



Marsden, J., Stillwell, G., Jones, H. E., Cooper, A., Eastwood, B., Farrell, M., Lowden, T., Maddalena, N., Metcalfe, C., Shaw, J., & Hickman, M. (2017). Does exposure to opioid substitution treatment in prison reduce the risk of death after release? A national prospective observational study in England. *Addiction*, 112(8), 1408-1418.  
<https://doi.org/10.1111/add.13779>

Peer reviewed version

License (if available):  
CC BY-NC

Link to published version (if available):  
[10.1111/add.13779](https://doi.org/10.1111/add.13779)

[Link to publication record in Explore Bristol Research](#)  
PDF-document

This is the author accepted manuscript (AAM). The final published version (version of record) is available online via Wiley at <http://onlinelibrary.wiley.com/doi/10.1111/add.13779/abstract>. Please refer to any applicable terms of use of the publisher.

## University of Bristol - Explore Bristol Research

### General rights

This document is made available in accordance with publisher policies. Please cite only the published version using the reference above. Full terms of use are available:  
<http://www.bristol.ac.uk/red/research-policy/pure/user-guides/ebr-terms/>

# Does exposure to opioid substitution treatment in prison reduce the risk of death after release? A national prospective observational study in England

John Marsden<sup>1\*</sup>, Garry Stillwell<sup>1</sup>, Hayley Jones<sup>2</sup>, Alisha Cooper<sup>3</sup>,  
Brian Eastwood<sup>3</sup>, Michael Farrell<sup>4</sup>, Tim Lowden<sup>3</sup>, Nino Maddalena<sup>3</sup>,  
Chris Metcalfe<sup>2</sup>, Jenny Shaw<sup>5</sup>, Matthew Hickman<sup>2</sup>

<sup>1</sup> Addictions Department, Institute of Psychiatry, Psychology and Neuroscience, King's College London, SE5 8AF, United Kingdom;

<sup>2</sup> School of Social and Community Medicine, Faculty of Health Sciences, University of Bristol, BS8 2PS, United Kingdom;

<sup>3</sup> Alcohol, Drug and Tobacco Division, Health and Wellbeing Directorate, Public Health England, 2nd Floor, Skipton House, 80 London Road, London SE1 6LH, United Kingdom;

<sup>4</sup> National Drug and Alcohol Research Centre, University of New South Wales, NSW 2052, Australia;

<sup>5</sup> Institute of Brain, Behaviour and Mental Health, University of Manchester, M13 9PL, United Kingdom.

Abstract: 3971 words

Main text: 4,939 words

Tables in main text: 3

Tables for on-line material: 1

Figures for main text: 3

Figures for on-line material: 1

Total number of pages in manuscript: 30

Suggested running head: Prison-based OST and mortality after release

Keywords: heroin; prison; opioid substitution treatment; all-cause mortality; drug-related poisoning mortality

---

\* Corresponding author:

John Marsden, Professor of Addiction Psychology, Addictions Department, Box 48, Institute of Psychiatry, Psychology and Neuroscience, King's College London, DeCrespigny Park, Denmark Hill, London SE5 8AF, United Kingdom.

*e-mail address:* john.marsden@kcl.ac.uk

**ABSTRACT**

**BACKGROUND AND AIMS:** People with opioid use disorder (OUD) in prison face an acute risk of death after release. We estimated whether prison-based opioid substitution treatment (OST) reduces this risk.

**DESIGN:** Prospective observational cohort study using prison healthcare, national community drug misuse treatment and deaths registers.

**SETTING:** Recruitment at 39 adult prisons in England (32 male; 7 female) accounting for 95% of OST treatment in England during study planning.

**PARTICIPANTS:** Adult prisoners diagnosed with OUD (recruited: September 2010 to August 2013; first release: September 2010; last release: October 2014; follow-up to February 2016; n=15,141 in the risk set).

**INTERVENTION AND COMPARATOR:** At release, participants were classified as OST exposed (n=8,645) or OST unexposed (n=6,496). The OST unexposed group did not receive OST, or had been withdrawn, or had a low dose.

**MEASUREMENTS:** Primary outcome: all-cause mortality (ACM) in the first 4 weeks. Secondary outcomes: drug-related poisoning (DRP) deaths in the first 4 weeks; ACM and DRP mortality after 4 weeks to 1 year; admission to community drug misuse treatment in the first 4 weeks. Unadjusted and adjusted cox regression models (covariates: sex, age, drug injecting, problem alcohol use, use of benzodiazepines, cocaine, prison transfer and admission to community treatment), tested difference in mortality rates and community treatment uptake.

**FINDINGS:** In the first 4 weeks after prison release, there were 24 ACM deaths: 6 in the OST exposed group and 18 in the OST unexposed group (mortality rate 0.93 per 100 person years [PY] versus 3.67 per 100 PY; Hazard Ratio [HR] 0.25; 95% Confidence interval [CI] 0.10 to 0.64). There were 18 DRP deaths: OST exposed group mortality rate 0.47 per 100 PY versus 3.06 per 100 PY in the OST unexposed group (HR 0.15; 95% CI 0.04 to 0.53). There was no group difference in mortality risk after the first month. The OST exposed group was more likely to enter drug misuse treatment in the first month post-release (odds ratio 2.47, 95% CI 2.31 to 2.65). The OST mortality protective effect on ACM and DRP mortality risk was not attenuated by demographic, overdose risk factors, prison transfer or community treatment (fully adjusted HR 0.25; 95% CI 0.09 to 0.64 and HR 0.15; 95% CI 0.04 to 0.52, respectively).

**CONCLUSIONS:** In an English national study, prison-based opioid substitution treatment was associated with a 75% reduction in all-cause mortality and an 85% reduction in fatal drug-related poisoning in the first month after release.

## INTRODUCTION

Non-medical opioid use contributes significantly to the global burden of disease [1]. Illicit heroin is associated with a high risk of death (particularly among people who inject drugs [2]), and this increases with age and in men [3]. The leading cause of death in this population is accidental drug poisoning (overdose) associated with acute respiratory depression, hypoventilation and hypoxia [4]. Opioid overdose is a major public health problem in many countries. The United States (USA) saw a four-fold increase in opioid poisoning deaths between 1999 and 2009 [5]. In England and Wales, the highest ever mortality rate from drug poisonings was recorded in 2015: 43.8 cases per million population [6].

There is a very high prevalence of substance misuse in the prison population (globally: 10 to 48% for men and 30 to 60% for women [7]). Of concern is that prisoners with OUD face an acute risk of death on their release to the community. This is particularly high during the first month [8,9] and there is evidence that an elevated risk is seen across the first year [10].

There are likely to be several causes. The most likely physiological mechanism is that the reduction, or complete reversal, of opioid tolerance during incarceration means that ex-prisoners are acutely vulnerable to fatal overdose if a pre-incarceration dose is consumed at liberty.

Research has identified behavioural factors that also contribute: injecting an opioid acutely increases drug bioavailability and respiratory effects, and concurrent alcohol and benzodiazepine use can exacerbate suppression of the respiratory drive [11,12]; although concurrent cocaine use (common among illicit heroin users in the UK, USA and several other countries) can briefly antagonise respiratory suppression, this stimulant can induce life-threatening cardiovascular arrhythmias. Taken together, fatal drug-related poisoning (DRP) in this population can have a relatively straightforward or a more complex cause [13].

