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DATA INSIGHT

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Seasonal, weekly and other cyclical patterns in deaths due to drug poisoning in England and Wales

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Abstract

Background and aim: The rate of drug poisoning (or overdose) deaths in England and Wales has risen annually since 2010. We aimed to measure seasonal and other cyclical changes in these deaths within years.

Methods: We used the daily count of deaths due to drug poisoning in England and Wales between 1 January 1993 and 31 December 2018 to investigate variation by season, weekday, week-of-month and public holiday. We used Poisson regression to estimate the count of deaths per day for each of these variables and peak-to-low ratios. We also stratified the analysis by time period and whether an opioid was mentioned on the death certificate.

Results: 78 583 deaths occurred between 1993 and 2018, increasing from 5.50 (95% confidence interval [CI] = 5.24–5.77) per day in 1993 to 13.18 (95% CI = 12.66–13.72) per day in 2018. The rate peaked in Spring and was 1.07 (95% CI = 1.04–1.09) times higher in April than in October. This seasonal pattern emerged in the past decade and was only present for opioid-related deaths. The rate at New Year was 1.28 (95% CI = 1.17–1.41) times higher than on non-holidays; and this peak was only present for deaths that were not related to opioids. The rate was higher on Saturday than on other weekdays. We did not find evidence that the number of deaths varied by week-of-month.

Conclusions: Deaths due to drug poisoning in England and Wales are seasonal and peak in Spring and briefly at New Year. This suggests a role of external triggers. These seasonal variations are small compared with long-term increases in drug-related deaths.

KEYWORDS
Drug overdose, mortality, opioid-related disorders, poisoning, seasons, substance-related disorders

INTRODUCTION

The risk of many causes of death varies within years, including by season, day or even hour. Respiratory viruses such as influenza peak in winter months in temperate climates [1]; car crashes are more likely at the weekend [2], and heart attacks are more likely in the morning [3]. Causes of these trends include planetary cycles such as weather and climate, social cycles such as alcohol consumption or socialising indoors and physiological cycles such as circadian rhythms.

There has been relatively little research on short-term or cyclical trends in deaths due to drug poisoning. There may be demand-side drivers such as stress during holidays or monthly financial pressures

and supply-side drivers such as regular changes in the availability and potency of drugs [4, 5]. These cycles could be an important part of the 'risk environment' [6] for drug-related deaths. An understanding of these patterns could contribute to the planning of public health and clinical services that aim to prevent drug-related deaths.

Several studies, mostly in North America, have investigated cyclical risks with inconsistent findings. Studies in the United States found that drug-related deaths were 7% [7] and 17% [8] higher in the first week of each calendar month, relative to the previous week. Possible reasons include stressful events such as bill payments and evictions being more common at the start of the month and payments for many benefits being at the beginning of the month and leading to greater drug use at this time [9]. A study in Canada found that overdose deaths were 14% higher in winter than summer [10], and similarly, a study in the United States found that cold weather was associated with higher rates of drug-related deaths [11]. Possible reasons include the effect of cold weather on respiratory function and that people may be more likely to use drugs indoors and alone in winter, where they would be less likely to be seen and resuscitated in the event of an overdose. Two studies of weekly patterns in opioid-related deaths in England in the 1990s both found that deaths were highest on Saturdays [11, 12], although this pattern appeared to disappear in the early 2000s [13]. Studies of suicide by intentional drug overdose in the United States [14] and the United Kingdom (UK) [12] found that deaths were lowest around Christmas (but peaked on 1 January).

Using a new dataset of daily counts of drug-related deaths, we describe cyclical patterns of drug-related deaths in England and Wales. Based on previous studies, our hypotheses were that the rate of drug-related deaths would be highest: (i) in winter months, (ii) in the first week of the month, (iii) on Saturdays and (iv) on the New Year holiday.

METHOD

We analysed time trends in the daily count of drug-related deaths in England and Wales, following a published analysis plan [15]. The dataset was published by the Office for National Statistics [16] and includes the count of deaths due to drug poisoning by day of occurrence between 1 January 1993 and 31 December 2018. We did not include deaths occurring after 2018 because delays to death registration mean that more recent trends are unreliable. Deaths due to drug poisoning were defined by International Classification of Diseases (ICD)-9 or ICD-10 code for the underlying cause of death, with codes shown in the supporting information, following the Office for National Statistics definition of drug-related deaths. This includes deaths that are considered accidental (81% of drug-related deaths registered in 2021) [17] and those recorded as suicides.

