Global trends, local harms: Availability of Fentanyl-Type Drugs on the Dark Web and Accidental Overdoses in Ohio

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1. Abstract

As America's opioid crisis has become an epidemic of epidemics, Ohio has been identified as one of the high burden states regarding IMF-related overdose mortality. Hence, the need for the study of drug abuse and responsive prevention plays a considerable role in providing reliable and timely information to public health professionals. Ours is the first study to collect and analyze data on fentanyl and other synthetic opioid availability on cryptomarkets and to examine the association between local opioid-related overdose death trends. The main aims of the study are to compare and analyze the relationship between trends in availability of synthetic opioids on dark web and patterns of opioid-related overdoses in Ohio. We believe the hypothesis that monitoring the trends in illicit opioid supply and availability in cryptomarkets offers a valuable source of information for epidemiological surveillance by providing timely data regarding emerging substances and product forms. In this study, we present several statistics of availability of fentanyl drugs and its analogs. Also, We show the correlation between the availability of substances and overdose responses in Cincinnati fire department and Montgomery County Coroners Office Data.

2. Introduction

The United States is experiencing the worst opioid epidemic in its history. First fueled by increases in non-medical pharmaceutical opioid use, it was further escalated by the rise in heroin addiction (Rudd, Aleshire, Zibbell, & Matthew Gladden, 2016)(Rudd et al., 2014).

Since 2013-2014, illicitly manufactured fentanyl (IMF) has emerged as a significant threat to public health, contributing to unprecedented increases in unintentional overdoses in the U.S.(Rudd, 2016). Ohio has been identified as one of the high burden states regarding IMF-related overdose mortality (Rudd, 2016; Gladden, 2016; Daniulaityte, Juhascik, et al., 2017).

IMF is produced in clandestine laboratories and includes fentanyl analogs that display massive variability in potency. Fentanyl is approximately 50-100 times more potent than morphine, while carfentanil is about 100 times more potent than fentanyl (Suzuki & 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 th-rough ”Darknet markets”or ”cryptomarkets,”which use advanced encryption techniques to ensure the anonymity and security of unauthorized online transactions.(EMCDDA, 2013; Barratt, 2012; Buxton & Bingham, 2015; Van Hout & Bingham, 2014; Vo, van Wijk, Wu, Lynch, & Ho, 2017). A semi automated platform called eDarkTrends is de-veloped to monitor illicit online transactions of several synthetic opioids in dark web (F. Lamy & Sheth, n.d.).In this platform,Dark Web markets can be accessed using the TOR network and provide potential buyers with the ability to purchase opioid, (see Fi-gure 1) among other illicit drugs, anonymously. Particularly, as cannabis legalization issue in the U.S. has been a trending topic in the country as well as social media, Our team has Prior research on Twitter data analysis in this domain and such analysis proved effective for epidemiological prediction of emerging new drug trends (Ugur et al., 2018).

