (N=53). 1B depicts the linear relationship between the Google Trends national population size estimates and the rate of internet penetration in each country (N=53). 1C. depicts the linear relationship between the Google Trends national population size estimates and the level of stigma against LGBTQ+ persons in each country (N=53). 1D. depicts the linear relationship between the Google Trends national population size estimates and degree of criminalization against men who have sex with men population in each country (N=53).



Multimedia Appendixes

Supplementary Table 1.
URL: http://asset.jmir.pub/assets/b89ebff0498166ec01cfbdbb76ef5b3b.xlsx