We coded each day according to five variables: (i) the proportion of the calendar year elapsed (e.g. 2 July was coded as ~ 0.5), (ii) the week-of-month, defined as the first 7 days (e.g. in March, 1–7 March), last 7 days (e.g. 25–31 March) and other days (e.g. 8–24 March); (iii) weekday; (iv) public holidays, defined as Christmas (24–30 December); New Year (31 December to 1 January); other public holidays; and non-holidays; (v) time, defined as the number of days after 1 January 1993.

We fit a Poisson model where the dependent variable was the count of deaths and the independent variables listed above. To estimate long-term trends, we used polynomial terms of time, up to the fourth degree. To estimate seasonal trends, we used harmonic terms of the proportion of the calendar year elapsed, with three sine and cosine pairs. We used this model to predict the daily number of deaths for each variable, when other variables are at baseline values of (i) 1 January; (ii) last 7 days of the month; (iii) Monday; (iv) non-holidays; and (v) 31 December 2018. Statistical evidence for variation was estimated using a likelihood ratio test comparing models with and without each variable. For each variable, we estimated the peak-to-low ratio using a Monte Carlo method. We simulated 1000 datasets in which the daily count was sampled from a Poisson distribution with a mean of the observed count, estimated the expected count as described above, and then calculated the ratio between the minimum and maximum values for that variable. The 0.025 and 0.975 quantiles provided a 95% CI. We also estimate the absolute number of attributable deaths, defined as the difference between the observed deaths in 2018 (4586 deaths) and the number that would have occurred if the variable was held at its lowest value.

As a secondary analysis, we stratified the analysis by time period and whether an opioid was mentioned on the death certificate. The methodology for determining opioid-related deaths is described in the Office for National Statistics report [18]. We used three time periods: 1993 to 2001, 2002 to 2010 and 2011 to 2018. These periods are approximately equal-duration, and they also correspond to an earlier increase in drug-related deaths in the 1990s, a plateau in the 2000s and the recent increase in drug-related deaths [19]. The count of opioid-related deaths was not published for 3055/9504 (32%) days where there were fewer than three deaths and data were redacted for confidentiality purposes; these days were excluded from the stratified analysis. All analysis was done using R version 4.2.1, with data and code publicly available (https://github.com/danlewer/drd-time-trends).

RESULTS

The dataset included 78 583 deaths. In our estimate of the long-term trend, controlling for season, weekly, weekday and public holidays, the rate was 5.50 per day (95% CI = 5.24–5.77) on 1 January 1993 and 13.18 per day (95% CI = 12.66–13.72) on 31 December 2018 (Figure 1). This increase happened in two stages: a first increase from 1993 to 2000 and a second increase from 2010 to 2018.

The rate of drug poisoning deaths was highest in Spring and lowest in Autumn, with the number of deaths on 23 April typically 1.07 (95% CI = 1.04–1.09) times greater than on 15 October. If seasonal variation was eliminated and the rate was reduced to the lowest point in the year, in 2018, there would have been 142 (95% CI = 85–216) fewer deaths, out of a total of 4586 deaths (i.e. 3% of deaths).

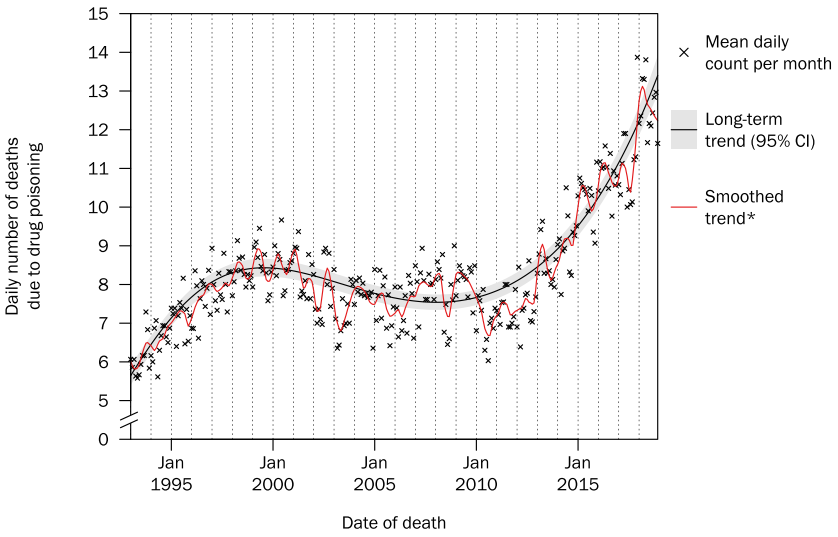

FIGURE 1 Long-term trends in the daily number of drug-related deaths in England and Wales. *The smoothed trend is estimated using local regression (LOESS) smoothing.

