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RESEARCH REPORT

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Incarceration history is associated with HIV infection among community-recruited people who inject drugs in Europe: A propensity-score matched analysis of cross-sectional studies

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Abstract

Aims: We measured the association between a history of incarceration and HIV positivity among people who inject drugs (PWID) across Europe.

Design, Setting and Participants: This was a cross-sectional, multi-site, multi-year propensity-score matched analysis conducted in Europe. Participants comprised community-recruited PWID who reported a recent injection (within the last 12 months).

Measurements: Data on incarceration history, demographics, substance use, sexual behavior and harm reduction service use originated from cross-sectional studies among PWID in Europe. Our primary outcome was HIV status. Generalized linear mixed models and propensity-score matching were used to compare HIV status between ever- and never-incarcerated PWID.

Findings: Among 43 807 PWID from 82 studies surveyed (in 22 sites and 13 countries), 58.7% reported having ever been in prison and 7.16% (*n* = 3099) tested HIV-positive. Incarceration was associated with 30% higher odds of HIV infection [adjusted odds ratio (aOR) = 1.32, 95% confidence interval (CI) = 1.09–1.59]; the association between a history of incarceration and HIV infection was strongest among PWID, with the lowest estimated propensity-score for having a history of incarceration (aOR = 1.78, 95%

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CI = 1.47–2.16). Additionally, mainly injecting cocaine and/or opioids (aOR = 2.16, 95% CI = 1.33–3.53), increased duration of injecting drugs (per 8 years aOR = 1.31, 95% CI = 1.16–1.48), ever sharing needles/syringes (aOR = 1.91, 95% CI = 1.59–2.28) and increased income inequality among the general population (measured by the Gini index, aOR = 1.34, 95% CI = 1.18–1.51) were associated with a higher odds of HIV infection. Older age (per 8 years aOR = 0.84, 95% CI = 0.76–0.94), male sex (aOR = 0.77, 95% CI = 0.65–0.91) and reporting pharmacies as the main source of clean syringes (aOR = 0.72, 95% CI = 0.59–0.88) were associated with lower odds of HIV positivity.

Conclusions: A history of incarceration appears to be independently associated with HIV infection among people who inject drugs (PWID) in Europe, with a stronger effect among PWID with lower probability of incarceration.

KEYWORDS

Europe, HIV, incarceration, injection drug use, prison, PWID

INTRODUCTION

The average regional HIV prevalence rates in prison populations world-wide range from 3% in Asia, 4% in North America and 5% in Europe to 6% in Africa [1]. Incarcerated individuals have a higher prevalence of HIV than the general population, primarily due to the over-representation of people who inject drugs (PWID) [2]. In Europe, the proportion of people with a history of injecting drugs among incarcerated people ranges from 5% (France, Poland) to 50% (Estonia, Lithuania) [3, 4]. Data from community-recruited PWID in European countries suggest that between 20 and 80% of PWID have a history of incarceration [5].

HIV prevalence among PWID in the community is highly variable across Europe [6]. In eastern Europe and most western European countries, HIV prevalence among PWID is higher than that among men who have sex with men (except in the UK and Finland) [7] or sex workers [8]. While data show that injection drug use continues in many prison systems [9] and that incarcerated PWID share injection equipment [10, 11], the evidence on HIV incidence in prison settings is scarce, and intra-prison transmission appears to be low in most countries, except for large-scale outbreaks in some [12, 13]. A systematic review found that recent incarceration was associated with an 81% increase in HIV acquisition risk among PWID [14]. It has been suggested that people living with HIV who have a history of incarceration are most likely to have contracted the disease in the community rather than while in prison, potentially due to a high-risk period immediately after release [15]. Following release from prison, social instability, re-engagement in key transmission risk behaviors and a disconnect from harm reduction services may lead to a high risk of blood-borne infections and high mortality [16].

It has been suggested that incarceration could also provide an opportunity to intervene, by providing or continuing opioid agonist maintenance treatment (OMT) [5], needle/syringe programs (NSPs) and by diagnosing unknown HIV and hepatitis C virus (HCV) infections and (re)starting anti-retroviral therapy (ART) and hepatitis C treatment [17]. HIV viral load suppression can be achieved in prison, promoted by a structured environment and routine clinical follow-up [16]. Internationally, however, HIV prevention efforts in prisons have been poor in comparison to those in the surrounding communities [6, 18]. Recent assessments of the access to HIV and HCV preventive interventions in prison settings of European countries have documented a low level of adherence to World Health Organization/United Nations Office on Drugs and Crime (WHO/UNODC) recommendations for these interventions (including OMT, NSPs and ART) [18, 19].

Overall, the benefits to the individuals who receive such treatment in prison are very likely to be outweighed by the serious harms associated with incarceration, including an increased risk of HIV infection and overdose death after release. We aimed to examine to what extent a history of incarceration is associated with an increased risk of HIV infection among community-recruited PWID in Europe.

METHODS

We pooled and analyzed individual-level data (2001–17) from 82 cross-sectional, multi-site and multi-year studies to assess the association between a history of incarceration and HIV status among community-recruited PWID in Europe.

Data

Data from PWID, who reported recent injections and had been recruited in community settings in 82 cross-sectional studies across Europe, were identified through an international collaboration of researchers and their contacts [20, 21] and collated into one data set (see Supporting information, Table S1, p. 2). We grouped the data into 22 'sites' based on the location (country or city), year and/or methodology of data collection (Table 1). Data from each country were merged into one site if they originated from data collected within a

TABLE 1 Characteristics of the research and data collection methods of the source data (22 sites across Europe).

