HHS Public Access

Author manuscript

Comput Math Organ Theory. Author manuscript; available in PMC 2020 June 23.

Published in final edited form as:

Comput Math Organ Theory. 2019 March ; 25(1): 48–59. doi:10.1007/s10588-018-09283-0.

Global trends, local harms: availability of fentanyl-type drugs on the dark web and accidental overdoses in Ohio

Usha Lokala[1], **Francois R. Lamy**[2], **Raminta Daniulaityte**[1,3], **Amit Sheth**[1], **Ramzi W. Nahhas**[4], **Jason I. Roden**[3], **Shweta Yadav**[1], **Robert G. Carlson**[1,3]

[1]Department of Computer Science and Engineering, Kno.e.sis Center, Wright State University, Dayton, OH, USA [2]Department of Society and Health, Faculty of Social Sciences and Humanities, Mahidol University, Nakhon Pathom, Thailand [3]Department of Population and Public Health Sciences, Center for Interventions, Treatment, and Addictions Research, Boonshoft School of Medicine, Wright State University, Dayton, OH, USA [4]Department of Population and Public Health Sciences, Department of Psychiatry, Boonshoft School of Medicine, Wright State University, Dayton, OH, USA

Abstract

As America's opioid crisis has become an "epidemic of epidemics," Ohio has been identified as one of the high burden states regarding fentanyl-related overdose mortality. This study aims to examine changes in the availability of fentanyl, fentanyl analogs, and other non-pharmaceutical opioids on cryptomarkets and assess relationship with the trends in unintentional overdoses in Ohio to provide timely information for epidemiologic surveillance. Cryptomarket data were collected at two distinct periods of time: (1) Agora data covered June 2014-September 2015 and were obtained from Grams archive; (2) Dream Market data from March-April 2018 were extracted using a dedicated crawler. A Named Entity Recognition algorithm was developed to identify and categorize the type of fentanyl and other synthetic opioids advertised on cryptomarkets. Time-lagged correlations were used to assess the relationship between the fentanyl, fentanyl analog and other synthetic opioid-related ads from cryptomarkets and overdose data from the Cincinnati Fire Department Emergency Responses and Montgomery County Coroner's Office. Analysis from the cryptomarket data reveals increases in fentanyl-like drugs and changes in the types of fentanyl analogues and other synthetic opioids advertised in 2015 and 2018 with potent substances like carfentanil available during the second period. The time-lagged correlation was the largest when comparing Agora data to Cincinnati Emergency Responses 1 month later 0.84 (95% CI 0.45, 0.96). The time-lagged correlation between Agora data and Montgomery County drug overdoses was the largest when comparing synthetic opioid-related Agora ads to Montgomery County overdose deaths 7 months later 0.78 (95% CI 0.47, 0.92). Further investigations are required to establish the relationship between cryptomarket availability and unintentional overdose trends related to specific fentanyl analogs and/or other illicit synthetic opioids.

Francois R. Lamy francois.lam@mahidol.ac.th.

Keywords

Fentanyl; Fentanyl analogs; Illicit synthetic opioids; Cryptomarkets; Opioid overdose; Ohio

1 Introduction

The United States is experiencing the worst opioid epidemic in its history. First fueled by increases in non-medical pharmaceutical opioid use, it escalated further through an increase in heroin addiction (Rudd et al. 2014, 2016). Since 2013–2014, fentanyl has emerged as a significant threat to public health, contributing to unprecedented increases in unintentional drug overdoses in the U.S. (O'Donnell et al. 2017; Somerville et al. 2017). Ohio has been identified as one of the high burden states regarding fentanyl-related overdose mortality (Gladden et al. 2016; Peterson et al. 2016; Daniulaityte et al. 2017a).

Most of these overdoses are linked to non-pharmaceutical fentanyl produced in clandestine laboratories including fentanyl analogs that display massive variability in potency (Ciccarone 2017). Fentanyl is approximately 50–100 times more potent than morphine, while carfentanil is about 100 times more potent than fentanyl (Suzuki and El-Haddad 2017). There is also growing evidence that novel psychoactive drugs such as illicit synthetic opioids are increasingly available online for purchase and distribution through "Darknet markets" or "cryptomarkets," which use advanced encryption techniques to ensure the anonymity and security of unauthorized online transactions (Barratt and Aldridge 2016). Several prior studies have examined cryptomarket data to assess the volume of substances provided, their prices, number of sellers, their revenue and country specificities (Burns et al. 2014; Van Buskirk et al. 2016; Cunliffe et al. 2017; Decary-Hetu et al. 2016). However, there is a limited number of studies monitoring the volume of substances sold on cryptomarkets and none dedicated to fentanyl, fentanyl analogs and other non-pharmaceutical synthetic opioids.