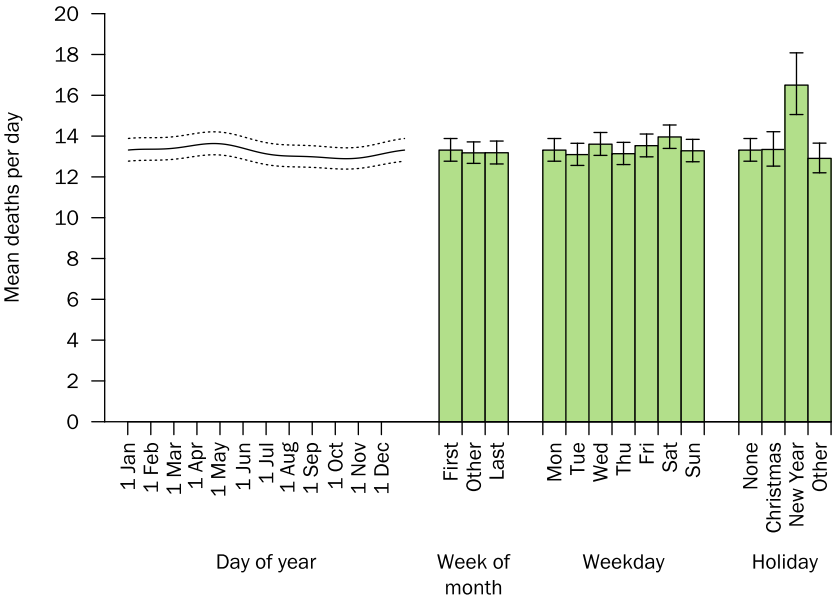

FIGURE 2 Daily deaths due to drug poisoning in England and Wales by calendar month, week of the month, weekday and public holiday, 1993–2018. Error bars show 95% CI.

TABLE 1 Summary of cyclical variation in drug-related deaths in England and Wales, 1993–2018.

Variable	Peak	Low	Evidence of variation[b]	Peak-to-low ratio (95% CI)	Attributable deaths[a] (95% CI)
Season	23 April	15 October	Strong (<0.001)	1.07 (1.04–1.09)	142 (85–216)
Week-of-month	First	Middle-of-month	None (0.497)	1.01 (1.00–1.03)	27 (6–77)
Weekday	Saturday	Tuesday	Strong (<0.001)	1.07 (1.05–1.10)	136 (85–208)
Public holiday	New Year	Other public holiday	Strong (<0.001)	1.28 (1.17–1.41)	160 (9–353)

[a]Of a total of 4586 deaths in 2018.
[b]Classified as strong where $P \leq 0.001$, moderate where $P \leq 0.01$, weak where $P \leq 0.05$ and none where $P > 0.05$.

There was no evidence that the rate differed by the week-of-month.

There was no clear pattern in the number of deaths due to drug poisoning across weekdays, although the rate was highest on Saturday and was typically 1.07 (95% CI = 1.05–1.10) times higher than the lowest weekday, which in this dataset was Tuesday. We estimated that 136 (95% CI = 85–208) deaths attributable to weekday variations in 2018.

The rate at New Year was 1.28 (95% CI = 1.17–1.41) times greater than on days that were not public holidays. In exploratory