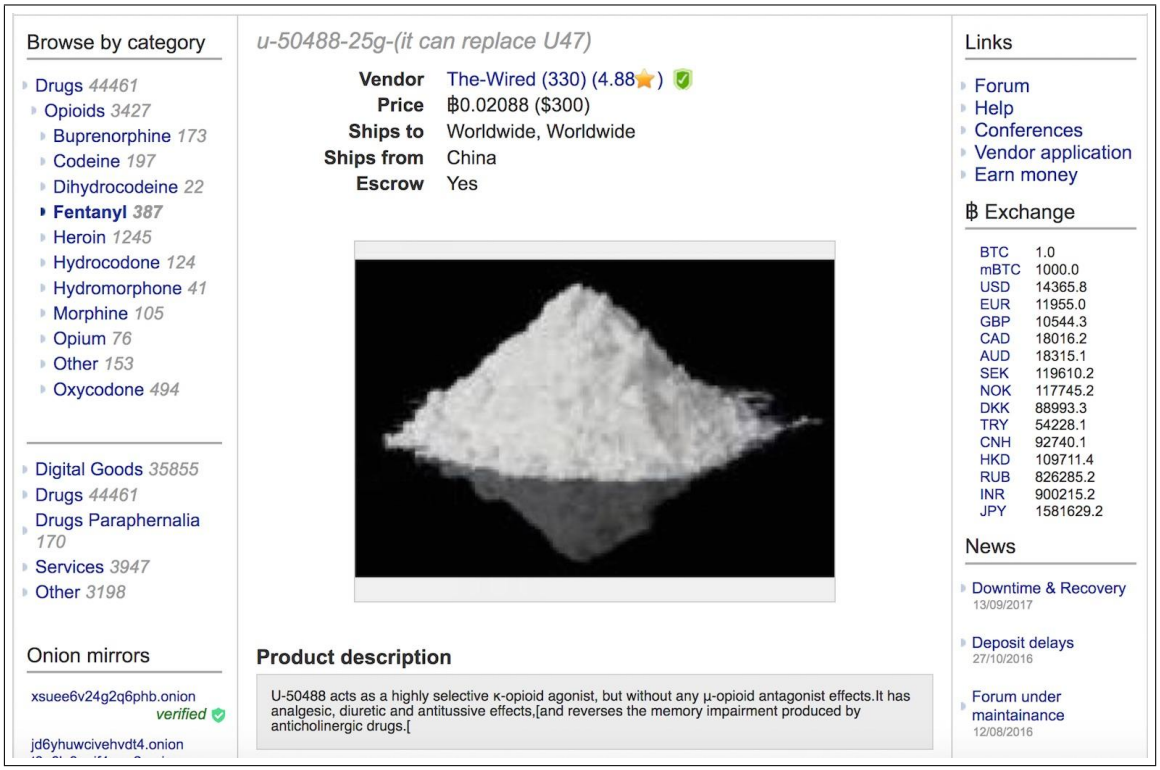

Figure. 1. Product Description

2.1. Theoretical framework

The study builds on the ecological framework that takes into account the complexity of macro, social and individual factors. These factors contribute to adverse consequences associated with opioid abuse (Fielding, Teutsch, & Breslow, 2010).The study focuses on one of the macro-level variables such as changes in the availability of drug supplies on the global illicit drug market which is assessed through crawling crypto market twice a week.

2.2. Research Aims

The main aims of the study are to compare and analyze the relationship between trends in availability of synthetic opioids on dark web and patterns of opioid-related overdoses in Ohio. For this purpose we use the following three data sets:
1) Cincinnati Fire Department Data `https://data.cincinnati-oh.gov/Safer-Streets/Cincinnati-Fire-Incidents-CAD-including-EMS-ALS-BL/vnsz-a3wp`
2)Accidental Overdose Death Cases analyzed at the Montgomery County Coroners Toxicology Laboratory `http://www.phdmc.org/coat/158-accidental-overdose-death-totals`
3) Cryptomarket/Dark Web product data.

2.3. Importance of the challenge in the context of Opioid crisis

Our findings could inform more timely interventions and policy responses to address problems inherent in changes in illicit drug marketing and supply