The study builds on an ecological framework (Fielding et al. 2010) that takes into account the complexity of macrosocial and individual factors. These factors contribute to adverse consequences associated with opioid abuse. The study focuses on the impact of one macro-level variable, the changes in the availability of fentanyl, fentanyl analogs and other non-pharmaceutical synthetic opioids on the global illicit drug market assessed through extraction of cryptomarket data. The main aims of the study are to compare and analyze trends in availability of fentanyl, fentanyl analogs, and other non-pharmaceutical synthetic opioids on cryptomarkets and patterns of opioid-related overdoses in Ohio. Results will provide a better understanding concerning the role that cryptomarkets might play in the current opioid crisis.

2 Methods

2.1 Overdose-related data sources

Data on overdose-related indicators included two data sources: (1) data on emergency responses related to opioid overdoses from 01/01/2015 until 02/28/2018 were obtained from

the Cincinnati Fire Department data portal (City of Cincinnati 2018); and (2) data on all accidental drug-related overdose death cases that occurred in Montgomery County (Ohio) from 01/2014 to 05/2018 were obtained from the Montgomery County Coroner's Office (Carlson et al. 2017; Public Health Dayton & Montgomery County 2018).

2.2 Cryptomarket data collection

eDarkTrends, a semi-automated platform, was developed to monitor advertisements of fentanyl, fentanyl analogs, and other non-pharmaceutical synthetic opioids on cryptomarkets to assess availability trends and identify emerging substances. Data sources included two different cryptomarkets—Agora and Dream Market—and covered two distinct time periods to help examine temporal changes. Agora was chosen because it was one of the largest cryptomarkets that emerged after the FBI shut down Silk Road in October 2013 (Greenberg 2014). Agora was eventually shut down in the fall of 2015. Based on data recently crawled by our team (August 2018), Dream Market is the largest existing cryptomarket with over 60,000 ads for drugs.

The archived data from Agora were downloaded from Grams dataset (Branwen et al. 2015) in CSV format. Available data covered the time period from July 2014 until early September 2015 (for a total of 268 crawls). The second dataset was collected from Dream Market since March 2018 using a dedicated crawler. This crawler is able to overcome the security measures integrated into Dream Market. The custom web crawler was developed using the Scrapy framework. It uses custom Scrapy downloader middleware to circumvent security measures. The custom crawler accessed the Deep Web by deploying a Linux virtual machine on AWS running the Tor daemon and Privoxy. Crawler's outputs are raw HyperText Markup Language files (HTML) of drug advertisements with image source attributes removed. Data extraction, storage and access procedures followed strict security measures that were reviewed and approved by the University's Information Security Office. Extracted data included the following information: product name provided by the vendor (these data were used in the current study), vendor screen pseudonym, vendor number of sales and level of trust, drug name(s), drug category, information about the product provided by the vendor, unit, quantity in stock, price (Bitcoin and US$), pricing per volume, country/region of origin, destination country/region and security measures concerning transactions. Web crawling only targeted cryptomarket sections related to synthetic opioids and excluded sections that advertised other types of products. Dream Market was crawled twice in March and five times in April.

2.3 Data processing

Extracted cryptomarket data were further processed to identify relevant drug mentions using the eDarkTrends-dedicated Named Entity Recognition (NER) algorithm (Fig. 1). NER was developed in the Python programming language and integrated the following key components: (1) text segments from collected data were curated and processed using the Natural Language ToolKit (NLTK) library methods; (2) relevant entities were extracted using Regular Expressions compiled based on the Drug Abuse Ontology (DAO) (Cameron et al. 2013; Daniu-laityte et al. 2017b; Lamy et al. 2017) and, (3) Regular Expressions were used to capture objects of interest based on patterns of characters, offering the possibility to

identify product names with minor misspellings. These patterns build on the entities populating the DAO that functions as a domain-specific conceptual framework for interconnecting sets (named “classes”) of drug-focused lexicons. One of the key benefits of using an ontology-enhanced semantic approach is the ability to identify all variants of a concept in data (e.g., generic names, slang terms, scientific names). The DAO contains names of psychoactive substances (e.g., heroin, fentanyl), including synthetic substances (e.g., U-47,700, MT-45), brand and generic names of pharmaceutical drugs (e.g., Duragesic, fentanyl transdermal system) and slang terms (e.g., roxy, fent). It also contains information regarding the route of administration (e.g., oral, IV), unit of dosage (e.g., gr, gram, pint, tablets), physiological effects (e.g., dysphoria, vomiting) and substance form (e.g., powder, liquid, hcl).

Opioid-related mentions were grouped into four categories: (1) non-pharmaceutical (including mentions of “synthetic heroin” and “china white”) and pharmaceutical fentanyl; (2) fentanyl analogs (e.g., acetyl fentanyl, carfentanil, furanyl fentanyl, acryl fentanyl, and other analogs); (3) other novel non-pharmaceutical synthetic opioids (e.g., U-47,700, MT-45, AH-7921); and, (4) any opioid-related mention (including heroin, morphine, and all other pharmaceutical and non-pharmaceutical opioids).

