Geospatial pattern analyses of drug poisoning deaths to inform substance use disorder research

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Today’s talk

• This work represents a collaboration between researchers at the CGIS and Center for Substance Abuse Research (CESAR) at the University of Maryland

• CESAR is also a coordinating center for the National Drug Early Warning System (NDEWS) and this group is interested in
  • monitoring drug trends across the US,
  • identifying emerging trends, and also in
  • prevention, intervention and treatment programs for substance use disorders

• We started with an investigation of geographic patterns of drug deaths involving heroin and have expanded to some other, related topics...
**Heroin deaths (2016)**

*Data Source:*

CDC WONDER’s online database with a focus on deaths involving heroin by county by year
MCD-ICD-10: T40.1 Heroin
UCD-ICD-10: X40-44 accidental poisoning
  - X60-64 intentional poisoning
  - X85 assault
  - Y10-Y14 poisoning undetermined intent
Data are **suppressed** when raw count is below 10

Although we show raw counts here, it is generally considered that estimating rates based on raw counts may lead to unstable estimates so we apply an empirical bayes method and smooth the rates
Spatially smoothed age-adjusted drug poisoning death rates per 100,000 by county involving heroin

- 2005: 126 counties
  - Baltimore, MD

- 2010: 160 counties
  - St. Louis

- 2015: 523 counties
  - Cabell Co, WV

- 2016: 657 counties
  - Cabell Co, WV
  - Rio Arriba Co, NM
For 2016...

Localized areas where spatially smoothed age adjusted estimates are higher for Black and Hispanic groups than smoothed rates estimated for White.
### Impact on racial and ethnic groups

Hotspots for different population groups based on spatially smoothed age-adjusted estimated death rates involving heroin

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<thead>
<tr>
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<tbody>
<tr>
<td><strong>White</strong></td>
<td>Kern County, CA</td>
<td>Bernalillo County, NM, Northern PA and eastern MI</td>
<td>Ohio, Missouri</td>
<td>Marion County, OH; Cabell County, WV</td>
<td>Cabell, WV; Rio Arriba, NM; St. Louis, MO</td>
</tr>
<tr>
<td></td>
<td>(56.9%)</td>
<td>(88%)</td>
<td>(~100%)</td>
<td>(87.7%)</td>
<td>(85.03%)</td>
</tr>
<tr>
<td><strong>Black</strong></td>
<td>Essex County, NJ</td>
<td>Macomb County, MI</td>
<td>N/A</td>
<td>St. Louis, MO; Chicago IL; Baltimore, MD</td>
<td>St. Louis, MO; Pittsburg, PA; DC-Baltimore</td>
</tr>
<tr>
<td></td>
<td>(43.1%)</td>
<td>(12%)</td>
<td>(&lt;1%)</td>
<td>(12.3%)</td>
<td>(14.97%)</td>
</tr>
<tr>
<td><strong>Hispanic</strong></td>
<td>LA, CA</td>
<td>San Antonio, TX</td>
<td>Bernalillo, NM; San Antonio, TX</td>
<td>Bernalillo, NM</td>
<td>Rio Arriba, NM; Hartford, CT; Milwaukee, WI</td>
</tr>
<tr>
<td></td>
<td>(0.8%)</td>
<td>(15.6%)</td>
<td>(4.9%)</td>
<td>(3.3%)</td>
<td>(30.6%)</td>
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Percentage of total spatially smoothed estimated death rates involving heroin for each group
### Impact on age and gender groups

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<tbody>
<tr>
<td><strong>18 - 24 yrs</strong></td>
<td>N/A</td>
<td>Dallas, TX</td>
<td>San Antonio &amp; Dallas, TX</td>
<td>Great Lakes region, Mid-Atlantic</td>
<td>Cleveland, OH; Mid-Atlantic</td>
</tr>
<tr>
<td>N/A</td>
<td>6.8%</td>
<td>11%</td>
<td>12%</td>
<td>5.2%</td>
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</tr>
<tr>
<td><strong>25 - 34 yrs</strong></td>
<td>New England and Mid-Atlantic</td>
<td>Pittsburgh, PA; Detroit, MI</td>
<td>St. Louis, MO; Detroit, MI; Cincinnati, OH; Pittsburgh, PA;</td>
<td>Mountain region, Great Lakes region, Ohio Valley, New England</td>
<td>Ohio Valley, Mid-Atlantic</td>
</tr>
<tr>
<td></td>
<td>21.7%</td>
<td>14%</td>
<td>41%</td>
<td>45%</td>
<td>55.13%</td>
</tr>
<tr>
<td><strong>35 - 54 yrs</strong></td>
<td>Mountain region</td>
<td>Mountain, Great Lakes, New England, Mid-Atlantic</td>
<td>Cincinnati, OH; Baltimore, MD;</td>
<td>New England, Ohio Valley, Great Lakes region</td>
<td>St. Louis, MO; Ohio Valley; New England</td>
</tr>
<tr>
<td></td>
<td>72.3%</td>
<td>78%</td>
<td>40%</td>
<td>37%</td>
<td>34.6%</td>
</tr>
<tr>
<td><strong>55 yrs and above</strong></td>
<td>LA, CA</td>
<td>LA, CA</td>
<td>LA, Detroit</td>
<td>S. CA, Great Lakes</td>
<td>DC-Baltimore, Ohio Valley, Great Lakes</td>
</tr>
<tr>
<td></td>
<td>6%</td>
<td>1.2%</td>
<td>8%</td>
<td>6%</td>
<td>5.1%</td>
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<tbody>
<tr>
<td>Males</td>
<td>96.3%</td>
<td>94.6%</td>
<td>91.3%</td>
<td>85.4%</td>
<td>81.4%</td>
</tr>
<tr>
<td>Females</td>
<td>3.7%</td>
<td>5.4%</td>
<td>8.7%</td>
<td>14.6%</td>
<td>18.6%</td>
</tr>
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</table>