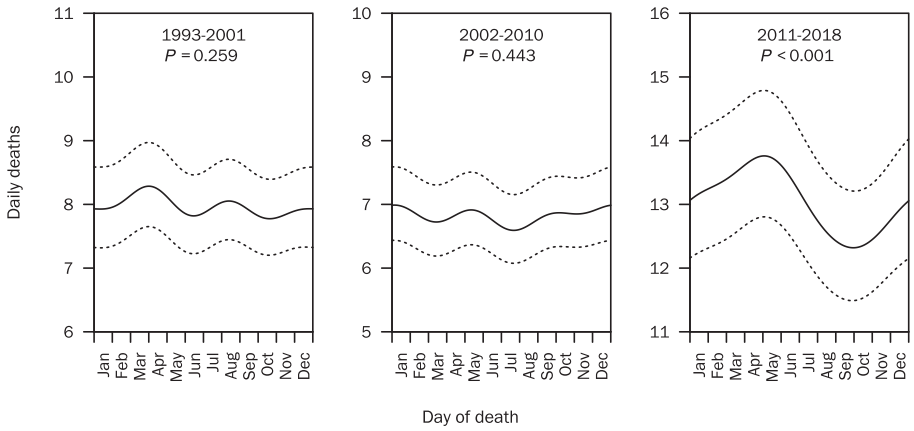

FIGURE 3 Daily drug-related deaths in England and Wales by calendar month across three time periods (1993–2001, 2002–2010 and 2011–2018). Error bars show 95% CI. Note that *y*-axes differ across panels and do not start from zero.

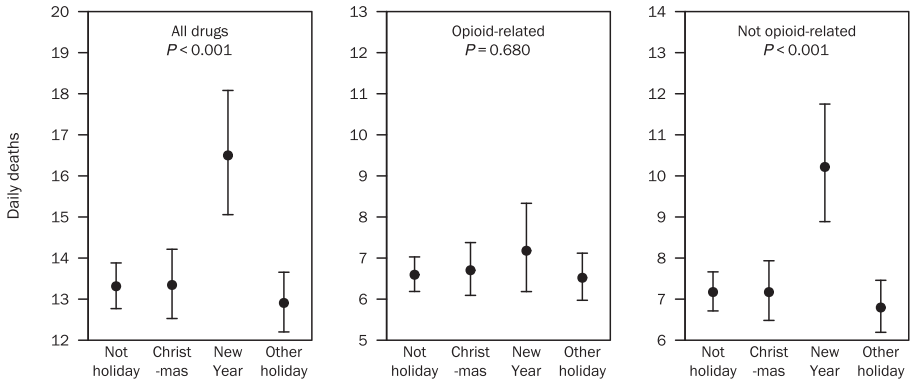

FIGURE 4 Daily drug-related deaths in England and Wales by public holiday, 1993–2018. Error bars show 95% CI. Note that *y*-axes differ between panels and do not start from zero.

analysis of daily rates in drug-related deaths, we found that the 'New Year' effect was because of a higher rate on 1 January and not 31 December (Supporting information). We did not find evidence that the rate at Christmas or other public holidays was different to days that were not public holidays. We estimated 160 (95% CI = 9–353) deaths attributable to variations related to public holidays in 2018. Cyclical variation in drug-related deaths are summarised in Figure 2 and Table 1.

When we stratified the analysis by time period (1993–2001, 2002–2010 and 2011–2018), absolute rates were highest in 2011–2018 but cyclical trends were similar across all three. The exception was the pattern by season. In 1993–2001 and 2002–2010, there was no evidence of a seasonal pattern (either visually or statistically), and the number of deaths was similar each month. In the final period (2011–2018), there was strong evidence of a seasonal pattern in which the rate of deaths on 4 May was 1.13 (95% CI = 1.09–1.18) times greater than on 30 September (Figure 3).

Similar to our unstratified analysis, in each time period, there was no evidence of variation by week-of-month; deaths were higher on Saturday than other weekdays, and there was a peak at New Year (Supporting information).

When we stratified analyses into opioid-related deaths and other (non-opioid) deaths, seasonal variation was apparent for opioid-related deaths, but not for other deaths (Supporting information). The peak at New Year was driven by non-opioid-related deaths (Figure 4), with no evidence of a peak in opioid-related deaths at this time. Full stratified results are shown in Supporting information.

DISCUSSION

Between 1993 and 2018, the number of drug-related deaths in England and Wales was higher in Spring than in Autumn, higher on Saturday than on other days and peaked at New Year. The peak in Spring appears to have emerged in the most recent decade and is related to opioids rather than other drugs. These trends suggest a role of external triggers for drug-related deaths, although these seasonal and cyclical variations are small compared with long-term increases in drug-related deaths.

The peak in Spring was an unexpected finding, given studies in North America have found that drug-related deaths are more common in winter [10] or increase after cold weather [11]. The seasonal pattern in our study appears to be a recent phenomenon related to opioids rather than other drugs. This may suggest that it is the result of recent changes in the risk environment for people who use heroin and other opioids. For example, there may be recent seasonal variations in initiation or discontinuation of opioid agonist therapies that contribute to patterns in opioid-related deaths. Discharge from opioid agonist treatment is associated with increased risk of death [20], so seasonal patterns in discharge

may affect the number of drug-related deaths. This theory could be investigated using data on discharges from drug treatment services [21].