2.4 Data analyses

To examine trends over time, numbers of overdose-related data obtained from Cincinnati EMC and Montgomery County Coroner’s office that occurred each month were calculated and presented in a timeline graph. For cryptomarket data, the average number of ads per day for each month was calculated by summing up the total number of extracted ads mentioning specific drugs for each day and averaging these daily totals over the number of days of crawling that occurred during the specified month (in this way controlling for the fact that some months had fewer days of crawling). Since available Dream Market data only covered the spring of 2018, to compare differences between the two markets and two time periods, we used a portion of Agora dataset that was extracted in the spring of 2015.

Spearman’s rank correlation (and 95% CI) was used to assess the relationship between the availability of fentanyl, fentanyl analogs and other non-pharmaceutical synthetic opioids on cryptomarkets (monthly average number of items posted for sale per day) and overdose-related data obtained from the Cincinnati EMC and Montgomery County Coroner’s Office. Additionally, time-lagged correlations were used to assess if changes in cryptomarket availability were predictive of differences in subsequent EMC responses and overdoses. For example, to compute the time-lagged correlation between Agora posts and overdoses k months later, we would shift the vector of overdose monthly counts by k months so that instead of concurrent (Agora, overdose) pairs we would have (Agora at month k, overdoses at month k + 1), and then compute Pearson correlation between these pairs.

3 Results

In total, 72,751 ads were collected, including 7898 from Dream Market and 72,751 from Agora. Agora data file contained a greater number of items because it included all types of products sold during that time period, while Dream Market data collection focused on

opioid-related section of the cryptomarket. eDarkTrends NER algorithm extracted a total of 10,712 ads that were related to any type of opioid, including 6976 from Dream Market and 3736 from Agora. A total of 866 ads were related to fentanyl, 334 for fentanyl analogs, and 87 for other non-pharmaceutical synthetic opioids.

Extracted cryptomarket data suggest an increase in availability of fentanyl-containing products when comparing average monthly fentanyl, fentanyl analogs and other non-pharmaceutical ads from archived 2015 data and data obtained in the spring of 2018 (Table 1). For example, in March 2015, there were 186 ads on Agora cryptomarket that offered fentanyl-containing products. In March 2018, Dream Market contained an average of 294 ads that offered to sell fentanyl-containing products. Moreover, analysis of the collected data show increased numbers and types of fentanyl analogs offered in 2018 compared to 2015 data. As seen from Table 1, acetyl fentanyl and butyr fentanyl were predominant in 2015, but appeared to have been mostly replaced by furanyl fentanyl, methoxyacetyl fentanyl, 4-fluoroisobutyr-fentanyl, carfentanil and 3-methoxymethylfentanyl in the 2018 dataset. Similarly, other non-pharmaceutical synthetic opioids, such as W-18, MT-45, AH-7921 and U-47,700 were advertised on Agora cryptomarket in 2015, but appear to have been substituted over time (except U-47,700) by newer synthetic opioids (e.g., U-48,800, U-4TDP) according to the data collected on Dream Market. Furthermore, 2015 data from Agora did not contain any ads for carfentanil, one of the most potent fentanyl analogs used in veterinary medicine as large animal tranquilizer, while in March 2018 there were 12 average daily ads for carfentanil on Dream Market (Table 1).

Cincinnati Fire Department data included information about 6061 opioid-related overdose responses that occurred between January 2015 and February 2018. The number of overdose responses increased over time, peaking in September 2016, before decreasing and peaking again in March 2017. The number of emergency responses then slowly decreased to return to 2015–2016 levels (Fig. 1). Montgomery County unintentional overdose death numbers steadily increased from January 2015 to March 2016, followed by a slow decrease before displaying a sharp increase early 2017 with 81 casualties in May 2017. The trend then recedes to 2015–2016 levels (Fig. 2).

Between January 2015 and September 2015, the concurrent correlation between daily average fentanyl, fentanyl analogs and other non-pharmaceutical related Agora ads and Cincinnati EMC overdose responses was 0.50 (95% CI - 0.25, 0.87) (Fig. 3). The time-lagged correlation, however, was largest when comparing Agora to Cincinnati Emergency Responses one month later 0.84 (95% CI 0.45, 0.96). Based on the 16 months from June 2014 through September 2015 for which we have data both for Agora and Montgomery County drug overdoses, the concurrent correlation between the two was - 0.15 (95% CI - 0.60, 0.38) (Fig. 4). The time-lagged correlation, however, was largest when comparing fentanyl, fentanyl analogs and other non-pharmaceutical Agora ads to Montgomery County 7 months later 0.78 (95% CI 0.47, 0.92).

