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Leveraging black-market street buprenorphine pricing to increase capacity to treat opioid addiction, 2010–2018

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Abstract

Increasing capacity to provide buprenorphine, a treatment for opioid addiction, can help mitigate the opioid epidemic in the United States. This study models black-market pricing of buprenorphine to better understand supply and demand for opioid addiction treatment. A mixed effects linear model was used to quantify the effect of county-level racial composition, health insurance coverage, and drug characteristics on price variation. From November 2010 to June 2018, there were 2481 submissions for street buprenorphine transactions in the StreetRx dataset. The mean price was $3.95/mg (SD=$23.12/mg). Price decreased 3.05% each year and was highest in the summer and spring. Brand name buprenorphine was on average 11.18% more expensive than generic buprenorphine. Buprenorphine/naloxone combinations were on average 19.75% less expensive than pure buprenorphine. Purchases in bulk were on average 10.51% cheaper than purchases not in bulk. Street buprenorphine in film form was on average 14.34% more expensive than in pill/tablet form. Buprenorphine street price was 17.12% higher in spring and 22.26% higher in summer compared to fall. For every percentage point increase in percent white, buprenorphine sold for 0.88% higher price. For every percentage point increase in health insurance coverage, street buprenorphine sold for 0.02% lower price. Findings demonstrate that geographic, demographic, and socioeconomic factors shape the diversion of opioid addiction treatment to the

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Author contribution

YH retrieved funding, was in charge of the overall direction and planning, designed the study, devised the models, interpreted the results, and took the lead in writing the manuscript. AZ devised the models, performed the analysis, contributed to the design, interpreted the results and helped write the manuscript. JSB retrieved funding, helped shaped the research, provided critical feedback and input.

black-market. Buprenorphine street pricing can help estimate public need, gaps in care and emerging public health priorities.

Keywords

Street Drugs; Black-market; Opioid Epidemic; Opiate Substitution Treatment; Medicated Assisted Treatment; Buprenorphine; Addiction; Access to Health Care; Health Insurance

Introduction

The opioid epidemic has risen to massive proportions in the past decade. In 2017, an estimated 1.7 million people in the United States suffered from substance use disorders related to prescription opioids and more than 47,000 Americans died as a result of opioid overdose (1). Buprenorphine is an effective, office-based medicated assisted treatment for opioid addiction with low abuse potential (2). As an opioid partial agonist that produces euphoric effects similar to full opioids but to a lesser degree, buprenorphine lowers the potential for opioid misuse, diminishes the effects of physical dependence to prescription and illicit opioids, and increases safety in cases of overdose (3). Increasing capacity to obtain affordable buprenorphine is needed to help patients receive the treatment they need. Understanding the social barriers that influence access to buprenorphine is important to informing policy and practice of opioid addiction treatment (4).

Black-market price data has been shown to effectively predict drug epidemiological patterns and guide law enforcement (5–7). In 2002, the Drug Enforcement Administration used illicit street price data to validate the rescheduling of buprenorphine from Schedule V to Schedule III, indicating greater potential for abuse (8). In these ways, information on black-market buprenorphine pricing has the potential to impact decision-making and public policies related to buprenorphine prescribing in the United States.

The goals of this study are to characterize trends in street buprenorphine, buprenorphine obtained on the illegal market through the diversion of prescription drugs from medical sources. We examine temporal and seasonal fluctuations in black-market price and macro-level ecological factors that may influence supply and demand of opioid addiction treatment to assess public need and gaps in access to care.

Methods

Data

Crowd-sourced Black-market Data from StreetRx—StreetRx is a publicly available crowdsourcing website that collects street price data in the United States for controlled substances on the black market (9). Users can voluntarily submit the street price they paid to StreetRx and compare it to what others paid to understand if they paid a fair price on the black market. Price, quantity, drug formulation, dosage information, and city/state of transaction are collected through user input. Submission time is recorded through the StreetRx website. Previous studies have validated this database as a source to identify drug demand and predict epidemiological, clinical, and pharmacological trends (5, 6).

Submissions for buprenorphine, including generic and brand name, received from the United States over the period from November 19, 2010 to June 30, 2018 were retrieved for this study's analysis. After removing 1002 entries that did not have geo-coordinates, 2481 submissions for buprenorphine representing 665 unique counties were used for this study's analysis. StreetRx locational data was used to assign each submission to a county by using the census geocode Python library (10).