Oral methadone and buprenorphine are the first-line, opioid agonist therapies for opioid use disorder (OUD; DSM-5 [14]; or the conceptually identical 'opioid dependence' diagnosis in ICD-10 [15]). These opioid substitution treatment (OST) medications are associated with cessation or lower drug use and injecting [16]; a lower risk of acquiring blood borne viral infections [17], and reduced mortality in the community setting [18,19]. Most national healthcare systems offer OST for

OUD. In the England, illicit heroin is the main drug used by the OUD population, and OST (with adjunctive psychosocial interventions) is accessible in all local treatment systems [20].

Between 2006 and 2010, an Integrated Drug Treatment System (IDTS) was introduced to provide OST in English prisons and to guide referral of prisoners to community drug misuse treatment services after their release [21]. OST in the IDTS involves oral methadone or buprenorphine for maintenance and (as indicated) withdrawal. Treatment is offered on a voluntarily basis according to a clinical assessment and the patient's preference. OST is provided as continued maintenance from the community (or another prison), or as a new episode beginning at entry, or during incarceration. Prisoners receive an initial clinical screening by a member of the healthcare team and OUD diagnosis is confirmed by a doctor. The patient is then inducted onto OST as indicated.

With prison-based drug misuse treatment interventions intended to mirror and link to the provision of treatment in the community, case descriptive information on all treatment episodes is now captured by the English National Drug Treatment Monitoring System (NDTMS). NDTMS includes almost all publicly funded service providers and provides outcome and performance monitoring for each local treatment system [22].

Does prison-based OST exposure reduce post-release mortality? In 2012, a systematic review of 6 experimental and 15 observational studies concluded that there was limited evidence [23]. This was because studies either lacked a means of identifying prisoners with OUD and who had had OST, or were unable to record overdose risk factors and subsequent treatment to isolate a treatment effect. English prison healthcare records and the NDTMS capture all this information enabling a robust observational, cohort design with statistical control of confounders. An experimental design (i.e. patients assigned to OST maintenance or withdrawal before prison release) was rejected because medication is received voluntarily in the IDTS and we considered it unethical to enforce withdrawal.

Accordingly, in this large-scale national study our aims were:

(1) to estimate whether prison-based OST exposure at release reduces post-release mortality;

- (2) to estimate and compare the likelihood of admission to community drug-misuse treatment by OST exposure; and
- (3) to estimate whether a protective effect of prison-based OST at release is confounded by relevant covariates and admission to community treatment.

## **METHODS**

### **Design, prison sample, target population and exposure**

This was an English national prospective observational cohort study of prison-based OST exposure, reported following the STROBE guideline [24].

In 2009, routine OST prescribing data compiled by the National Treatment Agency for Substance Misuse was used to identify the population of prisons providing OST. 45 prisons provided OST in that year. However, 2 had very small caseloads (i.e. <4 new episodes of treatment initiated per quarter) so we decided to exclude these. 43 prisons were approached to take part in the study (35 male prisons and 8 female prisons).

The target population was adult prisoners ( $\geq 18$  years) with a diagnosis of OUD recorded on an electronic database at the prison. Allocation of the patient to methadone or buprenorphine is guided by clinical assessment and patient preference in the IDTS. Patient preference is usually informed by personal experience or beliefs about these medications; clinical history of response and drug-drug interaction issues with other medication may also point to one medication over the other.

During planning, we were aware that some patients were released from prison with a low-dose prescription for methadone or buprenorphine. Efficacy trials of OST have included participants receiving 20 to 120 mg/day (methadone) and 2 to 16 mg/day (buprenorphine) [25]. Accordingly, we set  $>20$  mg for methadone and  $>2$  mg for buprenorphine as the dose threshold for classifying OST exposure for all prisoners at release.

Prisoners who met the threshold (i.e. their last dose administered on the morning of release was  $>20$ mg methadone or  $>2$ mg buprenorphine) were classified as *OST exposed*. Prisoners with OUD

who had not received OST in prison, or had completed a medication withdrawal regimen while in prison, or had been prescribed less than the dose threshold on the day of release were classified as *OST unexposed*.

Given the fluctuating nature of the English prison population – with people entering, some transferred to another prison, leaving, and some re-incarcerated – we expected a proportion of the study cohort to enter the risk set more than once during recruitment (see statistical analysis).

### **Outcome measures**

We selected all-cause mortality (ACM) in the first 4 weeks following release (i.e. day 1 to 28), expressed as risk per 100 person years (PY), as the appropriate primary outcome measure. The null hypothesis was that there would be no difference in the ACM risk between the OST exposed and OST unexposed groups.

Secondary outcome measures (also tested as null hypotheses) were as follows:

- (1) DRP mortality in the first 4 weeks following release (expressed as risk per 100 PY);
- (2) ACM and DRP mortality after 4 weeks to 1 year (expressed as risk per 100 PY); and

admission to community drug misuse treatment in the first 4 weeks following release. DRP deaths were classified by the Office for National Statistics' definition [26] using the following codes from ICD-10 and referencing the coroner's inquest report and death certificate:

- 'Mental and behavioural disorders due to drug use' (ICD-10 codes: F11-F16, F18, F19);
- 'Accidental poisoning by drugs, medicaments and biological substances' (X40-X44);
- 'Intentional self-poisoning by drugs, medicaments and biological substances' (X60-X64);
- 'Assault by drugs, medicaments and biological substances' (X85); and
- 'Poisoning by drugs, medicaments and biological substances, undetermined intent' (Y10-Y14).

### **Sample size calculation**

For the first 4 weeks, pooled risk estimates from two previous studies [8,27] suggested that there would be 3.4 deaths per 100 PY compared to 0.7 per 100 PY for adults with OUD in the

community. We estimated that a sample of 20,000 (50% OST exposed) would give at least 90% power to detect a five-fold or greater reduction in the mortality rate associated with prison-based OST exposure.

## **Procedure**

We secured National Health Service research ethical approval for a recruitment procedure in which prison healthcare staff would identify and approach eligible prisoners and obtain their informed, signed consent<sup>1</sup>. Of the 43 prisons approached to participate in recruitment, four prisons (3 male and 1 female) were unable to take part because of the anticipated administrative burden or healthcare staff shortages.

We provided on-site training on the study protocol for the remaining 39 prisons (32 for men and 7 for women). As a check on representativeness, we noted that these institutions accounted for 95% of OST treatment in England during the study planning phase. As part of efforts to ensure that people would not feel obligated to take part, we stressed to the healthcare teams that prisoner participation was voluntary.

Cohort recruitment started in September 2010. By April 2011 it was evident that we were not achieving the required level of recruitment. With the study steering committee's agreement, we proposed to retain data to this point and then adopt a non-explicit consent procedure. This would involve display of posters at multiple points throughout each prison presenting study information and stating that eligible prisoners receiving OST would be included unless they requested to opt out. We provided in-prison training with healthcare staff on this procedure so that they would alert each prisoner who met the inclusion criteria to the poster and answer questions, and also discuss the study with those needing help with written English.

This change was approved by the National Information Governance Board in August 2011<sup>2</sup>, by the original ethics committee in November 2011, and by all local research governance offices in June 2012. Recruitment recommenced under these arrangements in June 2012 and was completed in August 2013.

---

<sup>1</sup> Essex NHS Research Ethics Committee (reference: 10/H0302/7; February 2010).

<sup>2</sup> Reference: ECC 5-04[d]/2011.