4 Discussion

To the best of our knowledge, this study is the first attempt to analyze correlations between cryptomarket supply of illicit substances and real-world epidemiological data. First, data obtained from Agora market from 2014 to 2015 were compared to more recent fentanyl-related cryptomarket data extracted from Dream Market in the spring of 2018. Trends in fentanyl, fentanyl analogs and other non-pharmaceutical supply from Agora were compared to opioid-related emergency responses in Cincinnati and unintentional overdose deaths in Montgomery County, Ohio. However, there were not enough concurrent months of data available to conduct similar analyses using Dream Market data. Results indicate moderate to strong time-lagged correlations between cryptomarket supply of fentanyl, fentanyl analogs and other non-pharmaceutical synthetic opioids and overdose-related data; however, the confidence intervals are quite wide given the limited sample sizes indicating much uncertainty in these estimates. The observation that the time-lagged correlation between Cincinnati EMC and fentanyl, fentanyl analogs and other non-pharmaceutical synthetic opioid supply on the Darknet was largest at 1 month could be explained by the time required for shipped products to reach destination. However, the longer time-lag at which the correlation between cryptomarket supply of fentanyl, fentanyl analogs and other non-pharmaceutical synthetic opioids and unintentional overdose deaths in Montgomery County was maximized (7 months) requires further investigation to accurately identify potential relations between these two indicators.

We also observed changes in the type of fentanyl analogs advertised on cryptomarkets. These observed changes are concomitant with the forensic reports of the National Forensic Laboratory Information System (NFLIS) from mid 2015 (U.S. Drug Enforcement Administration (DEA) 2016) and from the DEA “Emerging Threat Report” for the first quarter of 2018 (U.S. Drug Enforcement Administration (DEA) 2018). Carfentanil has been found to be responsible for local spikes of overdose deaths in the past 2 years (O’Donnell et al. 2018).

The second main result of this research consists in the platform designed to collect and process Darknet data. The crawlers were created to monitor the quantity of synthetic opioid ads on cryptomarkets that can be shipped to the U.S in order to assess availability trends. The Name Entity Recognition algorithm based on the Drug Abuse Ontology allows extracting all relevant drug names and their characteristics from the cryptomarket advertisements, as well as identifying emerging substances. In future work, we intend to automate all tasks to provide timely data in order to inform public health professionals promptly of changes in synthetic opioid marketing and supply, emerging substances and/or potentially harmful polysubstance mixtures.

Our study is not without limitations. First, overdose-related data that were used in the study did not include information about the types of opioids involved in the overdose events. However, prior research suggests that increases in overdose-related mortality in Montgomery county and other parts of Ohio in the past few years were fueled by illicitly manufactured fentanyl and fentanyl analogs (Daniulaityte et al. 2017a). Second, we cannot directly link the sale and distribution of fentanyl, fentanyl analogs and other non-

pharmaceutical synthetic opioids advertised on the Darknet to Cincinnati or Dayton, Ohio. Cryptomarket data in the current study are used as indirect indicators of fentanyl-related availability at the global level. More research is needed to better understand the destinations of fentanyl, fentanyl analogs and other non-pharmaceutical synthetic opioids products sold through the Darknet and their redistribution. This is becoming even more important considering the large number of ads offering large volumes of synthetic opioids. It is also possible that increases in the availability of fentanyl-related products on the Darknet are related to its sale and distribution to large-scale drug cartels in Mexico or Canada, for example, which may then ship to cities across the US, including Cincinnati and Dayton, Ohio. As we collect more data through the eDarkTrends platform, we will be able to conduct more robust analyses to assess the relationship between cryptomarket availability and unintentional overdose mortality related to specific analogs and/or illicit synthetic opioids (e.g., carfentanil).

Acknowledgements

Funding was provided by National Institute on Drug Abuse (Grant No. 5R21DA044518-02).

Biography

Usha Lokala, M.S, Graduate Research Assistant at Kno.e.sis, Wright State University, Ohio. Her research interests and planned dissertation research closely align with the topics of social machines, social mining and big data ecosystem, and Web and politics (and social/humanitarian/development policy). She is graduate research assistant at Kno.e.sis, where they have a number of projects that involve social, IoT and health big data. Recently, Usha also worked on a challenging cryptomarket crawler and was able to get unique data related to illicit drug products online sale from one of the major crypto market called Dream Market.

Francois R. Lamy, Ph.D., is a Lecturer at the Department of Society and Health, Mahidol University, Thailand. Dr. Lamy was awarded of a double Ph.D in Sociology and Computer Sciences in 2013 for his research on recreational polydrug users that leads to the design of an agent-based model simulating the career of these users. His double degree allows Dr. Lamy to conduct research requiring competences in both fields. Dr. Lamy has experienced in computational social sciences applied to drug use and abuse research including Geographical Informed Systems, Agent-based Modelling, Big Data Analysis and Natural Language Programming. Dr. Lamy is currently Principal Investigator for the eDarkTrends project focusing on availability of synthetic opioids on the Deep Web. His research interests include agent-based modelling applied to drug use and epidemiology, spatial epidemiology, BigData analysis applied to drug use, and crime analysis.