Percentage of total spatially smoothed estimated death rates involving heroin for each group.
Analyzing spatial-temporal patterns of drug poisoning deaths involving heroin 2000-2016

- Raw counts of deaths involving heroin by year
- Population by year

**SaTScan**

**Cluster**

- Strength ratio
- Year
- County ID
- Relative risk index of each county

**Space-time cluster:**
- Space-time scan statistic based on space-time retrospective analysis and a Poisson probability model

**Core cluster:**
- High percentage of counties with high relative risk in a cluster
- Likelihood ratio > 80
- P-value < 0.01 (from 999 MC)

**Sensitivity analysis:**
- Tests 8 different % of population at risk
- Frequency of being in a core cluster
- Also used to indicate stability

- Over 77% counties in cluster w/ RR>1
- Core cluster
- Heterogeneous cluster
- LLR decrease CC1 → CC23

- Core cluster
- Heterogeneous cluster

- Sensitivity Analysis
- 5% population at risk
Spatial-temporal patterns of drug poisoning deaths involving heroin 2000-2016

Early 2000s on the US west coast

Moves to Ohio Valley and New England by 2015 and 2016

Core cluster 1 is largest comprising 34 counties in New England and has the highest likelihood
Stability of counties in **core clusters** based on applying the sensitivity analysis and understanding how many times a county falls into a core cluster during scanning.
Spatial-temporal core clusters of drug poisoning deaths involving heroin 2000-2016 by urbanization

<table>
<thead>
<tr>
<th>Urbanization Level</th>
<th>n (N=191)</th>
<th>Percent</th>
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<tbody>
<tr>
<td>Large Metro</td>
<td>116</td>
<td>60.73%</td>
</tr>
<tr>
<td>Medium Metro</td>
<td>43</td>
<td>22.51%</td>
</tr>
<tr>
<td>Small Metro</td>
<td>12</td>
<td>6.28%</td>
</tr>
<tr>
<td>Rural</td>
<td>20</td>
<td>10.47%</td>
</tr>
</tbody>
</table>
Drug poisoning death rates involving heroin and cocaine (2016) are based on age-adjusted spatial empirical Bayes’ estimation per 100,000.

Comparing spatially smoothed death rates involving both heroin and cocaine (2016)

OLS test
Correlation Coefficient 0.240372 (99.9% CI)
Spatial clustering based on the sum of heroin and cocaine

Spatial autocorrelation
Moran’s I value: 0.107827
(99.9%CI)

High-high clusters: Counties with high death rates with neighbors that are also high

Low-low clusters: Counties with low death rates with neighbors that are also low
SOM analysis of drug poisoning deaths involving heroin and cocaine

• Kohonen package in R
  • Running length: 100
  • Learning rate: 0.05-0.01
  • Grid: hexagon

• Variables (all based on age-adjusted spatial empirical Bayes’ estimated rates) for heroin and cocaine:
  • Race: White, Black, Hispanic,
  • Gender: Male, Female,
  • Age: 18-24yrs, 25-34 yrs, 35-54 yrs, over 55 yrs
SOM analysis
SOM results based on age-adjusted spatially smoothed adjusted drug poisoning death rates for heroin and cocaine

Heroin and Cocaine: 18-24 yrs

Heroin and Cocaine: 25-34 yrs or 35-54 yrs
Comparing spatially smoothed death rates involving **both heroin and synthetic narcotics** (2016)

Drug poisoning death rates involving heroin and synthetic narcotics are based on age-adjusted spatial empirical Bayes’ estimation per 100,000 (2016).

**OLS test**
Correlation Coefficient
0.2281741 (99.9% CI)
Spatial clustering based on multi-attribute heroin and synthetic narcotics analysis (2016)

Spatial autocorrelation
Moran’s I value: 0.223332
(99.9%CI)
• A National Drug Early Warning System (NDEWS) HotSpot study* was launched in 2016 in response to the sharp increase in illicit fentanyl-related overdose deaths in New Hampshire

• Geospatial analysis for 505 persons who died between 01/01/2015-09/30/2016 were analyzed as part of this study. Most victims were white, male, 20-39 years

Fantasy deaths:
Differences between location of
deceased's residence and
location of fatal drug use

Locations where deceased fatal drug use and
residence are the same

Trajectories between residence and fatal drug use locations
It should be noted...

• Previous studies have pointed out that drug poisoning deaths data may be understimated as classifying drug poisoning deaths relies heavily on the professional judgment of medical examiners and coroners
  • methods and expertise may vary widely across jurisdictions
  • this could have a substantial impact when analyzing county level drug deaths data
  • Although we have used smoothed estimated rates, results may still be underrepresenting the possible number of deaths.

• In addition, regarding the use of drug-specific drug-involved poisoning deaths (e.g., heroin), there may be variability in attributing drug type to drug poisoning deaths, and frequently there are multiple causes of death. In some cases, researchers have also noted that drug type may not always be available.
Let’s wrap up...

- We investigated **geographic patterns** of drug poisoning deaths involving heroin, cocaine, and synthetic narcotics and found... that **geography matters**...

- Looking at **space** together with **time** reveals trends that are especially important for surveillance and monitoring of substance use and catching emerging trends
  - Counties where deaths from **multiple substances** are high, and locations where **one substance in particular** (e.g., synthetic narcotic such as fentanyl) is associated with high death rates

- Understanding variations in **spatial accessibility** to different treatment options highlights where gaps might exist or improvements made
Acknowledgements

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