## Data sources

Information was collected from 5 centralised and local data sources, as follows:

- Prison National Offender Management Information Service (P-NOMIS): prison where recruited; name, sex, date of birth (age grouped for analysis as follows: <30; 30 to 34; 35 to 39;  $\geq 40$  years);
- Prison IDTS healthcare provider: OST medication; dose at release; date of last dose if withdrawal regimen provided;
- Justice Statistics Analytical Services (JSAS database): name of releasing prison and date;
- Office for National Statistics, national deaths register, accessed from the Health and Social Care Information Centre (HSCIC): date of death and specified ICD-10 codes<sup>3</sup>;
- English National Drug Treatment Monitoring System (NDTMS): route of drug administration (injecting/other route); prisoner self-report of problem alcohol use; non-medical benzodiazepine use; cocaine use (all for past month before incarceration); date of admission to community drug misuse treatment (all types of structured interventions including OST) within 4 weeks following release<sup>4</sup>.

## Participant recruitment

During the recruitment period (September 2010 to August 2013) each person was assigned a study identification number. As noted above, participants could be recruited multiple times (i.e. on each occasion of incarceration during the recruitment period). The risk set was identified in 3 stages, as follows:

### Stage 1

Prison healthcare services identified an initial sample of 22,623 prisoners. Of these, 567 were removed because they were administrative duplicates on P-NOMIS, and 56 people opted out and withdrew their consent.

---

<sup>3</sup> There are extensive checks on accuracy for HSCIC but it is possible in all studies of this kind in England that in a small number of deaths, the person died abroad and there was a failure of registration.

<sup>4</sup> The search for community treatment in NDTMS used a probabilistic case matching protocol [28].

Among the remaining 22,000 prisoners, 9,093 (41.3%) were convicted and sentenced, 7,956 (36.2%) were on remand awaiting trial and 1,612 (7.3%) were incarcerated for another reason (e.g. failure to meet conditions of probation). Sentence type information was not recorded for the remaining 3,339 prisoners (15.2%). In total, we recruited 3,769 participants (17.1%) by individual consent and 18,231 by the 'opt-out' procedure (82.9%).

## **Stage 2**

From the JSAS database 1,368 of 22,000 people recruited were removed because they did not leave prison, and a further 2,186 were removed because a prison release date could not be verified. At completion of this stage, 18,446 prisoners were successfully matched to a release date.

The number of prisoners recruited from the 39 recruiting prisons ranged from 41 to 1,704, and the number of prisoners released from prisons ranged from 40 to 1,366. An additional 84 prisons (79 male and 5 female prisons) released 3,184 prisoners (17.2%) due to transfer across the system.

## **Stage 3**

Of the 18,446 releases identified in Stage 2, HSCIC could flag 96% for monitoring on the deaths register (a loss of 770 people). After gathering all available OST information from IDTS healthcare records, we removed a further 2,527 releases because there was no medication information recorded, or because the healthcare provider was unable to undertake a manual search. 8 people were also removed because they had died in prison.

At completion of this procedure, the risk set comprised 15,141 releases (relating to 12,260 people). The first release was in September 2010 and the last was in October 2014. We were notified of deaths by the HSISC until February 2016.

## **Statistical analysis**

All analyses were done in Stata v14. The data contained one or more exposure and risk periods for each person. Risk periods were censored at the earliest date of re-entry into the study, or one year after release date. Kaplan Meier 1-year survival curves were plotted.

We fitted a Cox proportional hazards model, stratified by post-release period, to estimate hazard ratios ([HR], with associated 95% confidence intervals [CI]) for the ACM and DRP deaths during day 1 to 28, and months 2 to 4 (days 29 to 121), and months 5 to 12 (days 122 to 365). The assumption of proportional hazards within each of these periods was evaluated by plotting Nelson-Aalen cumulative hazard estimates and testing for a linear relationship between scaled Schoenfeld residuals and logged time within each period [29]. Random effects (shared frailty) terms were included to adjust for potential clustering by prison of release.

In addition to the unadjusted (crude) HRs, the following covariates (overdose risk factors) were included in a multivariable Cox regression for the 4-week mortality outcomes: sex; age group; drug injecting; problem alcohol use; non-medical benzodiazepine use; and cocaine use. We adjusted for the potential confounding factor of prison transfer (i.e. people released from a different prison to the one at entry), hypothesising that transfer could be associated with a reduced likelihood of OST exposure at release.

Admission to community drug misuse treatment in the first 4 weeks was also incorporated as a time-varying covariate to test whether any effect of OST exposure at release could be accounted for by subsequent treatment. If no NDTMS record for community treatment could be found, the released prisoner was assumed not to have been admitted. The Likelihood Ratio Test (LRT) was used to test for evidence of mediation for community treatment and OST exposure on mortality risk. To assess further whether community treatment might be a mediator in any association between OST exposure and 4-week mortality, we fitted an additional Cox Proportional Hazards model with time to community treatment as the outcome variable (and OST at prison release as the exposure). For this analysis, risk periods were censored at the earliest point during the first 4-weeks post-release, at re-entry into the study population, or death.

So that all releases could contribute to the analysis, we multiply imputed missing covariate values using chained equations, assuming the missing values to be missing-at-random. Model estimates were based on 50 sets of imputed values and included the outcome measure, admission to community treatment, the estimated cumulative hazard for mortality and community treatment, and all other covariates [30,31].

There were three sensitivity checks: Firstly, the analysis was repeated using only those releases with complete covariate information (a 'complete case' analysis). Second, we checked that the multiple prison releases of some people did not lead to spuriously precise results. Here, the 'conditional gap time method' was used to stratify the baseline hazard by order of appearance in the study [31]. Finally, we compared the mortality risk from the time of entry to the study to 1-year, for releases that were linked to the deaths register but had missing information on prison release or OST exposure.

## RESULTS

Among the 12,260 people in the risk set, 82.1% entered the study once. The remainder entered the study between 2 and 7 times by re-incarceration (n=2,194)<sup>5</sup>. The median time from recruitment to release was 60 days (inter-quartile range [IQR] 28 to 156 days).

### Intervention exposure and participant characteristics

We classified 8,645 releases (57.1%) as *OST exposed*. Of these, 7,614 (88.1%) received methadone (median daily dose on the day of release was 40 mg [IQR 30 to 50 mg]) and 1,031 (11.9%) received buprenorphine (median dose 8 mg [IQR 8 to 12 mg]). A minority of the OST exposure group was released from a different prison to the prison of recruitment (n=942; 10.9%).

The remaining 6,496 releases (42.9%) were classified as *OST unexposed*. These included 2,369 people (36.5%) prescribed lower daily dose medication; 2,110 (32.5%) who had been withdrawn from OST in prison; and 2,017 (31.0%) diagnosed with current OUD but with no record of OST.

**Table 1** shows the characteristics of the study participants in the intervention and comparator groups. The proportion of women was greater in the OST exposed group (24.1% versus 19.3%) due to proportionately more women's prisons agreeing to participate in the study and relatively higher individual participation rates within these institutions. The OST exposed group had a higher proportion of people who injected drugs, used non-medical benzodiazepines and cocaine, and a lower proportion of problem drinkers.

---

<sup>5</sup> Over half of the re-incarcerated offenders were sentenced, with the remainder remanded or in prison for another reason (e.g. breaking probation conditions).

## Post-prison release mortality

Within the first year of release, there were 160 deaths, of which 102 (63.8%) were DRP (mortality rate: 1.22 and 0.78 per 100 PY, respectively). The other 58 deaths were recorded as: suicide and other injury (n=22); liver disease due to viral hepatitis or alcohol (n=13); drug injection-related infection (n=5); respiratory disease (n=8); cardio-vascular disease (n=7); and other non-communicable disease (n=3).