Drug Properties—Drug properties were collected from the StreetRx database through user input. "Bulk purchase" was defined as a binary variable indicating whether the drug was purchased in bulk and not for singular use. "Formulation" was defined as a categorical variable describing the physical presentation of the drug: pill/tablet or film. "Combination" was defined as a binary variable indicating whether the drug was bought as purely buprenorphine or mixed with other drugs. "Brand name" was defined as a binary variable indicating whether the purchased drug was marketed and patented by a pharmacological company.

Temporal and Seasonal Variables—Temporality was measured in the number of years since the first StreetRx post (November 19, 2010). Seasonality was accounted by binary variables indicating whether the submission was posted in "Winter" (December-February), "Spring" (March-May), "Summer" (June-August), "Fall" (September-November). Fall was used as the reference group in the regression analysis.

Buprenorphine Practitioner Data—A catalogue of addresses of practitioners licensed to prescribe buprenorphine was obtained from the Substance Abuse and Mental Health Services Administration (SAMHSA) website in October 2018 (11). There were 32,441 practitioners in the database in the 50 US States and Washington, DC. A county FIPS code was assigned to each practitioner location from the provided ZIP code using a ZIP code to FIPS code conversion table. Practitioner location data was aggregated to calculate density of practitioners per county population.

Demographic Data from the US Census

County-level data on median income, percent covered by health insurance, percent rurality, and percent white was obtained from the US Census Bureau Decennial 2010 Survey (12).

Analysis

The geographic coordinates of StreetRx submissions were plotted on a United States map with red coloring indicating higher street price for buprenorphine and blue coloring indicating lower street price using the Bokeh visualization library (13).

A linear mixed effect model was used to model natural log of street price of buprenorphine from socioeconomic, demographic, temporal, health insurance coverage, and drug property variables shown to be associated with drug use patterning (14, 15). The fixed effects were composed of county median income, county percent white, county percent with health insurance, county buprenorphine practitioner density, year of posting, season of posting, bulk purchasing, combination drug, brand name, and drug formulation. Since many of the

independent variables were described at the county level, we allowed for a random intercept for each county. A hierarchical model in which StreetRx submissions are nested in counties enabled us to evaluate the effect of the independent variables while accounting for price variation across counties. While StreetRx submission volume may have been a useful second measure for gauging street market activity, it was not considered because of possible confounding with website user base volume.

Model:

$$\log(\text{price}) \sim \text{time} + \text{race} + \text{SES} + \text{health insurance coverage} + \text{drug properties} + (1|\text{county}) + \varepsilon$$

Results

Descriptive Results

From November 2010 to June 2018, the average number of postings per year was 310.13 and increased at a rate of 44.38 entries per year. Across the United States, the mean street buprenorphine price was $3.95/mg (SD=$23.12/mg), the average dose was 8mg (SD=59mg), and the mean number of postings per county was 3.73 (SD=6.04). Figure 1 shows the distribution of buprenorphine postings across the United States color-coded by price per mg, with red indicating higher posting price and blue indicating lower posting price. While the StreetRx dataset encompasses all 50 states and 665 counties, the Midwest and West regions are less represented in this dataset.

Linear Mixed-Effects Model Results

Regression results are shown in Table 2. Of the original 2481 postings, 2421 (98%) of the postings were located in a county with data on buprenorphine provider density, and this subset of data was used for the regression analysis. For variables significant at the alpha=0.05 level, percent effect on price was calculated as 100 * (*exp exp* (*estimated coefficient*) − 1) and represents the percent change in price given one unit increase of the variable under consideration. For the variables in units of percent (percent white, percent health insurance), percent change in price was calculated per percentage point unit increase as 100 * (0.01 * *estimated coefficient*) − 1).

Controlling for all other variables, street buprenorphine purchased in bulk was on average 11.1% cheaper than not in bulk. Street buprenorphine purchased as a combination drug was on average 22.0% cheaper than pure buprenorphine. Brand name buprenorphine was on average 10.6% more expensive than generic buprenorphine. Street buprenorphine in film form was on average 14.34% more expensive than in pill/tablet form. Over time, street buprenorphine decreased 3.05% in price each year from 2010 to 2018. On average, street buprenorphine sold for 17.12% more in the spring and 22.26% more in the summer compared to in the fall. For every percentage point increase in percent white, street buprenorphine sold for 0.64% higher price. For every percentage point increase in percent with health insurance, street buprenorphine sold for 0.02% lower price. County level variance was 0.058.

Discussion

Through the examination of black-market street buprenorphine pricing, our results highlight the need for capacity building as it relates to temporal, socio-spatial, and seasonal forces. Furthermore, our study provides insight into the dynamics of street pricing and how knowledge of formulation and other drug properties can be used to identify population interests and demand. Previous studies have monitored buprenorphine diversion through survey assessment (16). However, our study is the first to conduct a large-scale quantitative analysis on street drug pricing of buprenorphine in relation to social epidemiological patterns of disease. Validation of our novel dataset can be seen through how our results align with known economic trends: in our dataset, brand name buprenorphine and more effective modes of drug use absorption (film) have higher pricing while buprenorphine bought in bulk has lower pricing.