Raminta Daniulaityte, Ph.D., is an Associate Professor and Associate Director at the Center for Interventions, Treatment, and Addictions Research (CITAR) at the Department of Population and Public Health Sciences at Wright State University, Boonshoft School of Medicine. She is also an affiliated faculty member at the Ohio Center of Excellence in Knowledge-enabled Computing (Kno.e.sis) at Wright State University. Dr. Daniulaityte has

15 years of experience conducting drug abuse research, including community-based research with illicit opioid, stimulant, and other drug users, ethnographic and mixed methods research, epidemiological surveillance of emerging substance use patterns and trends, and social media and web-based studies. Currently, she leads three NIDA-funded studies that focus on illicit opioid use. Dr. Daniulaityte has experience in leading interdisciplinary projects and has successfully collaborated with the Computer Science and Engineering Department at Wright State to adapt advanced computational techniques for extraction of web-based data for drug abuse research.

Amit Sheth, Ph.D, is an Educator, Researcher and Entrepreneur. He is the LexisNexis Ohio Eminent Scholar, executive director of Kno.e.sis-Ohio Center of Excellence in Knowledge-enabled Computing and BioHealth Innovations, an IEEE Fellow, and an AAAI fellow. He is currently leading projects encompassing collection and analysis of social, IoT/wearable, and clinical big data for personalized digital health, public health and epidemiology applications involving pediatric asthma, bariatric surgery, dementia, mental health, opioid crisis, etc. He has founded three companies, cofounded two and several commercial products and deployed systems have resulted from his research. http://knoesis.org/amit/.

Ramzi W. Nahhas, Ph.D., is an Associate Professor in the Department of Population and Public Health Sciences and the Department of Psychiatry, Boonshoft School of Medicine, Wright State University. He received his PhD in Biostatistics from The Ohio State University in 1999. He is highly active in collaborative projects, utilizing modern statistical and epidemiological methods to analyze data from a wide range of biomedical research areas, including public health, psychiatry, illicit drug use, childhood growth and development, and obesity. Additionally, he serves as the resident biostatistician for WSU's Center for Interventions, Treatment, and Addictions Research and the Department of Psychiatry, engaged in statistical collaboration and training of residents and fellows.

Jason I. Roden is a graduate student at Wright State University studying to become a Clinical Mental Health counselor. He is interested in the process of addiction and helping clients who struggle with it. He is honored to have had the opportunity to contribute to research in the field and hopes to continue to do so in the future.

Shweta Yadav, M.S, is a Ph.D. student in the department of Computer Science and Engineering, Indian Institute of Technology Patna, India. Her current research interests include Natural Language Processing, information extraction, machine learning applications, Opinion Mining, and Text mining in the biomedical and clinical domain. In these areas she has authored or coauthored 14 papers in the journals like Soft Computing, Knowledge and Information System; and several international conferences (EACL, NAACL, ICPR, NLDB, LREC).

Robert Carlson, Ph.D., is Director of the Center for Interventions, Treatment and Addictions Research and Professor in the Department of Population and Public Health Sciences, Wright State University Boonshoft School of Medicine. He received his Ph.D. in Cultural Anthropology from the University of Illinois at Urbana-Champaign in 1989. Since 1989, Dr. Carlson has conducted ethnographic and mixed-methods research on HIV risk

behaviors, epidemiologic trends, and health services use among injection drug and other non-medical drug users in Ohio. Recently, he was Principal Investigator of an R56 NIH award to construct a national emerging drug surveillance network combining data streams from a network of medical toxicologists who work in emergency departments and analysis of social media data on substance abuse. His research interests include ethnographic methods, the epidemiology of non-medical drug use, natural history research, HIV prevention, social media research, health services research, and the political economy of substance use.

References

Barratt MJ, Aldridge J (2016) Everything you always wanted to know about drug cryptomarkets* (*but were afraid to ask). Int J Drug Policy 35:1–6 [PubMed: 27523571]

Branwen G, Christin N, Décary-Hétu D, Munksgaard R, Presidente E (2015) Dark net market archives, 2011–2015. Retrieved 8, 28

Burns L, Roxburgh A, Bruno R, Van Buskirk J (2014) Monitoring drug markets in the internet age and the evolution of drug monitoring systems in Australia. Drug Test Anal 6(7–8):840–845 [PubMed: 24574080]

Cameron D, Smith GA, Daniulaityte R, Sheth AP, Dave D, Chen L, Anand G, Carlson R, Watkins KZ, Falck R (2013) PREDOSE: a semantic web platform for drug abuse epidemiology using social media. J Biomed Inform 46:985–997 [PubMed: 23892295]

Carlson R, Li L, Daniulaityte R (2017) Montgomery county poisoning death review, 2010–2016