Person follow-up time, mortality rates and number of deaths were as follows:

- 1 to 28 days (1,133 PY): ACM 2.12 per 100 PY (24 deaths); DRP 1.58 per 100 PY (18 deaths);
- 29 to 121 days (3,521 PY); ACM 1.14 per 100 PY (40 deaths); DRP 0.68 per 100 PY (24 deaths); and,
- 122 to 365 days (8,478 PY); ACM 1.13 per 100 PY (96 deaths); DRP 0.71 per 100 PY (60 deaths).

The survival curve for the OST exposed and unexposed groups for ACM and DRP mortality is displayed in **Figures 1** and **2**, respectively.

## Association between OST exposure and mortality

Among the 24 ACM cases within 4 weeks of prison release, 6 were members of the OST exposed group and 18 were members of the OST unexposed group (mortality rate 0.93 per 100 PY versus 3.67 per 100 PY; HR 0.25 [95% CI 0.10 to 0.64]).

In the first 4 weeks, there were 18 DRP deaths. Three were members of the OST exposed group and 15 were members of the OST unexposed group (mortality rate 0.47 per 100 PY versus 3.06 per 100 PY; HR 0.15; 95% CI 0.04 to 0.53).

After the first 4 weeks, the mortality difference narrowed between the two groups (**Figure S1**).

There was no evidence of between-group difference in risk of ACM or DRP mortality during the second to fourth month (29 to 121 days) and from the fifth month to 1 year (122 to 365 days; **Table**

2). There was no evidence against the proportional hazards assumption within any of these three periods (minimum P value 0.17) and no evidence of clustering of mortality by prison of release.

### **Multivariable model of OST exposure on mortality**

**Table 3** shows the unadjusted and adjusted analysis of OST exposure and mortality outcomes in the first 4 weeks. For ACM, the protective effect of OST exposure was not attenuated following adjustment for age and risk factors (adjusted HR 0.24; 95% CI 0.09 to 0.61), or by adjustment for community treatment (HR 0.28; 95% CI 0.11 to 0.71). The fully adjusted HR for all covariates, including prison transfer was 0.26 (95% CI 0.09 to 0.64). The protective effect of OST exposure on DRP mortality was similarly not attenuated (fully adjusted HR 0.15; 95% CI 0.04 to 0.52). There was also no evidence of mediation between community treatment and OST exposure on ACM (ratio of HR 0.97; 95% CI 0.12 to 7.97; LRT P value 0.98) or DRP mortality (ratio of HR 1.26; 95% CI 0.07 to 21.29; LRT P value 0.86).

### **Community drug misuse treatment**

6,140 releases (40.6%) were admitted to drug misuse treatment within the first 4 weeks. The OST exposed group was more likely to enter treatment than the unexposed group (odds ratio 2.47, 95% CI 2.31-2.65). Following adjustment for clustering by prison (P value for clustering <0.001), the HR for being admitted to treatment was 2.13 (95% CI 2.01 to 2.25; with no evidence for non-proportional hazards [P value 0.50]; **Figure 3**). There was no statistical association between community drug misuse treatment and the risk of ACM or DRP mortality (HR 0.51; 95% CI 0.19 to 1.39 and HR 0.39; 95% CI 0.11 to 1.36, respectively), and no evidence of non-proportional hazards (P value 0.18 and 0.34, respectively).

### **Sensitivity analyses**

With complete covariate information available on 86.9% of releases (missing observations for behavioural covariates: 10% to 16%), the 'complete case' analysis also showed a protective effect of OST exposure on mortality risk (**Table S1**).

In the check on multiple prison releases, we confirmed that multiple appearances of some study participants did not lead to spuriously precise estimates. With baseline hazard stratified by the participant's release number, the HR for the association between OST exposure and 4 week ACM was 0.27 (95% CI 0.11 to 0.69).

There were 2,082 releases linked to the deaths register with missing prison release information, and 2,526 with missing OST exposure information. Excluding those not released, the mortality rate for the former group was 0.93 per 100 PY compared to 0.92 per 100 PY among those with no missing prison release information (Incidence Rate Ratio [IRR] 1.01; 95% CI 0.43 to 2.05). For the latter group the mortality rate was 1.57 per 100 PY compared to 1.23 per 100 PY among those with no missing OST exposure information (IRR 1.27; 95% CI 0.86 to 1.84).

## **DISCUSSION**

In this national study, OST exposure with oral methadone or buprenorphine removed the four-fold excess risk of death in the first 4 weeks after release for prisoners with OUD. OST was associated with a 75% reduction in ACM and an 85% reduction in DRP mortality. The protective effect of OST was not observed after the first month. Those in the OST exposed group were more than twice as likely to be admitted to community-based drug misuse treatment in the first month.

Strengths of our study include: the large sample of prisoners with OUD; the use of administrative databases for recording OST exposure; outcome estimates subject to confounder control; and clinically important findings which apply to both the prison and community drug misuse treatment systems in England and elsewhere.

We also acknowledge several study limitations: firstly, we were unable to report on the numbers of eligible prisoners who were approached and declined to take part the overall proportion of prisoners enrolled in OST across the 39 prisons. However, we believe it was unlikely that the revised procedure in our prospective design introduced a selection bias in relation to OST exposure and future mortality risk, and we received very few requests to opt out.

Second, some cases had to be removed because of duplication of records and matching failures, and some prisons were unable to give information on OST medication. Missing OST exposure and prison release data will have reduced statistical power, and we did not have sufficient samples to compare outcomes for men and women. However, we do not believe case attrition was likely to have introduced bias to the estimate of mortality risk. The protective effect of OST was not sensitive to imputation of missing confounders, and we showed that there were no differences in mortality risk for prisoners with or without missing data on prison release or OST exposure.

Third, OST exposure was not randomised. However, we show that differences in OST exposure for people who inject drugs, those using other drugs, and for those transferred between prisons did not alter the strength or direction of our findings. Our analyses tested and examined the impact of behavioural confounders and community treatment and found a mutually beneficial association with no evidence of any interaction or mediation. Furthermore, we believe a selection bias was highly unlikely as the outcome had not occurred by the time exposure had been determined.

### **Results in context**

The present findings align with a recent study of prison-based OST in New South Wales [33]. In this Australian study, the 4-week mortality rate after release comparing OST exposure and entry to community treatment versus no prison or community treatment was 0.64 and 3.67 per 100 PY, respectively. This is a slightly stronger protective effect than we observed, but this may be due to the exposure in the Australian study being continuous OST from prison to community in the first month, and for a greater potential for immortal time bias in this retrospective cohort design [34].

A recent study conducted in Scotland reported an overall reduction in mortality risk after introduction of prison-based OST (from 3.8 to 2.2 per 1,000 releases) but observed no protective effect for OST in the immediate period following release [35]. The researchers were unable to identify the OUD population in the prisons studied, nor adjust for risk factors, but they concluded that: "in-prison OST does not reduce early deaths after release" (page 1,617). Our adjusted models provide strong evidence against this conclusion for England.

### **Meaning of the study and its implications**

Physiological tolerance to opioids is the most likely mechanism of protective effect for people who leave prison enrolled in OST with relapse vulnerability. If heroin is used there is a reduced likelihood of acute respiratory depression. OST will also prevent the onset of opioid withdrawal symptoms which may motivate illicit drug use.

But how can the absence of protective effect after the first month following release be explained? We suspect that several factors are involved: some patients enrolled in community treatment will resume use of heroin, progressively returning to pre-prison levels; others will drop out of community treatment and relapse; and some people who are not enrolled in OST at release will present for community OST. Further studies are needed to explore these sub-populations and their trajectories and association with mortality outcome.