Country	Czech Republic (CZ)	Estonia (EE-T)	Finland (FI-7)	Greece (GR-A)	Hungary (HU)	Latvia (LV-5 s)	Latvia (LV-R)	Luxembourg (LU)
City/Region	National	Tallinn	Seven cities in Southern Finland	Athens	National	5 geographical areas of Latvia	Riga/surrounding areas	Luxembourg
Year of data collection	2002–03	2009, 2011, 2013	2014	2012–2013	2014–2015	2014, 2016	2012	2015–2017
Place of recruitment	Low-threshold center	NSP	Low- threshold center (NSP)	Site for community-based testing and linkage to care	NSP, OST, low- threshold center (without NSP)	NSP	NSP	NSP, drug treatment center
Sampling method	Convenience	RDS	Convenience	RDS	Convenience	Convenience	RDS	Convenience
Sample size (*n*)	760	1031	600	3320	1054	666	290	420
Inclusion criteria (definition of recent injection drug use[a])	Drug injecting in the last 12 months	Drugs injecting in the last 2 months	Current	Drug injecting in the last 12 months	Drug injecting in the last 4 weeks	Drug injecting in the last 4 weeks	Drug injecting in the last 4 weeks	Current
Inclusion criteria (other)[b]	Age > 15 years; not in OST	Age ≥ 18 years	None	Age ≥ 18 years	Drug injecting ever	Age ≥ 18 years	Age ≥ 18 years	Adults having taken once any illegal drug
Type of sample taken	Venous blood	Venous blood	Finger- prick blood	Venous blood	Dry blood spot	Finger prick testing	Venous blood	Venous blood
Measurement to detect HIV	Self-report	HIV-1/HIV-2 III Plus from Abbott Laboratories, Abbott Park, Illinois, USA	Abbott ARCHITECT HIV Ag/Ab Combo	Anti-HIV-1/2 (AxSYM HIV-1/2 gO; Abbott)	HIV Ab: Vironostika HIV Ag/Ab ELISA (bioMérieux)	Rapid test CHIV-201	Vironostika HIV Uniform II Ag/Ab (BioMerieux), Genscreen Plus HIV Ag Ab, (Bio-Rad, France)	Cobas roche Combo HIV Combi PT

Abbreviations: CZ, Czech Republic; EE-T, Tallinn, Estonia; EIA, enzyme immunoassay; ELISA, enzyme-linked immunosorbent assay; FI-7, seven cities (Helsinki, Vantaa, Espoo, Tampere, Turku, Lahti, Hämeenlinna), Finland; GR-A, Athens, Greece; HU, Hungary; LU, Luxembourg; LV-5 s, five geographical areas (Riga, Jurmala, Ogre, Liepaja, Bauska), Latvia; LV-R, Riga and surrounding areas, Latvia; NL-A, Amsterdam, the Netherlands; NSP, Needle/syringe program; OST, opioid substitution therapy; PL-G, Gdańsk, Poland; PL-GK, Gdańsk, Kraków, Poland; PL-Ms, in six regions: mazowieckie (Warszawa), lubuskie (Zielona Góra, Gorzów Wlkp., Cibórz, Nowy Dworek), śląskie (Katowice, Chorzów, Sosnowiec), dolnośląskie (Wrocław—two locations), lubelskie (Lublin, Puławy), warmińsko-mazurskie (Olsztyn, Elbląg, Barczewo), Poland; PL-W, Warszawa, Poland; PT-P, Porto, Portugal; PWID, people who inject drugs; RDS, respondent-driven sampling; RU-5 s, five cities (Barnaul, Volgograd, Naberezhnye, Chelny, Perm, Abakan), Russia; RU-IN, Ivanovo, Novosibirsk, Russia; RU-StP, St Petersburg, Russia; RU-V, Voronezh, Russia; SP-C, Catalonia, Spain; SP-C, Catalonia, Spain; FI-7, seven cities in Finland (Helsinki, Vantaa, Espoo, Tampere, Turku, Lahti, Hämeenlinna, Lahti); SPMBS, Madrid, Barcelona, Seville, Spain; SP-MBS, Madrid–Barcelona–Seville; Tallin, EE-T, Estonia; UK-EWnI, England, Wales and Northern Ireland, UK; UK-S, Scotland, UK.

[a]A stratified convenience sample of people who inject drugs was selected according to the type of center and country of origin using proportional allocation.

[b]Main inclusion criteria only.

TABLE 1 (Continued)

Country	Netherlands (NL-A)	Poland (PL-G)	Poland (PL-GK)	Poland (PL-Ms)	Poland (PL-W)	Portugal (PT-P)	Russia (RU-5 s)
City/Region	Amsterdam	Gdańsk	Gdańsk, Kraków	Multiple sites	Warszawa	Regional (Porto)	5 cities
Year of data collection	2010–2014	2002	2008–2009	2004–2005	2013	2009–2010	2014
Place of recruitment	Public Health Service	Drug treatment center; street	Research center	Drug treatment center; research center	Research center	Drug treatment centers; Infectious diseases hospitals	NSP
Sampling method	Convenience	Convenience	RDS	Convenience + snowball	RDS	Convenience	RDS
Sample size (*n*)	262	200	193	776	95	253	520 (105 from each city)
Inclusion criteria (definition of recent injection drug use[a])	Drug injecting in the last 6 months	Drug injecting in the last 4 weeks	Drug injecting in the last 4 weeks	Drug injecting in the last 4 weeks	Drug injecting in the last 4 weeks	Drug injecting in the last 6 months	Drug injecting in the last 4 weeks
Inclusion criteria (other)[b]	Using drugs	Age ≥ 18 years	Age ≥ 18 years	Age ≥ 18 years	Age ≥ 18 years	Age ≥ 18 years; who had been diagnosed with HIV within five years of the date of the interview or HIV negative with a last negative test within 12 months of the date of the interview	Age ≥ 15 years
Type of sample taken	Venous blood	Venous blood	Venous blood	Venous blood	Venous blood	None	Venous blood
Measurement to detect HIV	INNO-LIA HIV-1 HIV-2 assay, Innogenetics	Ab commercial EIA	Ab commercial EIA	Ab commercial EIA	Ab commercial EIA	Self-report	EIA test certified in Russia

TABLE 1 (Continued)

