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Time location sampling in men who have sex with men in the HIV context: the importance of taking into account sampling weights and frequency of venue attendance

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Abstract

Sex between men is the most frequent mode of HIV transmission in industrialised countries. Monitoring risk behaviours among men who have sex with men (MSM) is crucial, especially to understand the drivers of the epidemic. A cross-sectional survey (PREVAGAY), based on time-location sampling, was conducted in 2015 among MSM attending gay venues in 5 metropolitan cities in France. We applied the generalised weight share method (GWSM) to estimate HIV seroprevalence for the first time in this population, taking into account the frequency of venue attendance (FVA). Our objectives were to describe the implementation of the sampling design and to demonstrate the importance of taking into account sampling weights, including FVA by comparing results obtained by GWSM and by other methods which use sample weights not including FVA or no weight. We found a global prevalence of 14.3% (95% CI (12.0–16.9)) using GWSM and an unweighted prevalence of 16.4% (95% CI (14.9–17.8)). Variance in HIV prevalence estimates in each city was lower when we did not take into account either the sampling weights or the FVA. We also highlighted an association of FVA and serological status in the most of investigated cities.

Introduction

Sex between men is the most frequent mode of HIV transmission in Western Europe, the USA and Australia [1]. The number of HIV cases diagnosed among men who have sex with men (MSM) has continued to rise in recent years worldwide [2, 3]. Similar trends have been observed in France [4, 5].

Given this dramatic context, monitoring risk behaviours in MSM is crucial to understand the drivers of HIV and other disease epidemics, and to plan and evaluate prevention interventions [6]. Because populations at high risk of HIV acquisition are often hard to reach, general population surveys – such as household surveys – typically do not include a large enough sample of the population of interest [7]. With respect to MSM, although some national probability surveys include questions on sexual behaviour and/or identity [8], they usually include relatively small numbers from this population [9]. Obtaining a sufficient sample size is one of the biggest challenges for researchers when conducting behavioural surveillance among MSM [10].

Time-location sampling (TLS), also called time-space sampling or venue-based sampling, is widely used to collect data from hard-to-reach populations who frequent known locations. This technique is especially used in surveys on MSM. The principle is to recruit individuals in physical places at times when they gather there (e.g. gay bars, clubs, backrooms) [11–13]. Using TLS means that a high proportion of venues attended by a priority population can be included in the sampling frame.

Two main issues of TLS have been discussed in the literature [14–16]: how to take into account the sampling design and how to deal with the frequency of venue attendance (FVA). Accordingly, it is necessary to produce unbiased estimates. Although the use of weights based on individual FVA is recommended and justified [17–21], it seems that in reality this practice is not frequently applied. Recently, Léon *et al.*[18] presented TLS in the context of sampling theory and proposed a design-based inference model taking into account sampling weights and the FVA. In their work, an indirect sampling framework and the generalised weight share method (GWSM) [22] were both used in a population of drug users. This method has been never used to produce unbiased estimates of HIV prevalence. To our knowledge, in order to estimate HIV prevalence among MSM attending gay venues, alone Gustafson *et al.*[17] used a methodology which took into account sampling weights and FVA in their inference. The weight calculation was different from GWSM, especially in using of FVA. Concerning inference, Gustafson *et al.* used a model-based method.

In 2015, Santé publique France, conducted a survey (Prevagay 2015), among MSM attending gay venues in five French metropolitan cities in order to estimate HIV prevalence among MSM attending gay venues. The main objective is to demonstrate the importance of using TLS associated with GWSM. In this paper, we present the methodology of the Prevagay 2015 survey, and describe the implementation of the sampling design. We estimate HIV seroprevalence in MSM attending gay venues in five French metropolitan cities using different sampling weights: no weight, no FVA, GWSM trimming or not extreme values in order to assess the impact of taking into account sampling weights and FVA in inference. Design-based method described by Léon *et al.*[18] was used for inference.

Material and methods

Survey design

The Prevagay 2015 survey was conducted in five French metropolitan cities (Lille, Lyon, Montpellier, Nice and Paris).