Ciccarone D (2017) Fentanyl in the US heroin supply: a rapidly changing risk environment. Int J Drug Policy 46:107–111 [PubMed: 28735776]

City of Cincinnati (2018) Heroin overdoses. https://insights.cincinnati-oh.gov/stories/s/Heroin/dm3s-ep3u. Accessed 21 Aug 2018

Cunliffe J, Martin J, Decary-Hetu D, Aldridge J (2017) An island apart? Risks and prices in the Australian cryptomarket drug trade. Int J Drug Policy 50:64–73 [PubMed: 29055855]

Daniulaityte R, Juhascik MP, Strayer KE, Sizemore IE, Harshbarger KE, Antonides HM, Carlson RR (2017a) Overdose deaths related to fentanyl and its analogs—Ohio, January-February 2017. MMWR Morb Mortal Wkly Rep 66:904–908 [PubMed: 28859050]

Daniulaityte R, Lamy FR, Smith GA, Nahhas RW, Carlson RG, Thirunarayan K, Martins SS, Boyer EW, Sheth A (2017b) “Retweet to pass the blunt”: analyzing geographic and content features of cannabis-related tweeting across the United States. J Stud Alcohol Drugs 78:910–915 [PubMed: 29087826]

Decary-Hetu D, Paquet-Clouston M, Aldridge J (2016) Going international? Risk taking by cryptomarket drug vendors. Int J Drug Policy 35:69–76 [PubMed: 27453145]

Fielding J, Teutsch S, Breslow L (2010) A framework for public health in the United States. Public Health Rev 174:176–177

Gladden RM, Martinez P, Seth P (2016) Fentanyl law enforcement submissions and increases in synthetic opioid-involved overdose deaths—27 States, 2013–2014. MMWR Morb Mortal Wkly Rep 65:837–843 [PubMed: 27560775]

Greenberg A (2014) Drug market ‘Agora’ replaces the ‘silk road’ as king of the dark net. In: Wired. https://www.wired.com/2014/09/agora-bigger-than-silk-road/. Accessed 21 Aug 2018

Lamy FR, Daniulaityte R, Nahhas RW, Barratt MJ, Smith AG, Sheth A, Martins SS, Boyer EW, Carlson RG (2017) Increases in synthetic cannabinoids-related harms: results from a longitudinal web-based content analysis. Int J Drug Policy 44:121–129 [PubMed: 28578250]

O’Donnell JK, Halpin J, Mattson CL, Goldberger BA, Gladden RM (2017) Deaths involving fentanyl, fentanyl analogs, and U-47700—10 states, July-December 2016. MMWR Morb Mortal Wkly Rep 66:1197–1202 [PubMed: 29095804]

O'Donnell J, Gladden RM, Mattson CL, Kariisa M (2018) Notes from the field: overdose deaths with carfentanil and other fentanyl analogs detected—10 states, July 2016-June 2017. Morb Mortal Wkly Rep 67:767

Peterson AB, Gladden RM, Delcher C, Spies E, Garcia-Williams A, Wang Y, Halpin J, Zibbell J, McCarty CL, DeFiore-Hyrmer J, DiOrio M, Goldberger BA (2016) Increases in fentanyl-related overdose deaths—Florida and Ohio, 2013–2015. MMWR Morb Mortal Wkly Rep 65:844–849 [PubMed: 27560948]

Public Health Dayton & Montgomery County (2018) Accidental overdose death totals, Mongomery County, Ohio, 2017

Rudd RA, Paulozzi LJ, Bauer MJ, Burleson RW, Carlson RE, Dao D, Davis JW, Dudek J, Eichler BA, Fernandes JC, Fondario A, Gabella B, Hume B, Huntamer T, Kariisa M, Largo TW, Miles J, Newmyer A, Nitcheva D, Perez BE, Proescholdbell SK, Sabel JC, Skiba J, Slavova S, Stone K, Tharp JM, Wendling T, Wright D, Zehner AM, Control Centers for Disease, and Prevention (2014) Increases in heroin overdose deaths—28 States, 2010 to 2012. MMWR Morb Mortal Wkly Rep 63:849–854 [PubMed: 25275328]

Rudd RA, Aleshire N, Zibbell JE, Gladden RM (2016) Increases in drug and opioid overdose deaths—United States, 2000–2014. MMWR Morb Mortal Wkly Rep 64:1378–1382 [PubMed: 26720857]

Somerville NJ, O'Donnell J, Gladden RM, Zibbell JE, Green TC, Younkin M, Ruiz S, Babakhanlou-Chase H, Chan M, Callis BP, Kuramoto-Crawford J, Nields HM, Walley AY (2017) Characteristics of fentanyl overdose—Massachusetts, 2014–2016. MMWR Morb Mortal Wkly Rep 66:382–386 [PubMed: 28406883]