2.4. Novel contribution

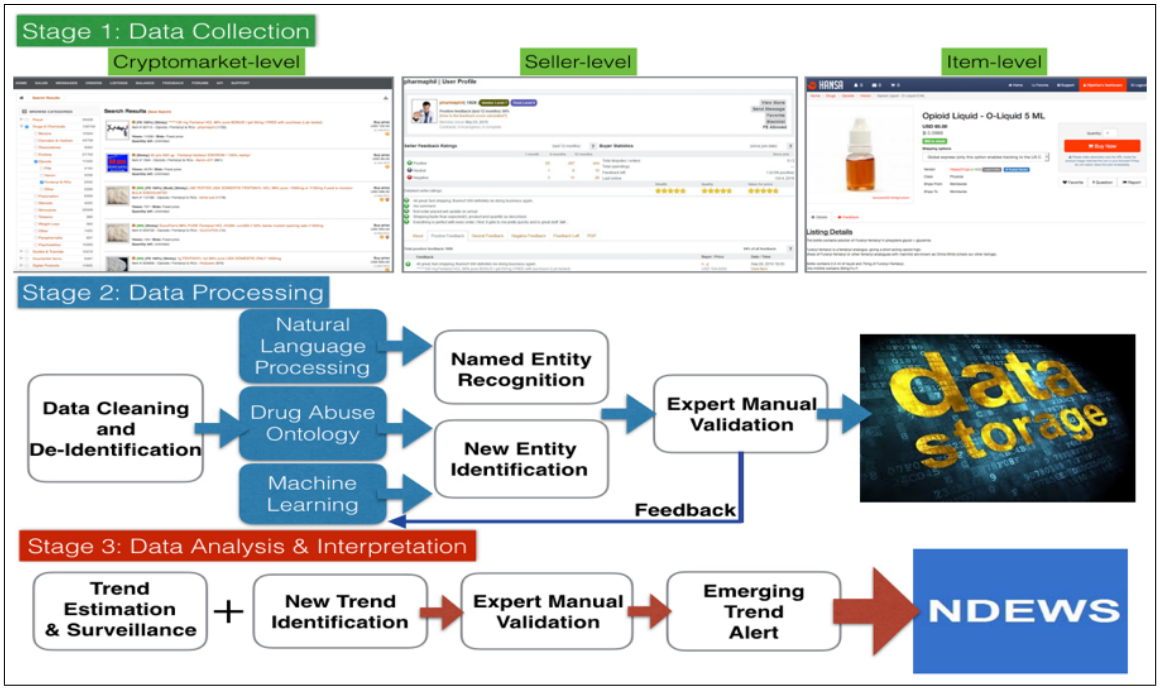

Figure. 2. eDarkTrends Global Architecture

Ours is the first study to collect and analyze data on fentanyl and other synthetic opioid availability on cryptomarkets and to examine the association between local opioid-related overdose death trends. This projects contributions consist of (1) the development of crawlers (i.e., automated software indexing web page content) dedicated to the Dark Web environment, which appeared to be a challenging task considering the security measures taken by cryptomarkets to guarantee the anonymity of their users; (2) the automated parsing of the data collected by the crawlers, and; (3) the implementation of a Named Entity Recognition algorithm based on our Drug Abuse Ontology to enable extraction of information related to the type of substances, dosage, form, and quantity of product advertised on dark Web markets. The combination of these three innovative components allows this study to semi-automatically capture and analyze the volume and variety of synthetic opioids sold on the Dark Web promptly.

3. Methods

3.1. Data Collection

Cincinnati Fire Department. Data from the Cincinnati Fire Department from 01/01/2015 until 02/28/2018 were first screened to extract only the emergency responses related to opioid overdoses. We selected entries based on the following criteria. Data from the field CFD INCIDENT TYPE GROUP marked as HEROIN OVERDOSE or OVERDOSE/POISONING (INGESTION) is selected. For responses under the field OVERDOSE/POISONING (INGESTION) category, we considered field INCIDENT TYPE DESC marked either as OVERDOSE/NARCOTICS or NARCOTICS or UNCONSCIOUS. For responses marked as UNCONSCIOUS, we finally selected either NAR: NARCAN ADMIN NO TRANSPORT or NART: NARCAN ADMIN TRANSPORT in the field DISPOSITION TEXT. Narcan is considered to be administered only in case of opioid overdoses. We further screened the data by removing the CANCEL INCIDENT cases.

Montgomery County Accidental Drug-Related Overdose Data: Data on all accidental drug-related overdose death cases were obtained from the Montgomery County Coroners Office. The data collected is from 2010 to 2017 and included information about drugs identified during postmortem toxicological analyses.

Cryptomarket Data: We include two datasets: i) The archived data from Agora market obtained from Grams dataset from July 2014 until August 2015, and ii) Recent data crawled from Dream Market between the 03/22/2018 and 04/26/2018. The second dataset was collected by using a newly developed crawler 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 which cycles through cookies of active sessions of multiple user accounts (randomly) to circumvent the site's anti-DDoS measures. The custom crawler accessed the DeepWeb by deploying a Linux virtual machine on AWS running the Tor daemon and Privoxy. Crawlers outputs are raw HyperText Markup Language files (HTML) of drug advertisements with image source attributes removed. Strict security measures are taken for securing access and storage of data given the sensitive nature of the data and the IRB protocol. For this particular project, we extend the normal reach of eDarkTrends by collecting all opioid advertisements to facilitate the comparison with the Cincinnati Fire Department and the Montgomery County, Ohio, Coroners office data.