The choice of these cities was based both on feasibility constraints and on epidemiological criteria. A minimum number of sufficiently frequented accessible venues was needed. Based on the number of new HIV diagnoses in MSM (French regional HIV monitoring data) [4], the number of HIV prevalence declaration (Gay and Lesbian press survey 2011) [23], and regional alerts of increasing numbers of STI, we chose four cities (in addition to Paris) with different HIV epidemiological profiles.

In each city, the expected sample size was determined from the expected HIV prevalence and the desired precision of the HIV prevalence estimate. Expected HIV prevalence was based on self-reported HIV status of respondents to the national 2011 Gay and Lesbian press survey, conducted via the internet [23].

Formative research was carried out in collaboration with the 'Equipe Nationale d'Intervention en Prévention et Santé pour les Entreprises' (ENIPSE), which is a long established national association that organises, among other activities, disease prevention actions in gay venues. Thanks to this association's long history, we were able to identify gay venues and gain an easier access to them and their managers in order to seek their agreement to participate. We decided to investigate commercial gay venues 4 days a week: bars (with or without backrooms), discos, saunas and sex clubs. The survey took place over 6 weeks in Paris, and 4 weeks in each of the other cities between September and December 2015.

We defined a *visit* duration as a period of 4 h in venues in Paris and 3 h in other cities. We built a sampling frame of venue-day-times (VDTs). For each venue, we chose two *visits* a day with a total of eight *visits* a week.

Once eligible venues were identified and had agreed to participate, we requested ENIPSE staff to collect information on opening hours and the estimated number of attendees eligible for the survey for each *visit*, in order to build the sampling frame for each venue.

A two-stage TLS design was used. During the first stage in each city, we selected VDTs using simple random sampling without replacement, with a minimum of one *visit* per venue. The number of sampled *visits* for a venue was proportional to the average number of MSM attending that venue in all *visits* over the survey period. In the second stage, for each VDT, MSM were selected using systematic random sampling.

A team of investigators (two to four persons) was created for each city, led by a local ENIPSE staff member. We decided to only use investigators belonging to the MSM community, in order to make contact easier with attendees of gay venues. All investigators were specifically trained to implement the survey.

During *visits*, each team recruited participants, using flyers and information letters about the survey. They also estimated the number of eligible attendees during the *visit* and noted the number of refusals to participate in the survey. A form collecting basic sociodemographic information was offered to MSM who refused to participate.

Recruitment for survey and data

MSM were eligible for the survey if they were at least 18 years old, had had sex with men in the previous 12 months, could read and speak French, and agreed to both perform finger-prick blood self-sampling, and answer the questionnaire. Participants responded to questionnaire using electronic tablets and no missing answers were permitted. HIV testing was performed by the National Reference Laboratory for HIV (Tours, France) on dried blood spots (DBS) with a combined immunoassay for detection of both p24 antigen and HIV antibodies (Genscreen ultra HIV Ag-Ab; Biorad), as previously described [24]. HIV-positive specimens were confirmed by a combination of assay of recent infection, serotyping and Western blot [24, 25].

Data collecting regarding FVA

We presented a list of all the participating gay venues for each city to each participant, asking them the following question: 'In the last month, how many times did you attend the following venues?' From this specific question, we estimated the number of FVA during the survey period for each individual by (1) summing the declared number of *visits* in different venues in the previous month, (2) dividing this number by 30 (mean number of days in a month) and (3) multiplying by the number of sampled days in the participant's city. We assumed that FVA did not vary over the survey period.

Sampling weights

To make inferences from the random sample to the population, a sampling weight was assigned to each participant.

At the first stage, the inclusion probability π_k^v of a VDT k is equal to the number of sampled *visits* of the specific gay venue divided by the total number of *visits* in the sampling frame of the corresponding city. The sampling weight of VDT k is the inverse of its inclusion probability: $w_k^v = 1/\pi_k^v$.

In the second stage, the inclusion probability $\pi_{i|k}$ corresponds to the probability that participant i attends the VDT k. All other things being equal, the probability $\pi_{i|k}$ is equal to the number of MSM surveyed in VDT k divided by the ENIPSE staff member's estimate of eligible men in k.