Suzuki J, El-Haddad S (2017) A review: fentanyl and non-pharmaceutical fentanyls. Drug Alcohol Depend 171:107–116 [PubMed: 28068563]

U.S. Drug Enforcement Administration (DEA) (2016) National Forensic Laboratory Information System: Midyear Report 2015. U.S. Drug Enforcement Administration, Springfield

U.S. Drug Enforcement Administration (DEA) (2018) Emerging threat report, first quarter 2018. U.S. Drug Enforcement Administration, Springfield

Van Buskirk J, Naicker S, Roxburgh A, Bruno R, Burns L (2016) Who sells what? Country specific differences in substance availability on the Agora cryptomarket. Int J Drug Policy 35:16–23 [PubMed: 27520115]

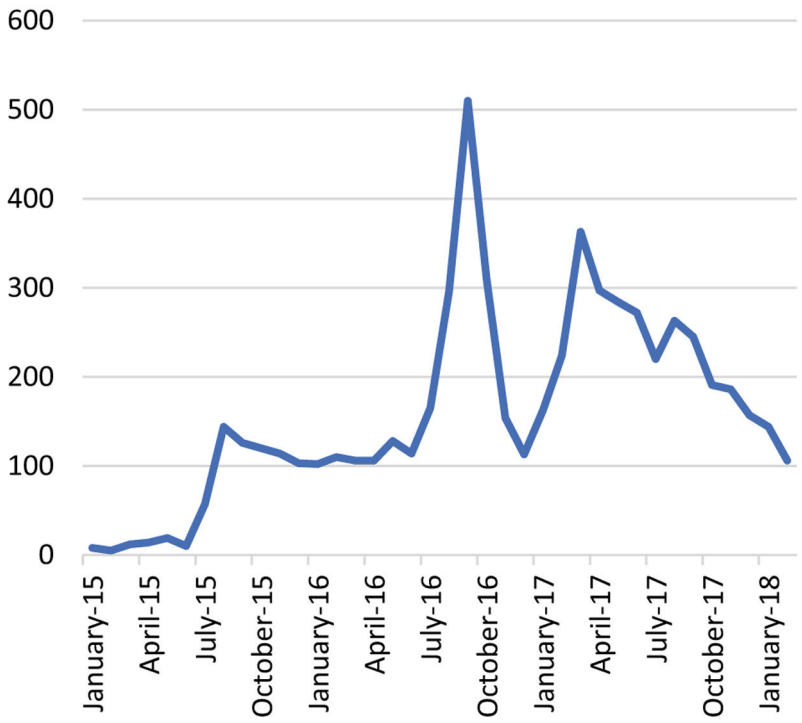

Fig. 1.
Cincinnati fire department responses for opioid overdoses, by month (2015–2018)

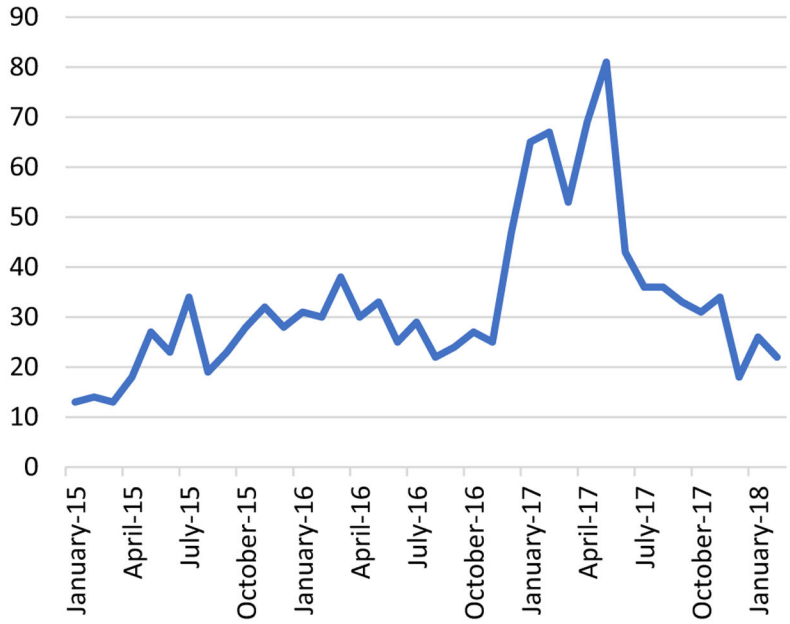

Fig. 2.
Unintentional overdose deaths in Montgomery County, by month (2015–2018)