3.2. Data Processing and Analysis

Once the ads are crawled, and the HTML files are processed, relevant data is extracted from the advertisement texts by using the eDarkTrends-dedicated Named Entity Recognition (NER) algorithm, developed in the Python programming language. Firstly, text segments from collected data are curated and processed using the Natural Language ToolKit (NLTK) library methods. Then, relevant entities are extracted using Regular Expressions compiled based on the Drug Abuse Ontology (DAO) (Cameron et al., 2013) (Daniulaityte, Lamy, et al., 2017) (Daniulaityte, Carlson, Brigham, Cameron, & Sheth, 2015) (F. R. Lamy et al., 2017). The Regular Expressions capture objects of interest based on patterns of characters, offering the possibility to identify product names with a minor misspelling. 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. The DAO contains names of psychoactive substances (e.g., heroin, fentanyl), synthetic opioids (e.g., U-47,700, JWH-018), and slang terms (e.g., roxy, spice). 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). The NER was used to extract entities from both collected datasets (Agora and DreamMarket) and its results aggregated by month for further comparisons. Pearsons correlation analysis is used to assess the relationship between the availability of fentanyl-type drugs and other synthetic opioids on cryptomarkets (average number of items posted for sale per month). Then the analysis is done between two outcome variables–a) number of Cincinnati EMC responses to opioid overdose per month; and b) number of accidental drug overdose deaths in Montgomery County per month. Additionally, time-lagged correlations will be used to assess if changes in cryptomarket availability are predictive of differences in subsequent EMC responses and overdoses.

4. Results

After curation of the Cincinnati Fire Department data, 6061 opioid-related overdose responses were identified between January 2015 and February 2018 (Figure 5). Also, Montgomery County Coroners Office Data is analyzed, and unintentional overdose deaths are recorded periodically from January 2015 to January 2018 (Figure 6). Also, Cryptomarket datasets like Agora(03/01/2015 till 05/29/2015) and Dream(03/22/2018 till 04/26/2018) are used to extract the average number of products advertised for fentanyl, Opiate and Synthetic opioids category through Named Entity Recognition algorithm as discussed previously. We plotted graphs for all the average number of ads daily in Agora and Dream. Also, We plotted overdose responses in Cincinnati and Montgomery County for the ease of Visualization and correlation (Figure 4). We also presented a statistical analysis of Fentanyl, its analogs and synthetic opioid counts in Agora and Dream market (Table 2,3) and their time-lagged correlation with overdose responses in Cincinnati and Montogomery (Figure 6). Also, we aggregated the average count of Fentanyl, its analogs and synthetic opioids in Agora and Dream through NER (Table 1)

5. Conclusion and Future work

The study done here is highly innovative as this is the first study to track and describe trends in illicit synthetic opioid supply on two cryptomarkets for epidemiological moni-

toring in Cincinnati and Montgomery County. The crawlers are created for U.S-focused cryptomarket tracking of illicit synthetic opioids supply and availability trends, and we made use of NER and drug abuse ontology to extract all the relevant drug names from the product names mentioned in crypto markets. The Cincinnati Fire Incidents data provided is quite similar to the Road Accidents data that we did a prior analysis on and built a classification model to classify the accident type from which we can adapt the same to this data in order to classify several incident types into the broad category from which we can understand the incident type in a opioid overdose context (Lokala, Sharma, & Nowduri, 2017). Classifying overdose responses by type can enable better capturing and highlighting of aspects such as trending topics, business profiling of cryptomarket products, and state-specific overdose responses (Kursuncu et al., 2018). In future, we intend to implement the automation of all the tasks discussed here from end to end process without much manual intervention. This helps us to do the cryptomarket research much efficiently to identify new emerging products automatically and explore several drug forms and combinations.