Thus, a sampling weight w_i for participant i can be equal to:

$$w_i = w_k^v \times w_{i|k}$$

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where

$$w_{i|k} = 1/\pi_{i|k}$$

However, in TLS, individual FVA is not equal for all participants making w_i biased. In this context, we define the GWSM weight, $\tilde{w}_i$, providing from the GWSM taking FVA into account by dividing the simple individual weight w_i by the number of *visits* in participating venues during the survey period (noted $n\mathrm{FVA}_i$ for participant i). Thus, the GWSM weight is equal to:

$$\tilde{w}_i = w_i/n\mathrm{FVA}_i$$

Trimmed GWSM sampling weights

Despite thorough formative research, changes from the initial design can occur. For instance, one could initially plan five visits to a gay venue for survey purposes, but only visit once because of the owner's refusal to allow survey staff to return. Another example is that a difference between the expected and the real mean number of MSM attending a venue in a given period could lead to fewer survey participants than initially planned. This can lead to extreme sampling weights which can over-represent individuals in the estimation of a statistic of interest (e.g. prevalence). The estimation of a statistic could have been biased and its variance overestimated. Accordingly, it was necessary to truncate the largest weights. We decided to replace (trim) the weights exceeding a threshold equal to the median weight plus four times the interquartile range of weights in each city, keeping the same sum of initial weights $\sum_{i=1}^{n} \tilde{w}_i$ where n is the sample size. The estimation of the population size was not modified. Let $\tilde{w}_{\mathrm{trim}\ i}$ be the trimmed weight of the participant i:

$$\tilde{w}_{\mathrm{trim}\ i} = (\tilde{w}_i \times 1_{\{\tilde{w}_i \leq T\}} + T \times 1_{\{\tilde{w}_i > T\}})^{*} \frac{\sum_{i=1}^{n} \tilde{w}_i}{\sum_{i=1}^{n} (\tilde{w}_i \times 1_{\{\tilde{w}_i \leq T\}} + T \times 1_{\{\tilde{w}_i > T\}})},$$

where

$1_{\{a<b\}} = 1$ if a $<b$ and 0, otherwise and T is the median weight plus four times the interquartile range of weights of the city of participant i.

These trimmed GWSM sampling weights are the weights used for the all analyses of the PREVAGAY survey.

Taking into account weights in inference

In general, the main objective of cross-sectional surveys is to estimate functions of interest in the population, such as a total (e.g. number of MSM frequenting gay venues), a proportion (e.g. prevalence of the HIV-infected in the population) or a mean (e.g. average age of HIV-seropositive men). We used the Horvitz–Thompson estimator [26] and its variance [27] which is widely used in surveys.

Data analysis

We declared survey design using sampling weights and stratification by city and finite correction population (fpc) at each stage. At the first stage, the fpc is equal to the number of sampled VDTs divided by the total number of VDTs. At the second stage, the fpc is equal to the number of interviewed MSM divided by the total number of MSM during visits.

We estimated biological HIV prevalence in each city. We compared HIV prevalence estimates and their 95% confidence intervals using different sampling weights: (1) no weight, (2) no FVA (w_i), (3) no trimmed GWSM ($\tilde{w}_i$) and (4) trimmed GWSM ($\tilde{w}_{\mathrm{trim}\ i}$). We also estimated the design effect of the estimated HIV prevalence in each city. The design effect is equal to the estimated variance of the estimated HIV prevalence taking into account TLS divided by the estimated variance of the estimated HIV prevalence with simple random sampling.

Results

Profile of respondents

The study recruited 2646 participants in the five cities (with a participation rate of 50%): 478 in Lille, 485 in Lyon, 266 in Montpellier, 328 in Nice and 1089 in Paris. A total of 247 *visits* took place: 45 in Lille, 42 in Lyon, 45 in Montpellier, 42 in Nice and 73 in Paris. On average, 14 persons in Paris and eight in other cities were included at each *visit*. The weighted median age of participants was 41 years old. Among them, 64% pursued studies after high school diploma, and 84% defined themselves as homosexuals. The details by city are described in Table 1.