Country	Russia (RU-IN)	Russia (RU-StP)	Russia (RU-V)	Spain (SP-C)	Spain (SP-MBS)	UK (UK-EWnI)	UK (UK-S)
City/Region	Ivanovo, Novosibirsk	Saint Petersburg	Voronezh	Catalonia	Madrid, Barcelona, Seville	England, Wales & Northern Ireland	Scotland (national)
Year of data collection	2010	2012–2013	2011	2014–2015	2001–03	2000–08	2013–14
Place of recruitment	HIV treatment center	NSP, street, mobile van	HIV treatment center	Harm reduction centers	Street	NSP, drug treatment center	NSP
Sampling method	RDS	RDS	RDS	Convenience[a]	Targeted + snowball	Purposive	Purposive
Sample size (*n*)	593 (Ivanovo 300; Novosibirsk 293)	811	310	730	637	27 823	2463
Inclusion criteria (definition of recent injection drug use[a])	Drug injecting in the last 4 weeks	Drug injecting in the last 4 weeks	Drug injecting in the last 4 weeks	Drug injecting in the last 6 months	Using heroin in the last 3 months	Active PWID	Active PWID
Inclusion criteria (other)[b]	Age ≥ 18 years	Age ≥ 16 years	Age ≥ 16 years	Age ≥ 18 years	Used heroin at least 12 days in the last 12 months and at least once in the past 3 months; age between 18 and 30 years	Active PWID	Active PWID
Type of sample taken	Venous blood	Saliva	Venous blood	Saliva	Dry blood spot	Oral fluid/dried blood spot	Dry blood spot
Measurement to detect HIV	EIA test certified in Russia	Rapid test (OraQuick)	Genscreen ULTRA HIV Ag–Ab, NEW LAV-BLOT	Genscreen HIV-1/2 Version 2.0 assay fromBio-Rad	ELISA Genscreen HIV1/2 version 2, Bio-Rad, Marnes La Coquette, France	Various tests	Ortho Save 3.0 EIA

Abbreviations: CZ, Czech Republic; EE-T, Tallinn, Estonia; EIA, enzyme immunoassay; ELISA, enzyme-linked immunosorbent assay; FI-7, seven cities (Helsinki, Vantaa, Espoo, Tampere, Turku, Lahti, Hämeenlinna), Finland; GR-A, Athens, Greece; HU, Hungary; LU, Luxembourg; LV-5 s, five geographical areas (Riga, Jurmala, Ogre, Liepaja, Bauska), Latvia; LV-R, Riga and surrounding areas, Latvia; NL-A, Amsterdam, the Netherlands; NSP, Needle/syringe program; OST, opioid substitution therapy; PL-G, Gdańsk, Poland; PL-GK, Gdańsk, Kraków, Poland; PL-Ms, in six regions: mazowieckie (Warszawa), lubuskie (Zielona Góra, Gorzów Wlkp., Cibórz, Nowy Dworek), śląskie (Katowice, Chorzów, Sosnowiec), dolnośląskie (Wrocław—two locations), lubelskie (Lublin, Puławy), warmińsko-mazurskie (Olsztyn, Elbląg, Barczewo), Poland; PL-W, Warszawa, Poland; PT-P, Porto, Portugal; PWID, people who inject drugs; RDS, respondent-driven sampling; RU-5 s, five cities (Barnaul, Volgograd, Naberezhnye, Chelny, Perm, Abakan), Russia; RU-IN, Ivanovo, Novosibirsk, Russia; RU-StP, St Petersburg, Russia; RU-V, Voronezh, Russia; SP-C, Catalonia, Spain; SP-C, Catalonia, Spain; FI-7, seven cities in Finland (Helsinki, Vantaa, Espoo, Tampere, Turku, Lahti, Hämeenlinna, Lahti); SPMBS, Madrid, Barcelona, Seville, Spain; SP-MBS, Madrid–Barcelona–Seville; Tallin, EE-T, Estonia; UK-EWnI, England, Wales and Northern Ireland, UK; UK-S, Scotland, UK.

[a]A stratified convenience sample of people who inject drugs was selected according to the type of center and country of origin using proportional allocation.

[b]Main inclusion criteria only.

short time-period (1–3 years) and same geographic region using the same study design. The methods of the included source studies are described in detail elsewhere (see references in Supporting information, pp. 4–6), and a summary is presented here (Table 1). In addition, aggregated (country- or site-level) data on structural-level variables (including the Gini index, HIV prevalence among PWID in the community, incarceration rates in the general population and among PWID and PWID population coverage of prevention and harm reduction services in prison and the community) were requested from all sites and screened by two authors (L.We, L.Wi; Supporting information, Table S3).

Sampling procedures, recruitment of participants and data collection

The source studies included HIV testing among the participating PWID and were carried out in different settings (mainly community-based low-threshold programs/NSPs and drug treatment programs) during 2001–17. Sampling/recruitment approaches suitable for hard-to-reach populations were used: respondent-driven sampling (RDS, nine sites), other chain referral methods (two sites) and venue-based convenience sampling (11 sites). Data on sociodemographic factors (age, sex), self-reported drug use (duration of drug injection, main drug injected, frequency of injection), injection (sharing needles/syringes, overdose experience) and sexual risk behaviors (e.g. number of sexual partners) were obtained. Recall periods for risk behaviors (needle/syringe sharing, number of sexual partners) varied across sites (see Supporting information, Table S2, p. 3). We use the term 'incarceration' to refer to the detention of people in prisons or other closed settings and use the term 'prison' to refer to any such setting where someone might be detained [14]. The exposure variable (a history of incarceration) was dichotomized: 'ever' versus 'never'. Given that the source data originated from multiple different studies, we applied standardized data definitions while compiling the single data set. Data were synchronized in terms of time—events with recall periods up to 12 months were categorized as 'recent' (recent needle/syringe sharing, recent main drug injected, recent frequency of injecting). Categorical variables were dichotomized into 'ever' and 'never' (OMT, needle/syringe sharing, overdose) (synchronized variables, see Table 2; source study variables, see Supporting information, Table S2). In the source studies, blood or oral fluid specimens were tested for HIV antibodies using standard enzyme immunoassays (see Supporting information, Table S2, p. 3). For two sites, HIV infection status was based on self-reported HIV status (Portugal 2009–10, Czech Republic 2002–03).

Summary statistics and data imputation

Table 2 presents the summary statistics, which are expressed as counts and percentages for categorical variables and as the means and standard deviations (SDs) for continuous variables. Figure 1 shows the data on HIV prevalence, proportion of people ever incarcerated, and age at and duration of injection among PWID by site.

Missing data resulted from either the entire variable missing from a site or data for that variable missing for a subset of the sample (the proportions of missing data by study and variable are provided in Supporting information, Table S2 and the overall proportions for each variable in Supporting information, Figure S3). The proportion of missing data varied between studies (see Supporting information, Table S2). We accounted for missing data in a two-staged imputation procedure, assuming that the probability of data being missing was random [22]. We applied multiple imputations for each country, using the variables that had at least some data available, which resulted in five imputed data sets for each country. We then combined imputed data sets (separately for each of the five imputations), which we then used for the second-level imputation. We performed five further imputations for each of the five data sets, resulting in 25 imputed data sets. We used two-level multiple imputation, with sites within the same country as the first level and between countries as the second, to make maximum use of country-specific information. See Supporting information, Statistical analysis, pp. 7–9 for further details on the imputation procedure (specific imputation methods, iterations to convergence).