Given an increasing global prison population, effective initiatives are needed to improve prisoners' health and reduce the burden of infectious and chronic disease and other causes of premature mortality. Prison-based OST is scarce in the USA and there is little or no provision in many other countries. In this context, we frame our findings in the clinical management of OUD and prevention of overdose. Firstly, the importance of continuity of OST from the community to the prison system is supported unequivocally by our findings. OST in prison enables prisoners to engage with recovery services and there are also important public health benefits. For example, a low incidence of Hepatitis C virus has been reported in Scottish prisons with OST provision [36]. OST withdrawal regimens should not be overlooked, but we contend that withdrawing a patient in prison should be done with a careful appraisal of post-release support and with full discussion of the risks.

Second, for prevention of fatal opioid overdose, a specific *ex-post* strategy is the supply of the short-acting opioid antagonist naloxone to prisoners at release for acute administration in the community. This strategy has not been implemented in English prisons to date. Encouragingly, the first two years of the national naloxone programme in Scotland were associated with a 36% reduction in the proportion of opioid-related deaths that occurred in the first month after release [37].

Third, for those with OUD who are abstinent from all opioids and have been appropriately informed and consented, there is also an opportunity to use the long-acting opioid antagonist, naltrexone, as

an *ex-ante* relapse prevention therapy. A 50 mg tablet of naltrexone blocks the effects of opioids for approximately 24 hours; an extended-release, intramuscular injection is also available. This treatment has not been systematically implemented in English prisons and is not viable for everyone (e.g. contraindication in liver disease and for some with chronic non-malignant pain). However, the feasibility of extended-release naltrexone has recently been demonstrated in two open-label trials in the USA (one study using an injection before prison release; the other using monthly injections in the community) [38,39].

## **Conclusion**

Opioid overdose is a major public health problem in many countries. People with OUD who reduce or stop using non-medical opioids while incarcerated face an acute risk of death on release if they use these drugs again. Our study shows that prison-based OST (with oral methadone or oral buprenorphine) is a highly effective means of reducing the risk of death among prisoners in the first 4 weeks after release. The clinical decision to withdraw prisoners from OST should be made with care and with further support.

## **DECLARATION OF COMPETING INTERESTS**

JM is supported by research grants from the Department of Health, Institute for Health Research (NIHR), Medical Research Council (Drugs Data Warehouse project with MH, Tim Millar, Graham Dun, Sheila Bird and Matthias Pierce) and the NIHR Biomedical Research Centre for Mental Health at South London and Maudsley NHS Mental Health Foundation Trust (SLaM MHFT). He has part-time employment as Senior Academic Advisor for the Alcohol, Drugs and Tobacco Division, Health and Wellbeing Directorate, Public Health England. He declares grant funding at IoPPN and SLaM MHFT for a study of psychological interventions in OST (2010-2016; Indivior PLC via Action on Addiction), support from NIHR (HTA) for a trial of extended-release naltrexone, and honoraria from Merck Serono (2013, 2015; clinical oncology medicine) and Indivior (via PCM Scientific) as speaker (2013), co-chair (2015-2016) and chair (2017) for the Improving Outcomes in Treatment of Opioid Dependence conference.

MH acknowledges support from NIHR Health Protection Research Unit in Evaluation of Interventions, the NIHR School of Public Health Research, and the Medical Research Council (Drugs Data Warehouse project with JM, Tim Millar, Graham Dun, Sheila Bird and Matthias Pierce). He has received unrestricted research grants and travel support from Gilead, Jansen and Merck Serono.

HJ acknowledges support from the Medical Research Council (MR/M014533/1).

No other disclosures by the other authors are reported.

## **DETAILS OF CONTRIBUTIONS**

Study concept and design: MF, MH and JM (the guarantors for the study). Acquisition, analysis and interpretation of data involved all authors and HJ and CM did the analysis with input from MH and JM. JM and MH drafted the manuscript and its revision with support from HJ and GS. All authors critically revised the manuscript for intellectual content. Administrative and technical help was provided by GS, AC, BE, TL and NM.

## **ROLE OF THE FUNDER**

The study was commissioned by NHS England (NHSE). The funder had no role in study design, data collection, the analysis and interpretation, or the writing of this report. The contents of this report do not necessarily reflect the views or stated position of NHSE, the Department of Health, Ministry of Justice, or Public Health England.

## **TRANSPARENCY DECLARATION**

JM affirms that the manuscript is an honest, accurate, and transparent account of the IDTS evaluation. HJ and CM had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

## **ACKNOWLEDGMENTS**

The authors wish to thank the IDTS healthcare staff, the JSAS team, and to the following for support: Mary Piper (Department of Health; Chair, steering committee); Sam Story (University of Bristol); Sarah Davidson (University of Manchester); Peter Boggiano (HSCIC); David Marteau, John McCracken (Department of Health); Christine Kelly, Glenda Webb (NHSE); Nick Manton (Home Office); Michael Spurr, Simon Marshall (National Offender Management); Kate Burns (Ministry of Justice); Cathy Cooke (Secure Environment Pharmacists Group); David Sheehan, Kieran Lynch, Craig Wright (Alcohol, Drugs and Tobacco Division, Public Health England). We gratefully acknowledge comments from the journal's independent reviewers on the submitted manuscript.

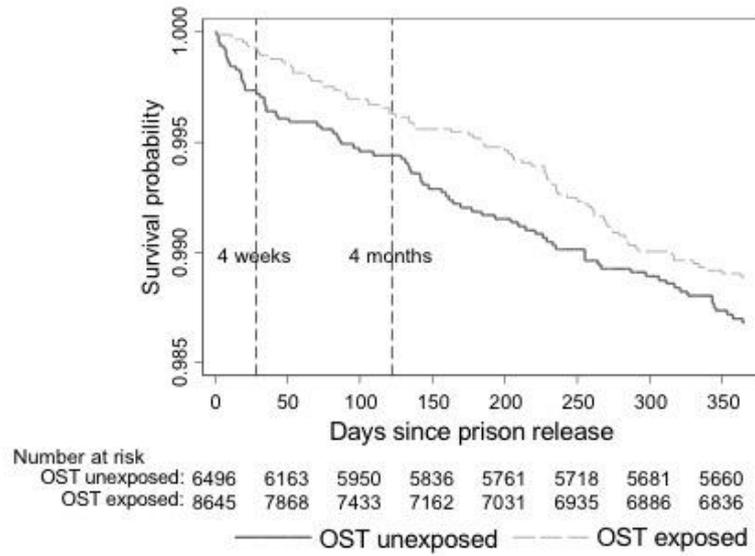
**Table 1: Demographic and characteristics of people in the risk set  
by intervention exposure status at prison release (n=12,260)**

	<b>OST Exposed (n = 6,662)</b>	<b>OST Unexposed (n = 5,598)</b>	<b>Odds ratio or mean difference (95% CI)</b>
Men, n (%)	5,054 (75.9)	4,515 (80.7)	0.75 (0.69 to 0.82)
Age, years (SD)	34.6 (7.1)	34.6 (8.0)	0.00 (-0.30 to 0.20)
Drug injecting, n (%) <sup>a</sup>	4,167 (72.1)	2,648 (56.3)	2.01 (1.85 to 2.18)
<i>Missing data</i> , n (%)	885 (13.3)	895 (16.0)	
Problem alcohol use n (%)	1,724 (28.7)	1,763 (35.8)	0.72 (0.67 to 0.78)
<i>Missing data</i> , n (%)	660 (9.9)	675 (12.1)	
Non-medical benzodiazepine use, n (%)	1,504 (25.0)	870 (17.6)	1.56 (1.42 to 1.71)
<i>Missing data</i> , n (%)	638 (9.6)	658 (11.8)	
Cocaine use, n (%)	2,438 (40.5)	1,741 (35.2)	1.25 (1.16 to 1.35)
<i>Missing data</i> , n (%)	638 (9.6)	658 (11.8)	