Sampling weight and FVA distribution

The sampling weights before trimming, $\tilde{w}_i$ varied between 0.025 and 200, with 85 participants having weights exceeding the median plus 4 interquartile in their city. The details by city are described in Table 2. The distribution of the trimmed sampling weights $\tilde{w}_{\mathrm{trim}\ i}$ for each city and all cities is illustrated in Figure 1. The FVA varied from 1 to 215 with a median of 6 FVA in the five cities: 4 in Lille, 6 in Lyon and Montpellier, 4 in Nice and 8 in Paris. The distribution of FVA is illustrated in Figure 2.

Table 1. Profile of respondents* unweighted** trimmed GWSM weighted

	Lille (n = 478)		Lyon (n = 485)		Montpellier (n = 266)		Nice (n = 328)		Paris (n = 1089)		Total (n = 2646)	
	UW*	W**	UW*	W**	UW*	W**	UW*	W**	UW*	W**	UW*	W**
Median age	36	38	35	32	37	42	40	41	43	44	40	41
Higher education (%)	58	63	61	62	63	65	55	53	70	69	64	64
Defined as homosexual (%)	84	79	86	84	88	86	86	83	88	85	87	84

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Table 2. Minimum and maximum sampling weights before trimming, value of threshold (median plus 4 interquartile of the city) and number of sampling weights greater than the threshold in each city

City	Min $\tilde{w}_i$	Max $\tilde{w}_i$	Threshold	Number $\tilde{w}_i$ > Threshold
Lille	0.025	39.7	15.9	7
Lyon	0.103	90.7	21.5	26
Montpellier	0.029	36	9.17	5
Nice	0.084	200	18.8	14
Paris	0.030	59.9	27.2	36

HIV prevalence estimation

HIV prevalence among MSM attending gay venues in the five cities studied was estimated at 14.3% (95% CI (12.0–16.9)). A weighted logistic regression on HIV status of all participants, adjusted for city, age and education level, concluded there was significant differences in HIV prevalence between all five cities ($P < 0.001$), particularly between Paris and Lille. However, no significant difference was observed between Paris and the other cities. More specifically, we estimated a prevalence of 7.6% (95% CI (5.1–11.1)) in Lille, 11.4% (95% CI (6.9–18.3)) in Lyon, 16.9% (95% CI (11.2–24.7)) in Montpellier, 17.1% (95% CI (11.8–24.1)) in Nice and 16.1% (95% CI (12.5–20.4)) in Paris.

A weighted logistic regression model used to explain the HIV serological status in each city according to the number of FVA, adjusted for age and education level, showed that FVA had a significant effect on the HIV status in Paris, Lille and Nice: the higher the FVA, the higher the risk of being seropositive for HIV

We compared HIV prevalence estimations using different sampling weights (Fig. 3). The unweighted 95% confidence intervals for HIV prevalence (no weight) overlapped with confidence intervals of estimations using $\tilde{w}_{\text{trim }i}$, $\tilde{w}_i$ and w_i. The unweighted prevalence estimates were included in the confidence intervals of estimations using $\tilde{w}_{\text{trim }i}$, $\tilde{w}_i$ and w_i for all cities but one (Nice). The variance of the unweighted prevalence was narrower than the variances based on GWSM (using $\tilde{w}_i$, and $\tilde{w}_{\text{trim }i}$).

We computed the design effect of the estimated HIV prevalence in each city (Table 3). Design effects were different according to cities, with a minimum in Lille and a maximum in Lyon. The design effect of estimated HIV prevalence ranged from 1.2 (Lille) to 4.0 (Lyon).

Discussion

We applied the GWSM to provide the most accurate estimations for HIV prevalence in MSM attending gay venues. This method took into account the TLS weights and individuals' FVA. Of all recently published studies about MSM attending gay venues, to our knowledge, only Gustafson *et al.*[17] produced estimates using sampling weights and FVA. However, they used a different estimation method than GWSM. Other studies in Australia and the USA used TLS, but provided estimations without taking into account FVA [12] and sometimes without weights [11, 13]. The need to use both sampling weights and FVA in inference of TLS studies has been demonstrated [17, 18]. In the present study, the variance of HIV prevalence estimates was lower than estimations based on GWSM when we did not take into account the sampling design (unweighted estimates). Unweighted estimates, although still commonly used, can incorrectly conclude that significant differences exist in HIV prevalence between cities adjusted for age and education level. We decided to trim extreme sampling weights in order to avoid a variance in estimates which was artificially too large. Although trimming is often used, there seems to be no consensus in the literature on how to trim extreme weights [28–31]. Our choice was based on a compromise between as small a change as possible in weights and the greatest reduction of variance of some key statistics (HIV prevalence and negative viral load prevalence).