Propensity-score matching

Propensity-score estimates for a history of incarceration, i.e. estimates of the probability that a PWID was ever incarcerated, were used to standardize the distribution of observed baseline covariates (including confounders) between the exposed (ever in prison) and unexposed (never in prison) subjects (a balancing weighting index) [23]. For each of the 25 imputed data sets, the propensity-scores were estimated using a logistic regression model that included country, site and year (as fixed effects) and all individual-level variables (except HIV status), based on the Akaike and Bayesian information criteria (Table 2) (see Supporting information, Statistical analysis, pp. 7–9). We applied nearest-neighbor matching, in which exposed subjects were matched to the nearest unexposed subjects based on the estimated propensity-scores, using a variable ratio-matching algorithm with replacement [24] with a 1:n variable ratio (distance tolerance equal to 1/100 000, and maximum number matches per exposed was set to 4) [25]. The variable ratio-matching algorithm controlled for additional bias by varying the number of never-incarcerated subjects matched to each ever-incarcerated subject according to a defined propensity-score tolerance range. To address heterogeneity, we used seven matching groups, defined by geographical and epidemiological similarities of sites (group 1: studies from the UK (UK-EWnI, UK-S); group 2: studies from Russia (RU-IN, RU-StP, RU-V, RU-5 s); group 3: a study from Greece (GR-A); group 4: studies from central Europe (CZ, HU, PL-G; PL-GK, PL-W, PL-Ms); group 5: studies from eastern Europe (EE-T, LV-5 s, LV-R); group 6: studies from western Europe

TABLE 2 Univariable and multivariable risk factors associated with HIV among PWID in Europe.

	Unimputed data		Imputed data					
			Univariable models		Univariable propensity-score matched models		Multivariable propensity-score matched models	
	HIV+/total	% HIV+	OR	95% CI	OR	95% CI	OR	95% CI
Socio-demographic characteristics								
Age (years; mean, range, SD) (all PWID)	32.77, 13–78, 8.42		1.16	1.10–1.22**	1.03	0.95–1.11	0.84	0.76–0.94**
Age (years; mean, range, SD) (HIV+ PWID)	33.61, 17–64, 7.61							
Gender								
Men	2378/32251	7.37%	0.97	0.88–1.07	0.74	0.63–0.87**	0.77	0.65–0.91**
Female	710/11165	6.36%	1		1		1	
Drug use characteristics								
Duration of injecting (years; mean, range, SD) (all PWID)	11.19, 0.02–53, 8.04		1.35	1.28–1.41**	1.21	1.11–1.33**	1.31	1.16–1.48**
Duration of injecting (years; mean, range, SD) (HIV+ PWID)	14.02, 0.33–40, 7.44							
Frequency of injecting (recent)[a] (yes, *n* %)								
Less than daily	1701/17551	9.69%	0.75	0.67–0.85**	0.86	0.73–1.01	0.9	0.76–1.07
Daily or more	1016/12449	8.16%	1		1		1	
Main drug injected (recent)[a] (yes, *n* %)								
Stimulants other than cocaine	171/1597	10.71%	1		1		1	
Cocaine	230/2030	11.33%	3.26	2.26–4.71**	3.42	2.22–5.29**	2.70	1.73–4.22**
Opioids	1796/22143	8.11%	1.93	1.56–2.39**	1.87	1.35–2.59**	1.52	1.05–2.18*
Opioid and cocaine	264/2282	11.57%	3.28	2.33–4.63**	2.74	1.73–4.34**	2.16	1.33–3.53**
Other	83/1304	6.37%	1.76	1.33–2.33**	1.64	0.94–2.88	1.55	0.88–2.72
Overdose (ever)[b] (yes, *n* %)								
Yes	1039/2432	42.72%	1.56	1.23–1.97**	1.42	1.10–1.83*	1.21	0.97–1.51
No	681/2928	23.26%	1		1		1	
Sharing needles/syringes (recent)[a] (yes, *n* %)								
Yes	608/6357	9.56%	1.46	1.30–1.63**	–		–	
No	596/14684	4.06%	1		–		–	
Sharing needles/syringes (ever)[b] (yes, *n* %)								
Yes	1697/11619	14.61%	1.88	1.70–2.09**	2.05	1.73–2.44**	1.91	1.59–2.28**
No	1119/19702	5.68%	1		1		1	

(Continues)

TABLE 2 (Continued)

	Unimputed data		Imputed data					
			Univariable models		Univariable propensity-score matched models		Multivariable propensity-score matched models	
	HIV+/total	% HIV+	OR	95% CI	OR	95% CI	OR	95% CI
Sexual behavior								
Number of partners (life-time)[b] (mean, range, SD) (all PWID)	3.36, 0–2400, 25.38		1.04	1.02–1.07**	1.04	1.002–1.07*	1.03	0.96–1.06
Number of partners (life-time)[b] (mean, range, SD) (HIV+ PWID)	7.85, 0–2400, 72.92							
Number of partners (life-time)[b] (yes, *n* %)								
≥ 10	207/1916	10.80%	1		–		–	
2–9	871/11385	7.65%	0.82	0.70–0.97*	–		–	
1	1102/15743	7.00%	0.87	0.75–1.02	–		–	
0	675/8883	7.60%	1.23	1.04–1.45*	–		–	
Environmental factors								
Opioid maintenance therapy (ever)[b] (yes, *n* %)								
Yes	1075/27047	3.97%	1.47	1.27–1.70**	1.39	1.11–1.74**	1.22	0.96–1.56
No	632/8915	7.09%	1		1		1	
Main source of clean syringes (ever)[b] (yes, *n* %)								
NSP and/or outreach	773/2451	31.54%	1		1		1	
Other	91/559	16.28%	0.74	0.54–1.02	0.8	0.54–1.17	0.88	0.59–1.31
Pharmacy	745/2368	31.46%	0.7	0.57–0.86**	0.73	0.59–0.90**	0.72	0.59–0.88**
Ever in prison (yes, *n* %)[b c]								
Yes	1803/24857	7.25%	1.76	1.61–1.94**	1.27	1.05–1.53*	1.32	1.09–1.59**
No	1239/17491	7.08%	1		1		1	
Study level measures								
GINI index[d] (mean, range, SD)	33.54, 25.4–44, 4.76		1.25	1.16–1.34**	1.35	1.19–1.51**	1.34	1.18–1.51**

Note: Eurostat = ES, FI, FR, GR, HU, LU, LV, NL, PL, PT, RO, UK; https://data.europa.eu/data/datasets/dvrrgg5nu7galdtl3xsyq?locale=en); (Worldbank: PL, PT; https://iresearch.worldbank.org/PovcalNet/index.htm); (Knoema: RU; https://knoema.com/atlas/Russian-Federation/GINI-index).