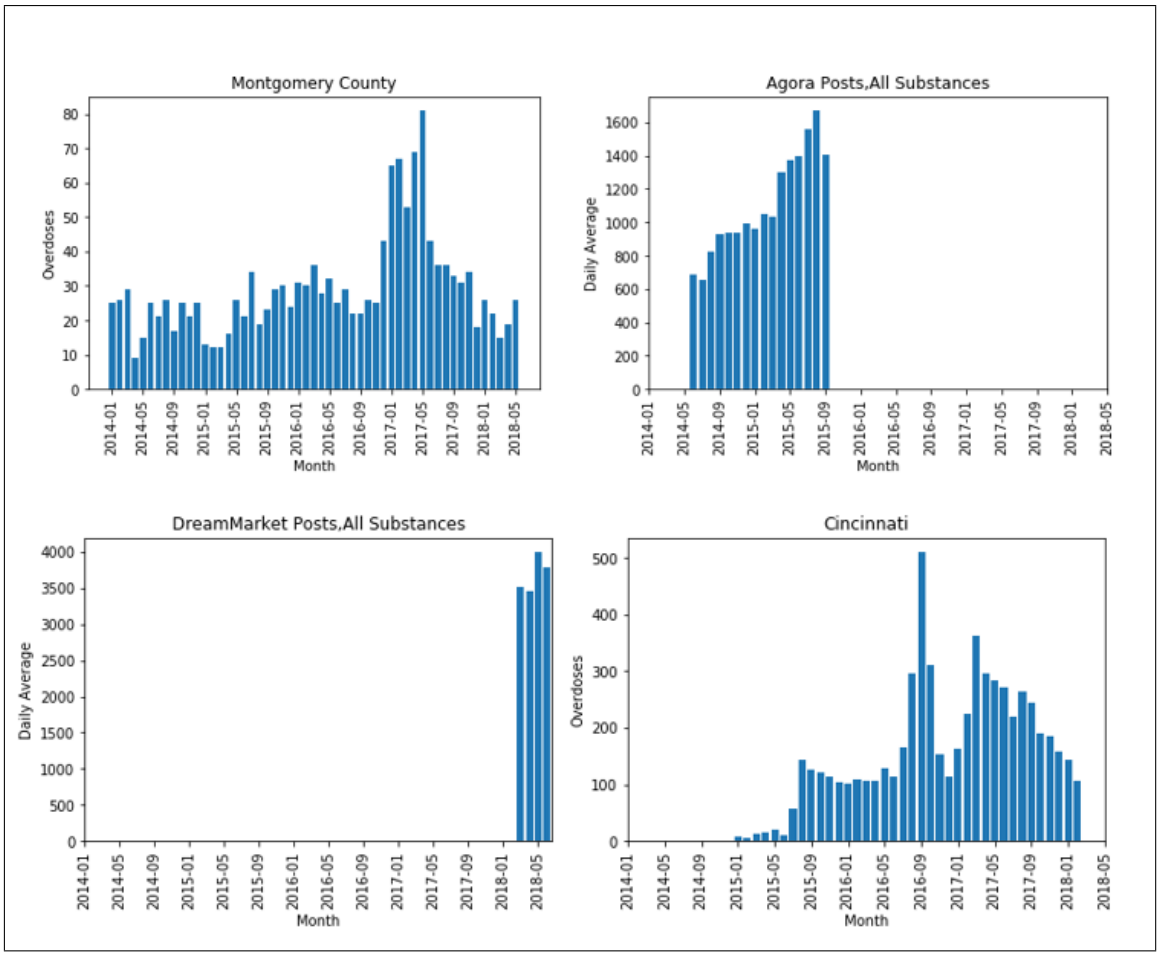

Figure. 3. Agora and Dream substances from 01/2014 till 05/2018

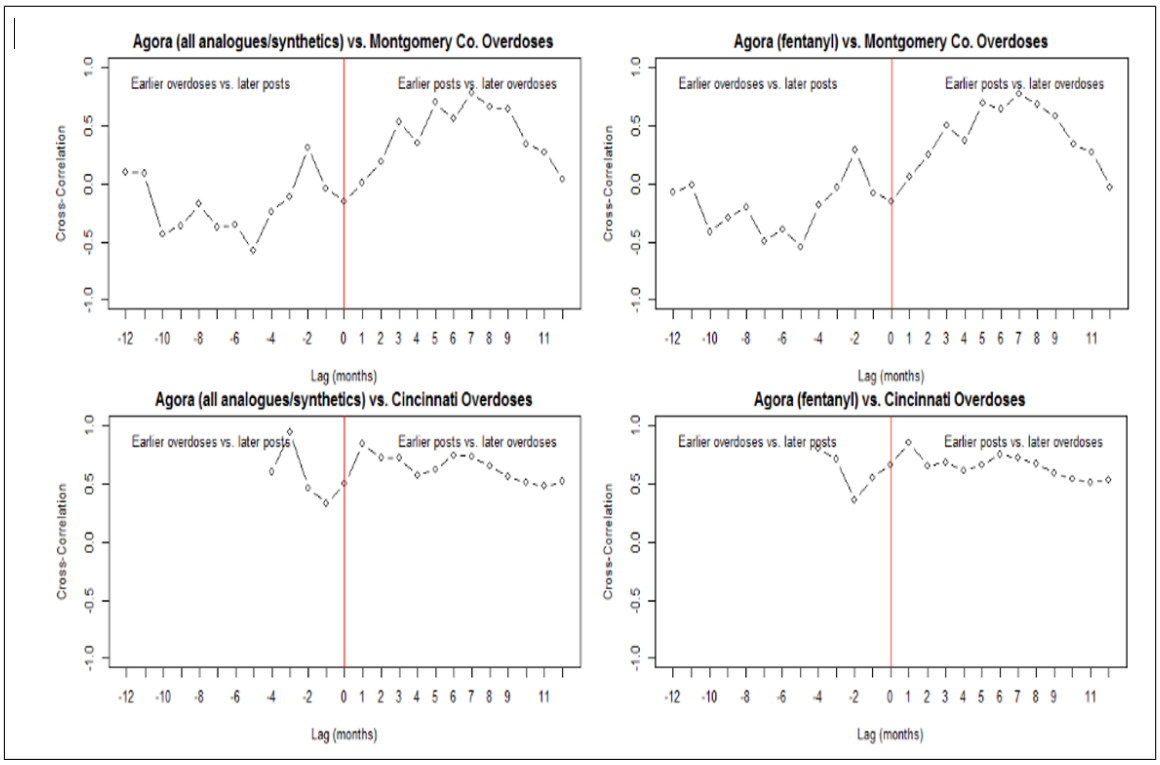

Figure. 