In this paper, we presented the design effect to help researchers calculate sample sizes when they set up similar survey designs. As the design effect ranged from 1.2 and 4 according to city, we recommend using the maximum value. It will then suffice to multiply the sample size needed from a simple random sampling hypothesis by the design effect.

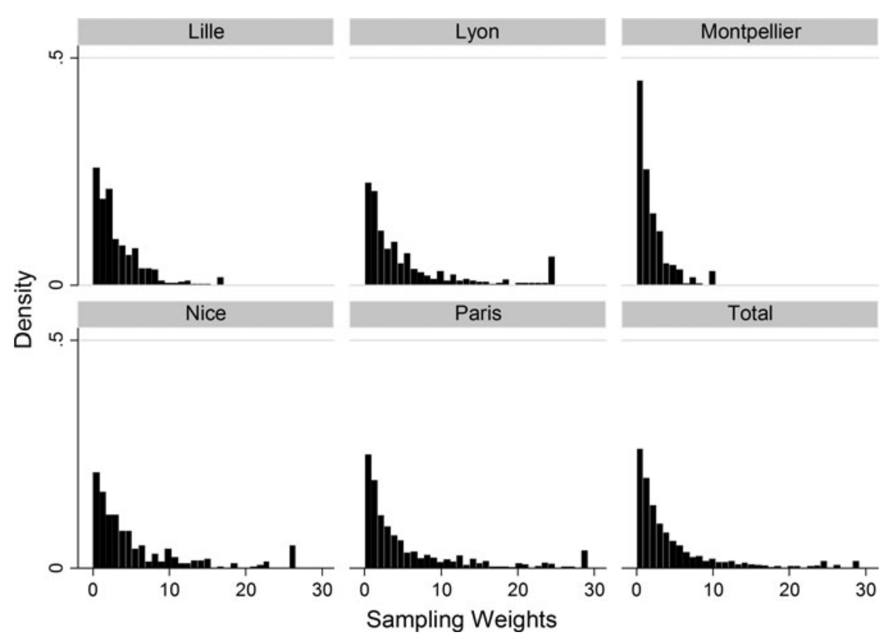

Fig. 1. Distribution of trimmed sampling weights.

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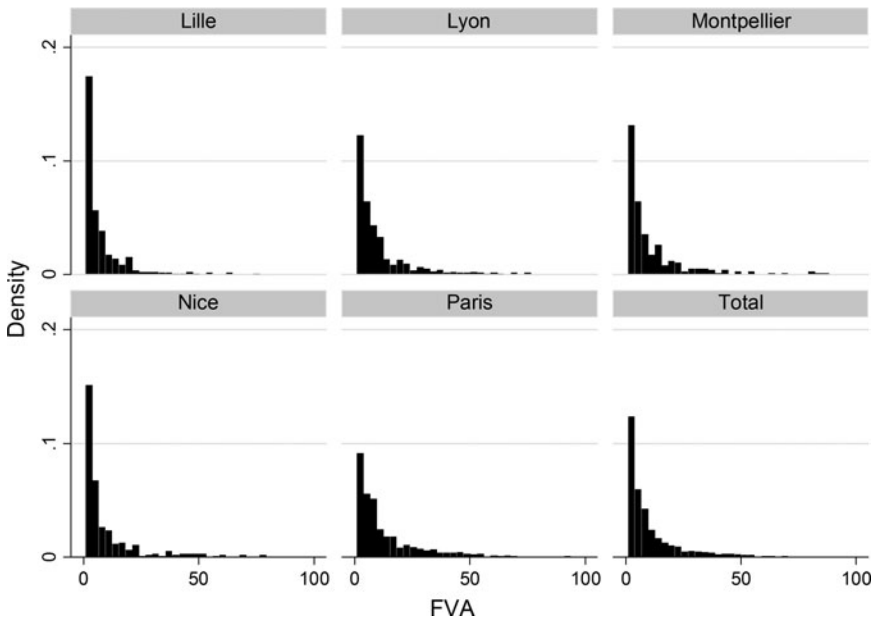

Fig. 2. Distribution of FVA (FVA >100 –*n* = 19– were removed).