Abbreviations: OR = odds ratio; CI = confidence interval; SD = standard deviation; PWID = people who inject drugs; NSP = needle/syringe programs.

[a]Recall times up to 12 months were categorized as 'recent'.

[b]Recall periods vary by sites and variables (see Supporting information, Table S2). For variables where life-time and recent had to be combined recall was categorized as 'ever'.

[c]A total of 24 857 (58.69%) study subjects reported a history of incarceration (46.7% when excluding the data for UK-EW-NI and UK-S, which constitutes 69.14% of the total sample size).

[d]Data derived from publicly available sources, and for the same years or closest available years to the respective site data collection period.

*$P < 0.05$.

**$P < 0.01$.

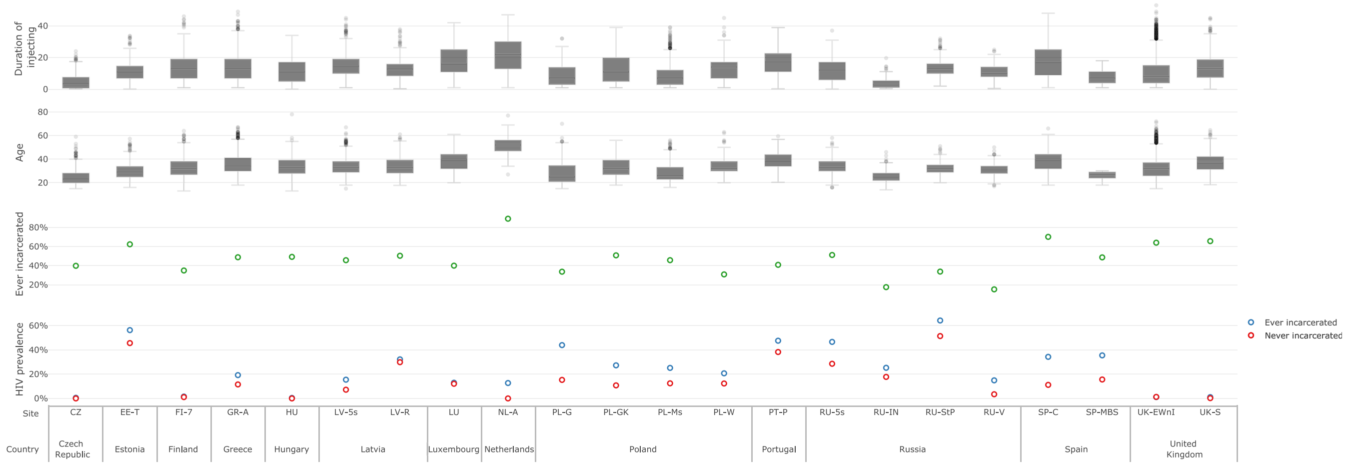

FIGURE 1 HIV prevalence, proportion ever incarcerated, age and duration of injection among people who inject drugs (PWID) by site.

LU, NL-A, FI-7); and group 7: studies from Spain and Portugal (PT-P, SP-C, SP-MBS); for the description of the abbreviations see Table 1 and Supporting information, Table S1. Based on the matching procedure, weights were assigned to individuals proportional to the number of 'never-incarcerated' PWID matched to each 'ever-incarcerated' subject. The weights were then used in a weighted generalized linear mixed model (GLMM) to estimate the association between a history of incarceration and HIV status.

Modeling

For each of the 25 matched data sets, we employed a GLMM to estimate the effect of incarceration on the probability of having a positive HIV status (Supporting information, p. 7). We used a logistic mixed-effects model with logit link, in which the variable 'study' (indicating one data collection round/period within a site and to account for the calendar period effect) and matching group were considered as nested random effects. Due to discontinuity in calendar years between sites, we could not assess a separate longitudinal parameter across different time-points. The weights from the propensity-score matching algorithm were introduced using weighted least squares. The multivariable model of the probability of being HIV-positive included all variables listed in Table 2 as covariates, except for recent needle/syringe sharing, which was omitted due to multicollinearity with ever needle/syringe sharing. Subsequently, we pooled the estimates of each of the 25 models, and we estimated odds ratios (ORs) and 95% confidence intervals (CIs) for each variable. Finally, we estimated ORs for the association between HIV status and a history of incarceration.

The association between socio-demographic (age, sex), behavioral (duration of injection, frequency of injection, main drug injected, overdose, needle/syringe sharing, number of partners) and service use (OMT status, main source of clean needles/syringes) factors and HIV positivity at the individual level was assessed with univariable (both unmatched and propensity-score matched) and multivariable (propensity-score matched) regression models (Table 2). Structural-level variables were tested univariably and included in the model if they were statistically significant (Supporting information, Statistical analysis, p. 8).

Associations were considered statistically significant at $P < 0.05$. The results are presented for a full model (adjusted for all measured variables) and reduced models (the exact parameter estimates togather with standard errors and *P*-values are presented in Supporting information, Table S4).

Sensitivity analysis

In sensitivity analyses, first a reduced model was used to evaluate the effect of removing the UK data (sites: UK-EWnl; UK-S) on the measure of association (given that the UK data constituted 69.1% of the total sample and thus dominated the analysis).

Secondly, to understand exposure effect heterogeneity, we estimated propensity stratum-specific associations. For stratification on the propensity-score of a history of incarceration, we ranked participants by estimated propensity-score and then divided the sample into quintiles of the propensity-score (from 1: lowest probability, to 5: highest probability of ever-incarceration). We estimated the incarceration effect within each stratum using a similar GLMM as that for the matched data, with the exception of random effects being defined here as 'study' and 'country'. Each of the stratum-specific effects described the HIV odds in the respective stratum, and to obtain the population-wide average (exposure) effect, we averaged the effects across the strata.