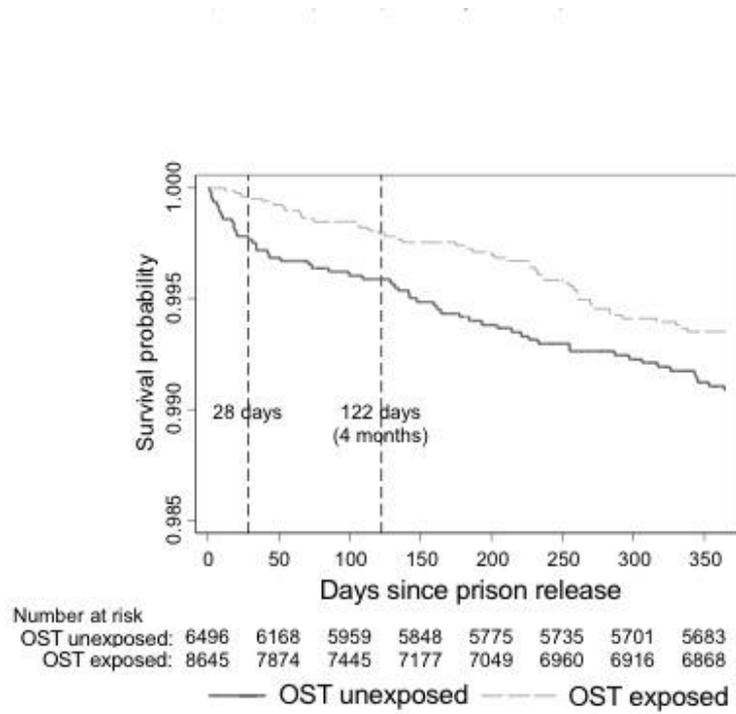
OST, opioid substitution treatment; CI, confidence interval.

<sup>a</sup> Injecting versus other route of drug administration (score: 1,0).

**Figure 1: Survival curve during the year following release  
(all-cause mortality)**



**Figure 2: Survival curve during the year following release  
(drug-related poisoning mortality)**



**Table 2: Person years, mortality rates and hazard ratios for ACM and DRP mortality, by intervention exposure at prison release and follow-up period**

<b>ACM</b>					
	<b>OST exposed</b>		<b>OST unexposed</b>		
<b>Period</b>	<b>PY at risk (n deaths)</b>	<b>Rate per 100 PY (95% CI)</b>	<b>PY at risk (n deaths)</b>	<b>Rate per 100 PY (95% CI)</b>	<b>HR (95% CI)<sup>§</sup></b>
1 to 28 days	643 (6)	0.93 (0.42 to 2.08)	490 (18)	3.67 (2.31 to 5.83)	0.25 (0.10 to 0.64)
29 to 121 days	1,966 (23)	1.17 (0.78 to 1.76)	1,555 (17)	1.09 (0.68 to 1.76)	1.07 (0.57 to 2.00)
122 to 365 days	4,654 (52)	1.12 (0.85 to 1.47)	3,824 (44)	1.15 (0.86 to 1.55)	0.97 (0.65 to 1.45)

<b>DRP mortality</b>					
	<b>OST exposed</b>		<b>OST unexposed</b>		
<b>Period</b>	<b>PY at risk (n deaths)</b>	<b>Rate per 100 PY (95% CI)</b>	<b>PY at risk (n deaths)</b>	<b>Rate per 100 PY (95% CI)</b>	<b>HR (95% CI)<sup>§</sup></b>
1 to 28 days	643 (3)	0.47 (0.15 to 1.45)	490 (15)	3.06 (1.85 to 5.08)	0.15 (0.04 to 0.53)
29 to 121 days	1,966 (13)	0.66 (0.38 to 1.14)	1,555 (11)	0.71 (0.39 to 1.28)	0.93 (0.42 to 2.08)
122 to 365 days	4,654 (31)	0.66 (0.47 to 0.94)	3,824 (29)	0.76 (0.53 to 1.09)	0.88 (0.53 to 1.46)

ACM, all-cause mortality; DRP, drug-related poisoning mortality;

OST, opioid substitution treatment;

PY, person years; CI, confidence interval; HR, unadjusted HR ratio.

<sup>§</sup> There was no statistical evidence of non-proportional hazards within each period ( $P > 0.05$ ).

**Table 3: Covariate adjusted effect of OST exposure at prison release on ACM and DRP mortality in the first 4 weeks (n = 15,141)**

Model	ACM (primary outcome)	DRP mortality
	HR (95% CI)	HR (95% CI)
OST (unadjusted) <sup>a</sup>	0.25 (0.10 to 0.60)	0.15 (0.04 to 0.53)
OST + age group <sup>b</sup>	0.26 (0.10 to 0.65)	0.15 (0.04 to 0.53)
OST + injecting <sup>c</sup>	0.23 (0.09 to 0.59) §	0.14 (0.04 to 0.47) §
OST + problem alcohol use	0.26 (0.10 to 0.65) §	0.16 (0.05 to 0.54) §
OST + non-medical benzodiazepine use	0.25 (0.10 to 0.62) §	0.14 (0.04 to 0.50) §
OST + cocaine use	0.26 (0.10 to 0.66) §	0.16 (0.05 to 0.54) §
OST + demographic and clinical covariates	0.24 (0.09 to 0.61) §	0.14 (0.04 to 0.47) §
OST + prison transfer <sup>d</sup>	0.25 (0.10 to 0.63)	0.15 (0.04 to 0.51)
OST + community treatment <sup>e</sup>	0.28 (0.11 to 0.71)	0.17 (0.05 to 0.59)
OST + all covariates <sup>f</sup>	0.25 (0.09 to 0.64) §	0.15 (0.04 to 0.52) §

ACM, all-cause mortality; DRP, drug-related poisoning mortality;

OST, opioid substitution treatment; HR, hazard ratio; CI, confidence interval.

§ Multiply imputed analysis with all releases. These analyses did not include shared frailty terms (random effects) for prison of release;

<sup>a</sup> OST exposed versus OST unexposed (scored: 1,0);

<sup>b</sup> Age group: <30, 30 to 34, 35 to 39, ≥ 40 years (no missing observations);