Our study also showed the impact of the non-use of FVA inference. Indeed, in cities where FVA was positively associated with serological status, prevalence estimates obtained without taking into account FVA were different from those obtained by GWSM. In their simulation work, Léon *et al.* showed that not considering FVA produced biased estimation [18].

With respect to FVA, despite the fact that the GWSM requires only the total number of FVA, we decided to ask participants how frequently they visited specific participating gay venues. We could have asked only one question on frequency attendance in gay venues but it could have been difficult to differentiate between participating venues and non-participating ones. Furthermore, as each city was studied independently, a global question could have led to an overestimation of frequentations for MSM who travelled between cities (i.e., visited participating venues in different cities studied). Moreover, we thought that asking for information on each venue would provide a more precise answer than a general question on all venues.

The participation rate was estimated at 50%. Among people who refused to participate, only 21% agreed to complete a refusal questionnaire. Accordingly, it was difficult to compare respondents with non-respondents. However, it is likely that only the most highly motivated men, for whom prevention is important, agreed to participate [24], and this most probably led to an underestimation of HIV prevalence in our population [10].

The overall HIV infection prevalence was estimated at 14.3% (12.0–16.9). The variations in HIV prevalence we observed across cities (from 7.6% (5.1–11.1) in Lille to 17.1% (11.8–24.1) in Nice) could partly be explained by the differences in the type of recruitment venues where participants were included. Differences in age distributions were also important to explain the differences in HIV prevalence. Despite differences in methodologies, our results

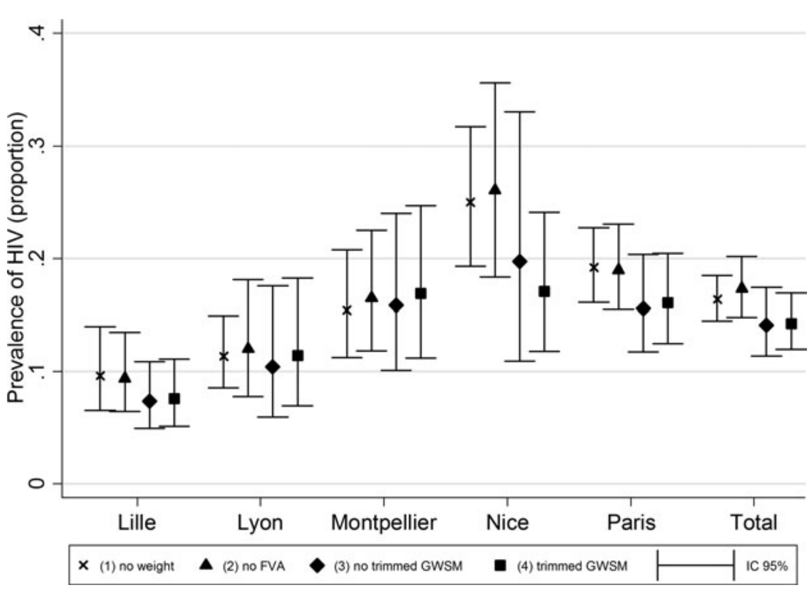

Fig. 3. Estimation of HIV prevalence in each city according to different weights: $\tilde{w}_{\mathrm{trim}\,i}$ (trimmed GWSM), $\tilde{w}_i$ (no trimmed GWSM), w_i (no FVA) and no weight.

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Table 3. Design effect of the estimated HIV prevalence in each city

	$\tilde{w}_{i\ \mathrm{trim}}$
Lille	1.2
Lyon	4.0
Montpellier	2.4
Nice	1.7
Paris	2.8
Total	3.1

regarding HIV prevalence were comparable with those from studies using TLS and conducted throughout cities in Europe [12], the USA [32] and Australia [11].