The models were estimated in R (version 3.5.1) using function glmer from the package lme4 (see additional details on the statistical analysis in the Supporting information, pp. 7–9)

The analysis was not pre-registered and the results should be considered exploratory.

RESULTS

Characteristics of the study population

Data on 43 807 PWID from 22 sites within 13 countries were included in the analyses. Country-level sample sizes ranged from 253 (Portugal) to 30 286 (UK).

The mean age of the participants was 32.81 years (range = 13–78, SD = 8.40). On average, they had injected drugs for 11.22 years (range = 0.02–53.01, SD = 8.02); 58.53% were injecting less than daily and 37.02% reported ever and 30.23% recent needle/syringe sharing. Among the 17 sites with data on number of sexual partners in the past 12 months, a small minority of the participants (5.32%) reported 10 or more sexual partners, three in 10 (30.04%) had two to nine partners and 41.50% had one partner. Ever receiving OMT was reported by 75.23% of PWID. Opioids were reported as the main injection drug used by a majority (75.43%) of PWID, combined use of opioids and cocaine was reported by 7.77% and cocaine only was reported by 6.91%.

Throughout the whole sample, 58.69% (*n* = 24 857) had ever been in prison (range = 15.08% in Voronezh, Russia, to 89.14% in Amsterdam, the Netherlands), and 7.16% (*n* = 3099) were HIV-positive (range = 0.19% in Hungary to 55.74% in St Petersburg, Russia). Among those who had ever been in prison, the HIV prevalence was 7.35% (95% CI = 7.02–7.67%), and among those who had never been in prison it was 7.28% (95% CI = 6.90–7.66%). When excluding the UK data (UK-EWnI; UK-S), the HIV prevalence was 27.0% (95% CI = 25.89–28.18%) among those who had ever been in prison and 16.7% (95% CI = 15.83–17.69%) among those who had never been in prison. Univariable site-specific estimates for the association between ever incarceration and HIV positivity are given in Figure 2 and study-specific estimates are given in Supporting information, Figure S1.

Association between a history of incarceration and HIV infection

After imputation and propensity-score matching, an average of 25 752 ever-incarcerated PWID were matched to never-incarcerated PWID. In univariable analysis, a history of incarceration was significantly associated with a positive HIV status (OR = 1.76, 95% CI = 1.61–1.94). Univariable significant associations of HIV status with frequency of injection (less than daily versus daily or more: OR = 0.75, 95% CI = 0.67–0.85), number of life-time sexual partners (per partner: OR = 1.04, 95% CI = 1.02–1.07), having ever had an overdose (OR = 1.56, 95% CI = 1.23–1.97) and having ever received OMT (OR = 1.47, 95% CI = 1.27–1.70) became non-significant in the multivariable analysis (Table 2). Of the structural variables, only the Gini index was significantly associated with HIV status in univariable analysis (OR = 1.25, 95% CI = 1.16–1.34) and was thus included in the multivariable model (Supporting information, Table S3).

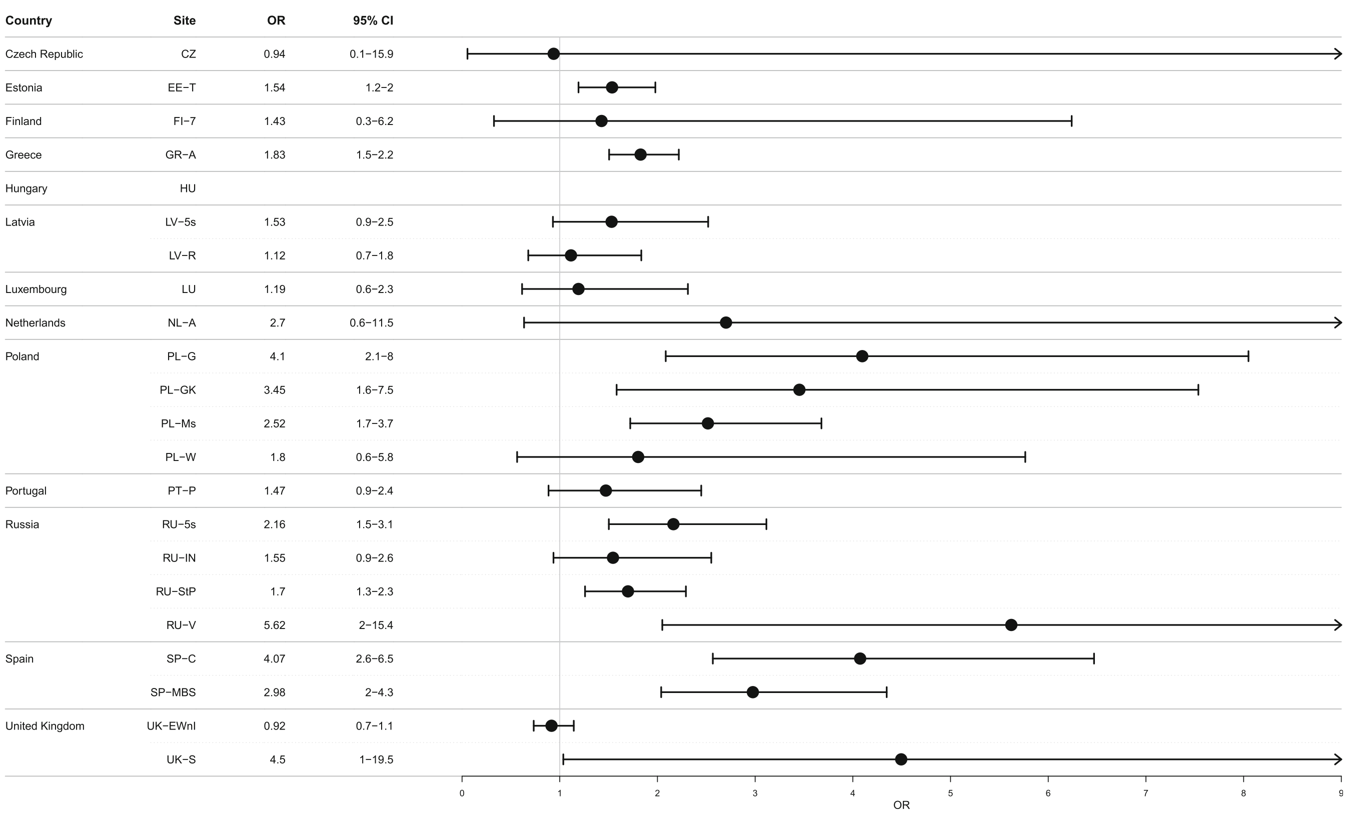

FIGURE 2 Univariable site-specific estimates for the association of incarceration with HIV positivity (odds ratio, 95% confidence interval).