4. Time lag co-relations between crypto-market data and overdose responses

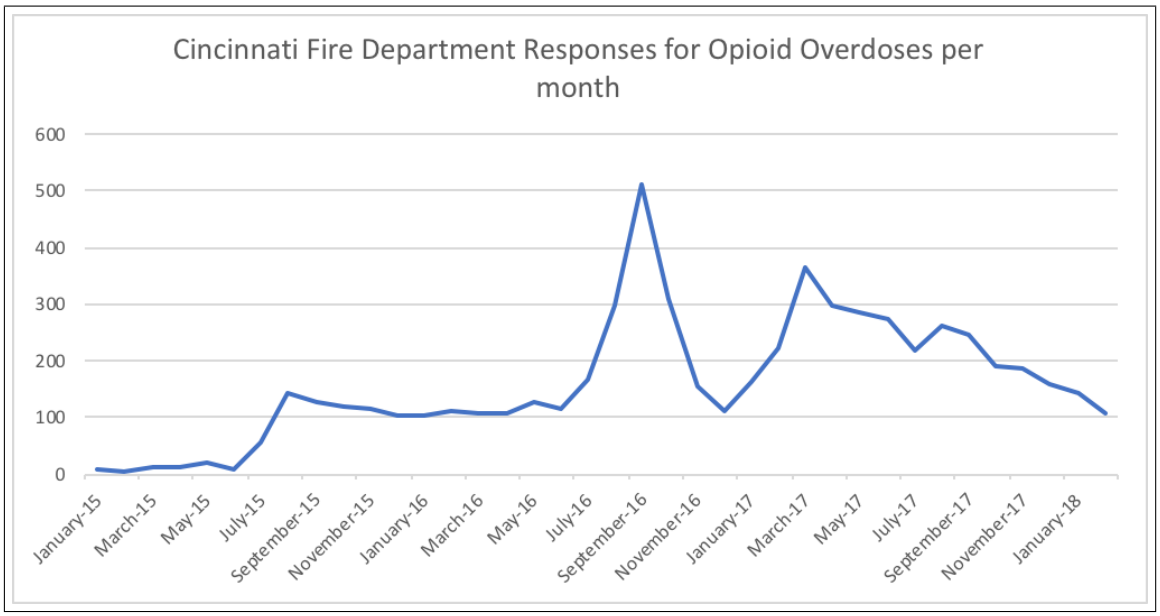

Figure. 5. Cincinnati Fire Department Response for Opioid Overdoses from 01/2015-02/2018