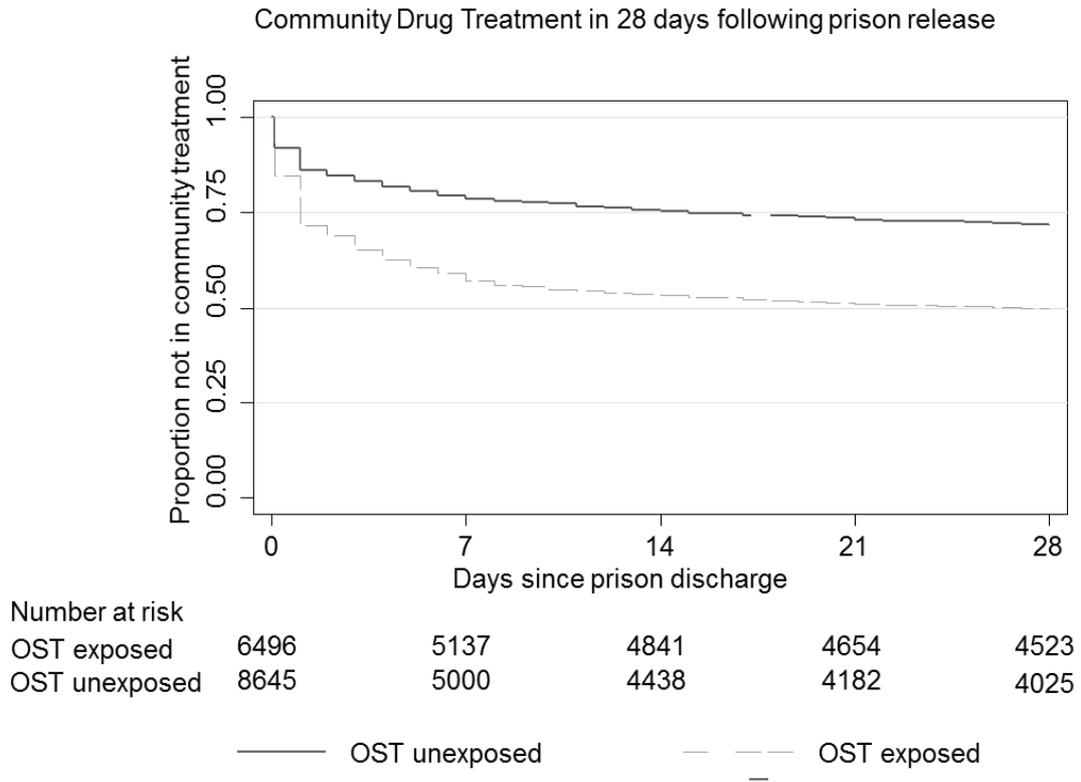
<sup>c</sup> Injecting (current/lifetime versus never; scored: 1,0);

<sup>d</sup> Prison of release different from recruitment prison

<sup>e</sup> Admitted to community drug misuse treatment within 4 weeks (time varying covariate).

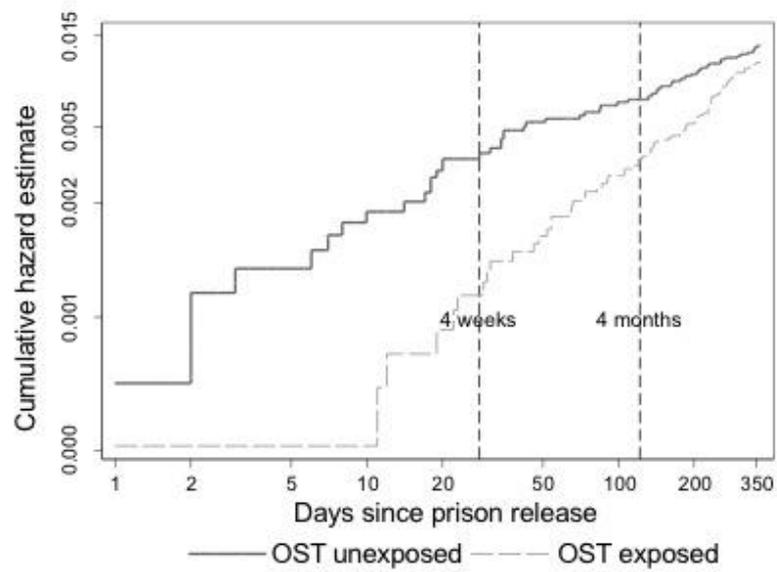
<sup>f</sup> i.e. all demographic, clinical, prison transfer and community treatment measures

**Figure 3: Time to admission to community drug misuse treatment in first 4 weeks after prison discharge by OST prison exposure: Kaplan-Meier plot.**



## SUPPLEMENTARY MATERIAL

**Figure S1: Plot of Nelson-Aalen estimates of cumulative hazard – comparing those OST exposed and unexposed to 1 year months after prison release**



**Table S1: Covariate adjusted effect of OST exposure at prison release on ACM and DRP mortality in the first 4 weeks: complete case analysis (n = 13,158)**

Model	ACM (primary outcome)	DRP mortality
	HR (95% CI)	HR (95% CI)
OST (unadjusted) <sup>a</sup> <sup>f</sup>	0.31 (0.11 to 0.88)	0.20 (0.06 to 0.72)
OST + age group <sup>b</sup> <sup>f</sup>	0.30 (0.11 to 0.86)	0.20 (0.06 to 0.71)
OST + injecting <sup>c</sup>	0.28 (0.10 to 0.80)	0.18 (0.05 to 0.65)
OST + problem alcohol use	0.31 (0.11 to 0.90)	0.21 (0.06 to 0.74)
OST + non-medical benzodiazepine use	0.30 (0.10 to 0.85)	0.19 (0.05 to 0.68)
OST + cocaine use	0.32 (0.11 to 0.91)	0.21 (0.06 to 0.75)
OST + demographic and clinical covariates	0.28 (0.10 to 0.82)	0.18 (0.05 to 0.66)
OST + prison transfer <sup>d</sup>	0.29 (0.10 to 0.82)	0.18 (0.05 to 0.65)
OST + community treatment <sup>e</sup> <sup>f</sup>	0.33 (0.11 to 0.96)	0.22 (0.06 to 0.80)
OST + all covariates <sup>f</sup>	0.29 (0.10 to 0.84)	0.18 (0.05 to 0.66)

ACM, all-cause mortality; DRP, drug-related poisoning mortality;

OST, opioid substitution treatment; HR, hazard ratio; CI, confidence interval.

<sup>a</sup> OST exposed versus OST unexposed (scored: 1,0);

<sup>b</sup> Age group: <30, 30 to 34, 35 to 39, ≥ 40 years

<sup>c</sup> Injecting (current/lifetime versus never; scored: 1,0);

<sup>d</sup> Prison of release different from recruitment prison

<sup>e</sup> Admitted to community drug misuse treatment within 4 weeks (time varying covariate);

<sup>f</sup> i.e. all demographic, clinical, prison transfer and community treatment measures

## REFERENCES

- 1 Degenhardt L, Hall W. Extent of illicit drug use and dependence, and their contribution to the global burden of disease. *Lancet* 2012; 379: 55-70.
- 2 Darke S, Kaye S, Duflou J. Systemic disease among cases of fatal opioid toxicity. *Addiction* 2006; 101: 1299-305.
- 3 Mathers BM, Degenhardt L, Bucello C, Lemon J, Wiessing L, Hickman M. Mortality among people who inject drugs: a systematic review and meta-analysis. *Bull World Health Organ* 2013; 91: 102-23.
- 4 White JM, Irvine RJ. Mechanisms of fatal opioid overdose. *Addiction* 1999; 94: 961-72.
- 5 Calcaterra S, Glanz J, Binswanger IA. National Trends in Pharmaceutical Opioid Related Overdose Deaths Compared to other Substance Related Overdose Deaths: 1999-2009. *Drug Alcohol Depend.* 2013; 131: 263–270.
- 6 Office for National Statistics. Statistical bulletin: Deaths related to drug poisoning in England and Wales: 2015 registrations. Accessed on 30.01.17 at URL: <http://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/death-related-to-drug-poisoning-in-england-and-wales/2015-registrations>. Self-Archived at WebCite® on 30.01.17 [<http://www.webcitation.org/6ntic0Z90>].
- 7 Fazel S, Bains P, Doll H. Substance abuse and dependence in prisoners: a systematic review. *Addiction* 2006; 101: 181-91.
- 8 Farrell M, Marsden J. Acute risk of drug-related death among newly released prisoners in England and Wales. *Addiction* 2008; 103: 251-55.
- 9 Merrall EL, Kariminia A, Binswanger IA, Hobbs MS, Farrell M, Marsden J, Hutchinson SJ, Bird SM. Meta-analysis of drug-related deaths soon after release from prison. *Addiction* 2010; 105: 1545-54.
- 10 Kinner SA, Forsyth S, Williams G. Systematic review of record linkage studies of mortality in ex-prisoners: why (good) methods matter. *Addiction* 2012; 108: 38-49.
- 11 Hill R, Lyndon A, Withey S, Roberts J, Kershaw Y, MacLachlan J, Lingford-Hughes A, Kelly E, Bailey C, Hickman M. Ethanol reversal of tolerance to the respiratory depressant effects of morphine. *Neuropsychopharmacology* 2016; 41(3): 762-773.
- 12 McCowan C, Kidd B, Fahey T. Factors associated with mortality in Scottish patients receiving methadone in primary care: retrospective cohort study. *BMJ* 2009: 338.
- 13 Krantz MJ, Rowan SB, Mehler PS. Cocaine-related torsade de pointes in a methadone maintenance patient. *J Addict Dis.* 2005; 24: 53-60.
- 14 American Psychiatric Association. Diagnostic and Statistical Manual of