In multivariable analysis, the odds of a positive HIV status were approximately 30% higher among PWID with a history of incarceration than among those without [adjusted odds ratio (aOR) = 1.32, 95% CI = 1.09–1.59]. In addition, individuals with a longer duration of injecting drugs (aOR = 1.31, 95% CI = 1.16–1.48 per 8 years) or a history of (ever) needle/syringe sharing (aOR = 1.91, 95% CI = 1.59–2.28) had higher odds of a positive HIV status (Table 2). The main drug injected was also associated with a positive HIV status, with the highest odds for cocaine (aOR = 2.70, 95% CI = 1.73–4.22), followed by opioids, together with cocaine (aOR = 2.16, 95% CI = 1.33–3.53), and only opioids (aOR = 1.52, 95% CI = 1.05–2.18), compared to those mainly injecting stimulants other than cocaine. Finally, older age (per 8-year increase in age: aOR = 0.84, 95% CI = 0.76–0.94), male sex (aOR = 0.77, 95% CI = 0.65–0.91) and obtaining new needles/syringes from pharmacies as opposed to NSPs and/or outreach programs showed a protective association (aOR = 0.72, 95% CI = 0.59–0.88).

A negative association between a positive HIV status and age appeared after adjusting for the duration of injection (aOR = 0.84, 95% CI = 0.76–0.94 per 8 years). Given the strong correlation between age and years of injection, we performed a sensitivity analysis, omitting age from our final model. This did not change our findings (ever in prison: aOR = 1.31 95% CI = 1.09–1.59).

We found an inverse dose–response association between a history of incarceration and HIV status among the five propensity-score strata for a history of incarceration (in other words, there was a weaker association among PWID with characteristics predicting a higher probability of having ever been in prison and a stronger association among those with a lower probability of having ever been in prison) (see the characteristics of PWID among each of the five propensity-score strata in Supporting information, Table S5). Thus, there was no statistically significant association among the PWID with the highest propensity-scores for a history of incarceration: fifth stratum aOR = 0.94, 95% CI = 0.68–1.29 and fourth stratum aOR = 1.15, 95% CI = 0.83–1.58, while the association became increasingly stronger among the PWID with lower propensity-scores for a history of incarceration: third stratum aOR = 1.30, 95% CI = 1.02–1.65; second stratum aOR = 1.63, 95% CI = 1.3–2.04; and first stratum aOR = 1.78, 95% CI = 1.47–2.16.

Sensitivity analyses

The effect-size estimate and the corresponding standard error of incarceration regarding HIV positivity remained stable after excluding the UK data from the model (full model: aOR = 1.58, 95% CI = 1.32–1.89).

Both the original (full model aOR = 1.32, 95% CI = 1.09–1.59) and the propensity-score stratification analysis (aOR = 1.32, 95% CI = 1.17–1.49) resulted in very similar effect sizes and standard error estimates, indicating that our analysis was not sensitive to the adjustment method.

DISCUSSION

To our knowledge, this is the largest study to date confirming the association between a history of incarceration and HIV infection among PWID. This is also the first study suggesting an inverse dose–response relationship between a history of incarceration and HIV infection by the propensity of PWID for having a history of incarceration—i.e. the association between a history of incarceration and HIV infection appears to be strongest among the PWID with characteristics associated with a lower likelihood of having ever been incarcerated. This novel finding may have been made possible by the large size of our sample, allowing for a wider range of likelihoods (propensity-scores) of a history of incarceration among PWID and greater statistical power in analyzing that range.

For decades, incarceration has been a frequent occurrence for PWID [6, 14]. For the majority of our sites, close to two-thirds of PWID reported having been incarcerated at some point in their lives. Relatively low life-time incarceration rates in the Russian sites, in particular (< 20%) Ivanovo and Voronezh, can probably be attributed to these sites having recruited a young population of PWID with short injection durations and a short time at risk for incarceration [26].

Our results suggest that past incarceration among PWID is associated on average with a 30% higher odds of HIV infection. Our findings are in agreement with those of a recent systematic review [14] (mainly including studies from non-European countries) that found a 25% increase in HIV acquisition risk among those who had ever experienced incarceration. Our study covered PWID from 13 countries across Europe, including eastern European countries with more recent injection drug use and a high prevalence of HIV, central European countries with recent but a low prevalence of HIV, and western and northern European countries with a much longer history of injection drug use and low to high rates of HIV among (older) injection drug users. Additionally, our results are in good agreement with those of a recent study that utilized aggregated data from 16 countries in Europe, where among PWID the population-attributable risk for the effect of incarceration on HIV was estimated at 26% [6].

The inverse relationship between the likelihood that a PWID has a history of incarceration, and the strength of the association between an incarceration history and HIV infection is potentially important for our understanding of the association between a history of incarceration and HIV infection. Here, a history of incarceration may act as a moderating variable in the relationship between injection drug use and HIV risk. For example, among PWID with a low risk of incarceration, being incarcerated might bring them into contact with high-risk injection PWID networks. High-risk networks might, for example, be larger (having more members), have higher rates of turnover, have higher HIV seroprevalence, potentially greater injection risk behaviors and greater visibility to the police (perhaps from engaging in street-level drug distribution). This supports our finding that the association between a history of incarceration and HIV infection appears to be independent of self-reported injection and sexual risk behaviors, and may be due to other additional factors linked to a history of incarceration.

In addition, HIV positivity was associated with cumulative exposure (injection duration), drug injection risks and risk behaviors (needle/syringe sharing, ever having an overdose) and sexual risk behaviors (greater number of sexual partners). These results are consistent with known HIV transmission risks. Obtaining new needles/syringes from sources other than NSPs/outreach services, i.e. using pharmacies as the main source of needles/syringes, was protective for HIV infection. Buying or receiving new needles/syringes via pharmacies might be more characteristic for 'lighter/more infrequent injectors' (often with shorter injection careers) and those with a higher socio-economic status, as opposed to frequent injectors [27].

In multivariable analysis, OMT was not associated with HIV infection, despite being positively associated in the univariable analysis. This latter result may reflect selection bias linked to the cross-sectional nature of our data; e.g. PWID who have ever received OMT have a longer injection duration and have been at risk of HIV infection for longer and have a higher (cumulative) HIV prevalence [28].