We did not find evidence that the rate of drug-related death in England and Wales was higher in the first week of the month, in contrast to studies in North America. This may relate to differing social support and benefits systems. In the United Kingdom, many benefits are paid monthly, but the day varies by recipient. 'Universal Credit', the main benefit for working-age people [22], is paid monthly, but can be paid on any day. Therefore, people who use drugs in the United Kingdom would not be affected by the 'cheque effect' [9], the population-level effect of paying benefits on the same day of the month and any individual-level effects are spread across the month.

The large peak at New Year, when the risk of death due to drug poisoning, was 1.3 times greater than other days, supported our hypothesis. Our secondary analysis suggested that this peak was driven by deaths where an opioid was not present on the death certificate. This may suggest that this peak is a result of drugs such as 3,4-methylenedioxymethamphetamine and cocaine that are associated with socialising or a result of suicides. The rate of suicides (including other methods such as hanging) on New Year's Day is 1.4 times higher than on non-public-holidays [23], and suicide is more commonly recorded among deaths due to non-opioid poisoning than among deaths related to opioids [17].

Although more research is needed to understand the reasons for the cyclical variations we observed, the small size of these variations suggests that interventions targeting cyclical and seasonal factors are unlikely to have a large impact on the number of drug-related deaths in the United Kingdom. Example of such interventions includes staggered income assistance payments to prevent the 'cheque effect' described above [24] or the prioritisation of harm reduction service at higher-risk times such as weekends. In the United Kingdom, such focused interventions may be less effective than a general expansion of overdose prevention strategies such as community-distributed naloxone, accessible opioid agonist treatment and overdose prevention centres.

The strength of this analysis is that daily data allowed us to investigate temporal patterns in drug-related deaths that have not previously been reported in England and Wales. There are five key limitations.

First, we used aggregate data (the daily count of deaths) and did not include information about individuals who died. This means we could not study potential mechanisms related to individual behaviours such as drug use or engagement with harm reduction services, which may vary over time.

Second, death may be recorded on a different day to the drug overdose. Usually, this would only be a one-day difference, when someone uses drugs late in the evening and dies early the next morning, but may be longer if someone was treated in hospital and received supportive care but ultimately died. We expect that this occurs in a minority of cases, as 85% of deaths due to drug poisoning happen in the community with no hospital care [25].

Third, our analysis is not designed to explain the large, annual increase in drug-related deaths that has happened over the past decade. The cyclical variations described here happen within years and are unlikely to be driving longer-term changes in the population or risk environment.

Fourth, the classification of deaths because of opioids did not distinguish between illicit and prescription opioids, which may have differing trends.

Fifth, we did not analyse non-fatal overdoses. The trends we observed may be because of variations in drug use and the rate of overdoses or variations in the probability of being given naloxone or taken to hospital after an overdose. A study of temporal trends in non-fatal overdoses could help untangle these effects.

We found modest variation in drug-related deaths in England and Wales by season and weekday. The recent emergence of seasonal variation in opioid-related deaths may inform further research.

AUTHOR CONTRIBUTIONS

Dan Lewer: Conceptualization (equal); formal analysis (equal); funding acquisition (equal); methodology (equal); software (equal); writing—original draft (equal); writing—review and editing (equal). **Thomas D. Brothers:** Conceptualization (equal); methodology (equal); writing—original draft (equal); writing—review and editing (equal). **Antonio Gasparrini:** Methodology (equal); writing—review and editing (equal). **John Strang:** Conceptualization (equal); methodology (equal); writing—original draft (equal); writing—review and editing (equal).

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DECLARATION OF INTERESTS

J.S. is a researcher and clinician who has chaired/contributed to guidelines on policy and practice and has also worked with pharmaceutical companies to investigate new or improved medications. This has included project-based research grant support to J.S.'s employer (King's College London) from, past 3 years, MundiPharma, Camurus, Molteni/Accord. For updated information see John Strang's info on Departmental website at http://www.kcl.ac.uk/ioppn/depts/addictions/people/hod.aspx.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available and published by Office for National Statistics: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/14989numberofdrugrelateddeathsbyindividualdayofoccurrenceenglandandwalesoccurredbetween1993and2018andregisteredbytheendof2021. The data are duplicated together with analysis code: https://github.com/danlewer/drd-time-trends.

ETHICS STATEMENT

All data used in this research are publicly available, and no ethical or other approvals were needed.

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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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