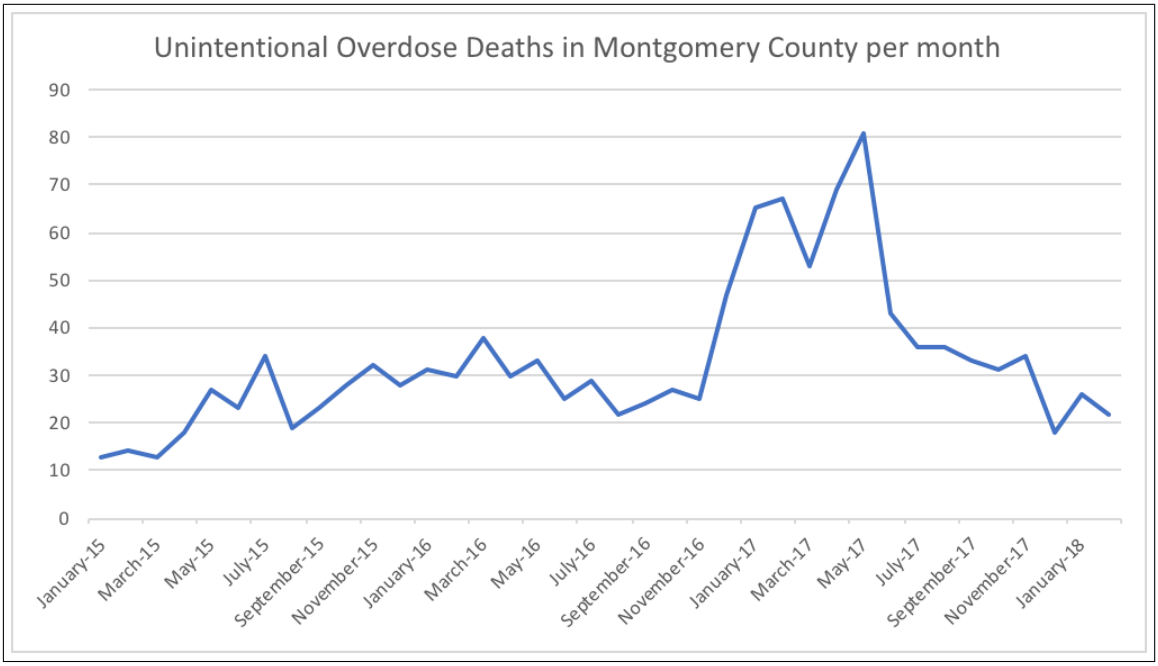

Figure. 6. Montgomery County Overdose Responses

Tabela 1. Aggregated Results from Dream and Agora through NER

Dream Market Products Statistics (03/22/2018 - 04/26/2018)					
Time Period	**No of Ads**	**Avg all Opioids**	**Avg Fentanyl**	**Avg Synth Opioids**	**Avg Opiates Ads**
March 2018	3804	3497	289	9	3199
April 2018	4094	3479	283	23	3173
Agora Market Products Statistics (03/01/2015 - 05/29/2015)					
Time Period	**No of Ads**	**Avg all Opioids**	**Avg Fentanyl**	**Avg Synth Opioids**	**Avg Opiates Ads**
March 2018	21389	1045	170	19	856
April 2018	21624	1313	203	16	1094
May 2018	21840	1378	183	20	1175

Avg :Average ; Ads : Advertisements

Tabela 2. Agora Fentanyl Counts

Agora Fentanyl Counts	Counts	Agora Fentanyl Counts	Counts
4 heroin fentanyl	0	fentanyl fentanyl	79
4 heroin china white	170	fentanyl heroin	152
chinawhite	258	fentanyl oxycontin	11
chinawhite heroin	269	fentanyl syntheticheroin chinawhite	9
china white heroin fentanyl	69	oxy fentanyl	0
china white heroin morphine	107	oxycodone a215 fentanyl	80
chinawhite syntheticheroin	131	oxycodone fentanyl	35
chinawhite syntheticheroin fentany	69	percocet fentanyl	279
fentany	2	suboxone fentanyl e	273
fentanyl	273	syntheticheroin chinawhite	93

Tabela 3. Agora Fentanyl analogues

Fentanyl analogues + Carfentanyl	Counts	Fentanyl analogues + Carfentanyl	Counts
1- Acetylfentanyl	325	7-3 methylfentanyl	13
2-butyrfentanyl	468	8-paramethoxyacetylfentanyl	107
3-furanyl fentanyl	107	9-Buff	0
4-fluorosibutyrfentanyl	0	10- carfentanyl	39
5-fluorofentanyl	44	11 - carfentanil	0
6-methoxyacetylfentanyl	0	12 - Synthetic Opioids	0

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