The higher risk of HIV infection among PWID who inject cocaine, due to the increase in injection frequency associated with cocaine injection, warrants attention. Together with the historical evidence [29], evidence from recently documented HIV outbreaks among people injecting cocaine in Glasgow (Scotland) [30] and Luxembourg [31] corroborate this finding. High rates of early HCV re-infection after treatment with direct-acting antivirals (DAAs) among people who inject heroin and/or cocaine in Madrid (Spain) [32] further confirm greater injection risks among PWID who inject cocaine. In recent years other stimulants [e.g. new psychoactive substances (NPSs)] have become more widespread, and new HIV outbreaks have been linked to these substances [33].

We found a lower risk of HIV infection among males in comparison to females who injected drugs. This result is consistent with those of earlier studies in Europe [34]. Differences in HIV prevalence between female and male PWID may be due to factors such as multi-layer stigma (also limiting access to much-needed services), high-risk sex and injection partners, dependence on male partners for drugs and injections and participation in sex work [34].

To our knowledge, our finding that HIV prevalence was lower among older PWID, after adjusting for duration of injection, has not been reported previously. This seems consistent with a recent finding that adjusted HIV incidence was not lower among young PWID in an HIV outbreak context; i.e. a positive association between HIV prevalence and age reported in many cross-sectional studies is largely due to cumulative risk exposure and does not reflect actual risks which may, in fact, be higher among young PWID, which our analysis approach and large sample size may have been able to distinguish more clearly [35]. Indeed, multiple studies have reported greater HIV risk behaviors and/or HCV incidence among young PWID [36]. Due to the difficulty of adjusting both for injection duration and age, given the strong correlation between these variables, this result can only be observed in a very large sample such as that in the present study, although it also suggests that caution is warranted and further confirmation is needed.

Among structural factors (aggregate-level variables), our only statistically significant finding was the association of HIV positivity with the Gini index, a measure of the level of socio-economic inequality in the general population. The Gini index has been found to be predictive of HIV outbreaks among PWID or substance misuse [37], and a higher Gini index is associated with a higher HIV prevalence among PWID [38].

Importantly, our finding of an association between a history of incarceration and HIV infection, after accounting for other known risk factors, may confirm the concept of incarceration as a high-risk environment in addition to known risk factors. For example, this could be due to a high prevalence of HIV among other people who are in prison or among other PWID in the period after release [6, 11] or limited access to effective HIV risk reduction interventions (OMT, behavioral interventions).

Our study has several limitations. We used data from cross-sectional studies in which the temporality between the exposure (a history of incarceration) and outcome (HIV status) or other potential risk factors (e.g. injection risk markers) could not be established. A history of incarceration could just be a marker for a period in life of extremely high risk (a confounder); i.e. in the absence of a causal relationship, those who injected more frequently in the past may also simply be more likely to have been ever incarcerated. With the available data, we were unable to disentangle the prison environment and the immediate period after release as related risk factors. Additionally, the data were derived from multiple studies with differences in the definitions of the behavioral measures (e.g. recall periods, wording of questions). However, the resulting errors would probably be non-differential for the PWID groups compared within sites and would therefore probably lead to underestimating their effects on our outcome variable. We could not exclude the possibility of a survival effect. Because incarceration is a risk factor for both mortality (protective inside prison, but increased after release) and HIV infection, we probably lacked data on some high-risk HIV-positive individuals who had been incarcerated and died after release, which might also lead to a (slight) underestimation of the association of interest. Approximately 2% of our total sample (Portugal 2009–10, Czech Republic 2002–03) was based upon self-reported HIV status. This is a small proportion in our total data set, and given that these sites had a stable HIV prevalence and high availability of harm reduction services, it seems likely that self-reported HIV status is an acceptable indicator of HIV infection in those sites [39]. The choice of variables used in the construction of the propensity-scores was limited to those measured in source studies. Our propensity-score analysis included the variables most likely to be confounders in the relationship between incarceration and HIV. However, not having data on homelessness, ethnicity or education might have caused residual confounding. A history of incarceration as the exposure variable was measured as a binary variable that should have captured both brief jail stays after arrest and longer periods of imprisonment. It may not be possible to generalize our results to all PWID in Europe, given the limits of the venue-based ('convenience') and/or social network-based sampling used in the studies. Finally, there is a diversity of drug policy laws in the included countries which, for example, included Russia, which has a highly punitive approach and where the provision of opioid maintenance programs is prohibited, and Portugal, where drug possession is decriminalized and where extensive harm reduction programs are in place.

The majority of PWID in this analysis were exposed to the high-risk environments of prison and the period following release [6], highlighting ample opportunities for alternatives to incarceration. Alternative responses include various decriminalization, diversion and depenalization schemes [40], primarily by diverting people with non-violent offences to alternatives for incarceration (in combination with treatment and harm reduction services in prison and after release or 'throughcare'). Importantly, apart from contributing to HIV transmission among PWID, incarceration is an expensive intervention [41]. Prisons are an extremely expensive location for treating substance use and other health problems. Negative health, economic and social wellbeing effects of incarceration and other health-related harms associated with prison, including tuberculosis, mental health and costs to families, coupled with the high public cost of current levels of incarceration, strengthen the argument for the decarceration of drug policies. A recent modeling study suggested that cost savings from the decriminalization of drug use could greatly reduce HIV transmission through increased coverage of opioid agonist therapy and ART in the context of the HIV epidemic driven by injection drug use (eastern Europe and central Asia) [42].

In conclusion, among community-recruited PWID in Europe, a history of incarceration was strongly and independently associated with HIV positivity, with a stronger association observed among PWID with a lower likelihood of having a history of incarceration. Given the high incarceration rates among PWID, drug policies that reduce incarceration rates of PWID and its associated risks and which provide health and social services, both in prison and upon release ('throughcare'), would probably have considerable public health impacts.

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DECLARATION OF INTERESTS

None to declare.

DATA AVAILABILITY STATEMENT

There are legal restrictions on sharing a de-identified data. The authors cannot publicly releasethe data received from the European Study Group for Mathematical Modelling and Epidemiological Analysis of Drug-Related Infectious Diseases. The data can be requested from-Lucas Wiessing (Lucas.Wiessing@emcdda.europa.eu).

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SUPPORTING INFORMATION

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

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