Mental Disorders 2013. Fifth edition, DSM5. American Psychiatric Association: American Psychiatric Publishing.

- 15 World Health Organization. International Classification of Diseases 2007.10th edition (ICD-10). Accessed on 30.01.17 at URL: <http://www.who.int/classifications/apps/icd/icd10online/>. Self-Archived at WebCite® on 30.01.17 [<http://www.webcitation.org/6ntipvNyx>].
- 16 Mattick RP, Breen C, Kimber J, Davoli M. Buprenorphine maintenance versus placebo or methadone maintenance for opioid dependence. *Cochrane Database Syst Rev* 2014. CD002207.
- 17 MacArthur GJ, Minozzi S, Martin N, Vickerman P, Deren S, Bruneau J, Degenhardt L, Hickman M. Opiate substitution treatment and HIV transmission in people who inject drugs: systematic review and meta-analysis. *BMJ* 2012; 345: e5945.
- 18 Pierce M, Bird SM, Hickman M, Marsden J, Dunn G, Jones A, Millar T. Impact of treatment for opioid dependence on fatal drug-related poisoning: a national cohort study in England. *Addiction* 2016; 111: 298-308.
- 19 White M, Burton R, Darke S, Eastwood B, Knight J, Millar T, Musto V, Marsden J. Fatal opioid poisoning: a counterfactual model to estimate the preventive effect of treatment for opioid use disorder in England. *Addiction* 2015; 110: 1321-1329.
- 20 Marsden J, Eastwood B, Bradbury C, Dale-Perera A, Farrell M, Hammond P, Knight J, Randhawa K, Wright C. National Drug Treatment Monitoring System Outcomes Study Group. Effectiveness of community treatments for heroin and crack cocaine addiction in England: a prospective, in-treatment cohort study. *Lancet* 2009; 374, 1262-70.
- 21 Marteau D, Palmer J, Stover H. Introduction of the Integrated Drug Treatment System (IDTS) in English Prisons. *International Journal of Prisoner Health* 2010; 6: 117-24.
- 22 Marsden J., Eastwood B., Bradbury C., Dale-Perera A., Farrell M., Hammond P., Knight J., Randhawa K., Wright C. Effectiveness of community treatments for heroin and crack cocaine addiction in England: a prospective, during treatment cohort study. *Lancet* 2009; **374**: 1262-70.
- 23 Hedrich D, Alves P, Farrell M, Stöver H, Møller, L, Mayet S. The effectiveness of opioid maintenance treatment in prison settings: a systematic review. *Addiction* 2012; 107: 501-17.
- 24 von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* 2007; 370: 1453-1457.
- 25 National Institute for Health and Care Excellence (NICE). Methadone and buprenorphine for the management of opioid dependence. NICE technology appraisal guidance [TA114]. Accessed on 30.01.17 at URL: <https://www.nice.org.uk/guidance/TA114/chapter/About-this-guidance>. Archived at WebCite® on 30.01.17 [<http://www.webcitation.org/6ntj6F7gs>].
- 26 Office for National Statistics. Accessed on 30.01.17 at URL:

<http://www.ons.gov.uk/ons/rel/subnational-health3/deaths-related-to-drug-poisoning/england-and-wales---2013/stb---deaths-related-to-drug-poisoning-in-england-and-wales--2013.html#tab-background-notes>. Archived at WebCite® on 30.01.17 [http://www.webcitation.org/6ntjD3rCb].

- 27 Davoli M, Bargagli AM, Perucci CA, Schifano P, Belleudi V, Hickman M, Salamina G, Diecidue R, Vigna-Taglianti F, Faggiano F: VEdeTTE Study Group. Risk of fatal overdose during and after specialist drug treatment: the VEdeTTE study, a national multi-site prospective cohort study. *Addiction* 2007; 102: 1954-9.
- 28 Willey H, Eastwood B, Gee IL, Marsden J. Is treatment for alcohol use disorder associated with reductions in criminal offending? A national data linkage cohort study in England. *Drug Alcohol Depend* 2016; 161: 67-76.
- 29 Andersen PK, Borgan Ø, Gil RD, Keiding N. *Statistical Models Based on Counting Processes*. Springer-Verlag: New York. 1993.
- 30 White IR, Royston P. Imputing missing covariate values for the Cox model. *Stat Med* 2009; 28: 1982-98.
- 31 Little RJA, Rubin DB. *Statistical Analysis with Missing Data*. New York: Wiley and Sons. 1987.
- 32 Prentice RL, Williams BJ, Peterson AV. On the regression analysis of multivariate failure time data. *Biometrika* 1981; 68:373-9.
- 33 Degenhardt L, Larney S, Kimber J, Gisev N, Farrell M, Dobbins T, Weatherburn DJ, Gibson A, Mattick R, Butler T, Burns L. The impact of opioid substitution therapy on mortality post-release from prison: retrospective data linkage study. *Addiction* 2014; 109: 1306-17.
- 34 Levesque LE, Hanley JA, Kezouh A, Suissa S. Problem of immortal time bias in cohort studies: example using statins for preventing progression of diabetes. *BMJ* 2010; 340: b5087.
- 35 Bird SM, Fischbacher CM, Graham L, Fraser A. Impact of opioid substitution therapy for Scotland's prisoners on drug-related deaths soon after prisoner release. *Addiction* 2015; 110: 1617-24.
- 36 Taylor A, Munro A, Allen E, Dunleavy K, Cameron S, Miller L, Hickman M. Low incidence of hepatitis C virus among prisoners in Scotland. *Addiction* 2013; 108: 1296-1304.
- 37 Bird SM, McAuley A, Perry S, Hunter C. Effectiveness of Scotland's National Naloxone Programme for reducing opioid-related deaths: a before (2006-10) versus after (2011-13) comparison. *Addiction* 2016; 111: 883-91.
- 38 Lee JD, McDonald R, Grossman E, McNeely J, Laska E, Rotrosen J, Gourevitch MN. Opioid treatment at release from jail using extended-release naltrexone: a pilot proof-of-concept randomized effectiveness trial. *Addiction* 2015; 110:1008-14.
- 39 Gordon MS, Kinlock TW, Vocci FJ, Fitzgerald TT, Memisoglu A, Silverman B. A Phase 4, Pilot, Open-Label Study of VIVITROL® (Extended-Release Naltrexone XR-NTX) for Prisoners. *J Subst Abuse Treat*. 2015; 59: 52-8.