Limitations

Despite TLS being the current method of choice to conduct surveys among hard-to-reach populations such as MSM, our results cannot be extended to the whole MSM population. Men recruited through TLS were more connected to the gay community than those recruited through Internet sampling, had a greater number of sexual partners, and had more risky sexual behaviours [33]. Accordingly, estimates of HIV prevalence in MSM attending gay venues may overestimate HIV prevalence in the MSM population. Respondent-driven sampling and surveys based on online recruitment, represent other alternatives, with the potential of recruiting a broader sample of MSM [23, 33]. However, neither allows pure random sampling [1].

Despite the carefully developed study protocol, individual unforeseen events affected the implementation of the survey and led to modifications in the sampling calendar. The terrorist attacks in Paris in November 2015 created a certain atmosphere of fear, with public disturbances occurring in the city's gay neighbourhood during the subsequent days. We consequently decided to suspend the survey for 1 week and to postpone the end of the data collection. In Nice, serious flooding occurred in October 2015 while the survey was being implemented. The events in Paris and Nice led very probably to a decrease in attendance of gay venues during the survey period. Thus, sampling weights could have been somehow miscalculated and could have introduced some biases in estimations.

Conclusion

Finally, the implementation of TLS and the use of GWSM made it possible, for the first time, to both perform a random survey among MSM in France attending gay venues and to produce reliable statistical results, in particular concerning the estimation of HIV prevalence in that population. In the last decade, a diversification in gay and other MSM social networks has been observed [33]. We observed a shift in the way in which MSM meet sexual partners, with a decline in the use of traditional venues (such as bars, saunas and backrooms) and an increase in internet use and apps [33]. These changes must be taken into account in MSM behavioural surveillance, for example modifications in recruitment methodologies. This of course creates new challenges as regards issues of representativeness. In order to understand the MSM population in all its diversity, it will be necessary to triangulate data collection methods (population probability surveys, internet convenience sampling and TLS) to implement HIV prevention interventions in line with changes in gay socialising.

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Data collection was carried out by B.V.A.

Declaration of interest

None.

References

1. **Beyrer C, *et al.*** (2012) Global epidemiology of HIV infection in men who have sex with men. *The Lancet* **380**, 367–377.
2. **Centers for Disease Control and Prevention** (2014) *HIV Surveillance Report* **26**, 12–18.
3. **Pharris A, *et al.*** (2015) Trends in HIV surveillance data in the EU/EEA, 2005 to 2014: new HIV diagnoses still increasing in men who have sex with men. *Euro Surveillance* **20**, 2–6.
4. **Cazein F, *et al.*** (2015) New HIV and AIDS diagnoses, France, 2003–2013. *Bulletin Epidémiologique Hebdomadaire* **9–10**, 154–161.
5. **Le Vu S, *et al.*** (2010) Population-based HIV-1 incidence in France, 2003–08: a modelling analysis. *The Lancet Infectious Diseases* **10**, 682–687.
6. **Dubois-Arber F, *et al.*** (2010) Mapping HIV/STI behavioural surveillance in Europe. *BMC Infectious Diseases* **10**, 290–299.
7. **McGarrigle C, *et al.*** (2002) Behavioural surveillance: the value of national coordination. *Sexually Transmitted Infections* **78**, 398–405.
8. **Bajos N, Bozon M and Beltzer N** (2008) Sexuality, prevention and gender relations during life. *Médecine Sciences* **24**, 24–32.
9. **Prah P, *et al.*** (2016) Men who have sex with men in Great Britain: comparing methods and estimates from probability and convenience sample surveys. *Sexually Transmitted Infections* **96**, 455–463.
10. **Elford J, *et al.*** (2009) HIV and STI behavioural surveillance among men who have sex with men in Europe. *Euro Surveillance* **14**, 12–18.
11. **Holt M, *et al.*** (2015) The prevalence and correlates of undiagnosed HIV among Australian gay and bisexual men: results of a national, community-based, bio-behavioural survey. *Journal of the International AIDS Society* **18**, 20526–20533.
12. **Mirandola M, *et al.*** (2016) The Sialon II Project. Report on a Bio-behavioural Survey among MSM in 13 European cities, pp. 29–42.
13. **Snowden JM, *et al.*** (2016) Prevalence and characteristics of users of pre-exposure prophylaxis (PrEP) among men who have sex with men,