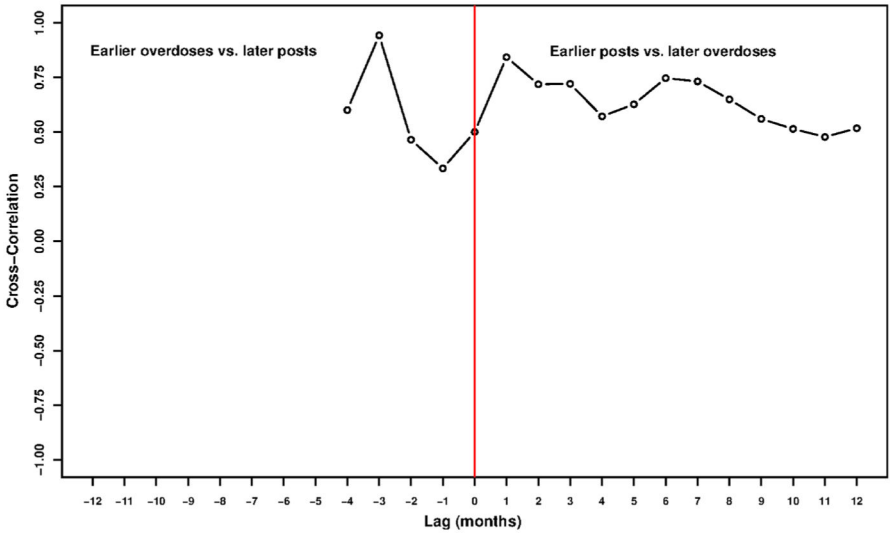

Fig. 3.

Time-lagged correlation between daily average Agora ads and total Cincinnati EMC overdose responses, by month (January 2015 to September 2015)

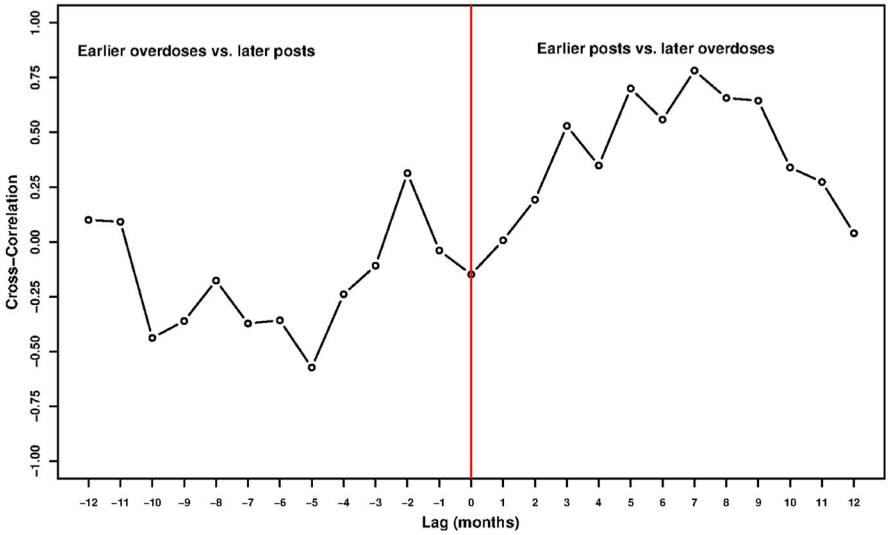

Fig. 4.

Time-lagged correlation between daily average Agora ads and total Montgomery County overdose deaths, by month (June 2014 through September 2015)

Table 1

Average number of fentanyl, fentanyl analogs and other non-pharmaceutical synthetic opioids advertised on cryptomarkets

Type of substances	Average number of ads per day, by month (number of crawls)				
	AGORA			Dream market	
	03/2015	04/2015	05/2015	03/2018	04/2018
Fentanyl[a]	130	174	139	207	216
Fentanyl analogs					
Acetyl fentanyl	44	39	41	3	1
Butyr fentanyl	12	10	17	6	7
Carfentanil	0	0	0	12	5
Furanyl fentanyl	0	0	1	31	39
MethoxyAcetyl fentanyl	0	0	0	14	14
4-FluoroIsoButyr fentanyl	0	0	0	19	16
3-MethoxyMethyl fentanyl	0	0	0	2	2
Total, fentanyl analogs	56	49	59	87	84
Other non-pharmaceutical synthetic opioids					
U-47,700	5	4	5	0	3
W-18	5	4	5	0	0
MT-45	9	8	9	0	0
AH-7921	0	0	1	0	0
U-48,800	0	0	0	1	7
U-49,900	0	0	0	0	1
U-4TDP	0	0	0	0	4
U-50,488	0	0	0	8	4
MPF-47700	0	0	0	0	5
Total, other NP synth opioids	19	16	20	9	24
Other opioids[b]	827	1061	1152	3211	3137
Total (any opioids)	1033	1300	1370	3512	3460

[a] Includes mentions of Fentanyl, China White Heroin, Synthetic Heroin, and mentions of pharmaceutical fentanyl, such as Duragesic, fentanyl patches, fentanyl transdermal system

[b] Includes mentions of heroin, opium, morphine and other types of pharmaceutical opioids (e.g., hydrocodone, oxycodone, hydromorphone) excluding pharmaceutical fentanyl