San Francisco, 2014 in a cross-sectional survey: implications for disparities. *Sexually Transmitted Infections* **93**, Jun 28.
14. **MacKellar D, *et al.*** (2007) Surveillance of HIV risk and prevention behaviors of men who have sex with men: a national application of venue-based, time-space sampling. *Public Health Reports* **122**, 39–47.
15. **Pollack L, *et al.*** (2005) Evaluation of the center for disease control and prevention's HIV behavioral surveillance of men who have sex with men: sampling issues. *Sexually Transmitted Diseases* **32**, 581–589.
16. **Stueve A, *et al.*** (2001) Time-space sampling in minority communities: results with young Latino men who have sex with men. *American Journal of Public Health* **91**, 922–926.
17. **Gustafson P, *et al.*** (2013) Impact of statistical adjustment for frequency of venue attendance in a venue-based survey of men who have sex with men. *American Journal of Epidemiology* **177**, 1157–1164.
18. **Léon L, Jauffret-Roustide M and Le Strat Y** (2015) Design-based inference in time-location sampling. *Biostatistics (Oxford, England)* **16**, 565–579.
19. **MacKellar D, *et al.*** (1996) The young men's survey: methods for estimating HIV seroprevalence and risk factors among young men who have sex with men. *Public Health Reports* **111**, 138–144.
20. **Reidy W, *et al.*** (2009) HIV risk associated with gay bathhouses and sex clubs: findings from 2 Seattle surveys of factors related to HIV and sexually transmitted infections. *American Journal of Public Health* **99**, 165–172.
21. **Xia Q, *et al.*** (2006) The effect of venue sampling on estimates of HIV prevalence and sexual risk behaviors in men who have sex with men. *Sexually Transmitted Diseases* **33**, 545–550.
22. **Deville J and Lavallée P** (2006) Indirect sampling: the foundations of the generalized weight share method. *Survey Methodology* **32**, 165–176.
23. **Velter A, *et al.*** (2015) Sexual and prevention practices in men who have sex with men in the era of combination HIV prevention: results from the Presse gays et Lesbiennes survey, France, 2011. *Euro Surveillance* **20**, 34–44.
24. **Velter A, *et al.*** (2013) HIV prevalence and sexual risk behaviors associated with awareness of HIV status among men who have sex with men in Paris, France. *AIDS and Behavior* **17**, 1266–1278.
25. **Le Vu S, *et al.*** (2012) Biomarker-based HIV incidence in a community sample of men who have sex with men in Paris, France. *PLoS ONE* **7**, e39872.
26. **Horvitz D and Thompson D** (1952) A generalization of sampling without replacement from a finite universe. *Journal of the American Statistical Association* **47**, 663–685.
27. **Särndal C, Swensson B and Wretman J** (2003) *Model Assisted Survey Sampling*. Springer Science & Business Media, pp. 133–144.
28. **Alexander C, Dahl S and Weidman L** (1997) *Making Estimates From the American Community Survey*. Anaheim, CA: Annual Meeting of the American Statistical Association (ASA).
29. **Elliott M** (2008) Model averaging methods for weight trimming. *Journal of Official Statistics* **24**, 517–521.
30. **Kish L** (1992) Weighting for unequal Pi. *Journal of Official Statistics* **8**, 183–200.
31. **Potter F** (1990) A study of procedures to identify and trim extreme survey weights. *JSM Proceedings of the Section, American Statistical Association, AMSTAT*, pp. 225–230. Available at: http://www.websm.org/db/12/15927/Web%20Survey%20Bibliography/A_study_of_procedures_to_identify_and_trim_extreme_sampling_weights/
32. **Raymond H, Chen Y and McFarland W** (2015) Estimating incidence of HIV infection among men who have sex with men, San Francisco, 2004–2014. *AIDS and Behavior* **20**, 17–21.
33. **Zablotska IB, *et al.*** (2014) Methodological challenges in collecting social and behavioural data regarding the HIV epidemic among gay and other men who have sex with men in Australia. *PLoS ONE* **9**, e113167.