Studies have shown that as high as 90% of diverted buprenorphine users indicate that their motivation for using diverted buprenorphine is to reduce withdrawal symptoms and to stop using other opioids rather than to get high (as low as 4%) (17, 18). Since 1999, opioid overdoses deaths have increased by over 600% (19) and results from our study show a steady decrease in the street price of buprenorphine. This temporal trend may reflect rising rates of buprenorphine diversion through increases in black-market supply because of public need for opioid addiction treatment (20).

Our study found that counties with higher percent health insurance coverage had lower average street price for buprenorphine. One of the most significant barriers to retrieving affordable buprenorphine treatment is lack of sufficient health insurance coverage (17, 18). Previous studies documented that health insurance coverage increases the ability to obtain affordable buprenorphine treatment and reduces seeking treatment through illicit means (21). Therefore, areas with high insurance coverage may have lower demand for black-market buprenorphine and as a result, reduced street pricing. However, it may also be the case that areas with high insurance coverage may have greater black-market supply through drug diversion of prescription buprenorphine to the illicit market. Our finding of a negative relationship between health insurance coverage and street price could be consistent with either hypotheses. Further research is needed to determine which pathway is more dominant in practice.

National reports document that a majority of buprenorphine patients and illicit buprenorphine purchasers are white (22, 23) (**cite**). In our study, a 10% increase in percent white was associated with a 6.4% increase in street buprenorphine price. Given that StreetRx users paid an average of $18.90 for a standard 8mg dose, this translates to a $1.21 increase in price, controlling for all other variables. This is a measurable difference in price considering the daily frequency and sustained course of buprenorphine treatment. While this suggests that areas with greater percent white experience greater black-market demand, higher *demand* among white buprenorphine users does not mean that treatment *need* is greater among whites. Racial disparities in income, insurance coverage, educational attainment, and access to treatment influence the apparent demand for buprenorphine. For example, although death rates involving opioids remain highest among whites, death rates

for other races rose significantly in the past five years, indicating growing need for treatment in these communities (24). Our finding of higher street price and thus greater implied demand in white areas despite high treatment need in many demographics indicates continued disparities and underscores the need to improve these education and access to care for disadvantaged communities facing growing opioid substance use crises.

Interestingly, we did not find a significant association between provider density and street pricing. The relationship between provider density and pricing may be complex such that our linear model was unable to capture it. For example, the effect of provider density on supply and price may be mediated by factors such as accepted insurance types and practice patterns by which providers distribute buprenorphine. Such information was not available and therefore not accounted for in our model. Future studies should focus on this relationship in greater detail. Additionally, DATA-waivered providers that do not give permission to be listed were not listed in the SAMHSA list of practitioners. Therefore, the SAMHSA list may not be reflective of the true density of buprenorphine providers. We cannot come to a definitive conclusion for why the coefficient on provider density was insignificant, but our model does not preclude the real-life possibility that buprenorphine influences street pricing in some way.

Holding all other variables constant, the price of street buprenorphine in summer months was 22.26% higher, which translates to a $4.21 increase per 8mg dose. EMS naloxone administration has been identified as a proxy indicator for opioid overdose and naloxone administration has been found to peak in summer months (25). Higher pricing in the summer for street buprenorphine may be related to increases in demand for opioid addiction treatment because of the greater number of opioid overdoses occurring in this season. In this way, future studies can utilize seasonal trends in buprenorphine street pricing to estimate timing of overdose incidences.

Limitations

Our study has several limitations. The first is the lack of user information because of user anonymity. Because of this, we were unable to interview users to obtain qualitative data regarding why users turn to the black-market to purchase buprenorphine. This limits the study to an ecological analysis using county-level variables. However, it also confers the benefit of greater data accuracy for underground activity in which users may feel less comfortable sharing information. Secondly, StreetRx may not comprehensively capture all black-market trafficking. For example, the Midwest region may be underrepresented in our sample. But since the closing of Silk Road, a primary online source for black-market drug trafficking, StreetRx is one of few reamining data sources with information on street drug pricing. Finally, our study studied solely buprenorphine to examine the need for treatment for opioid dependency. Other opioid treatment avenues are available and may be used instead of buprenorphine. Analysis of other opioids and opioid treatments was outside the scope of this study.

Conclusion

Modeling black-market buprenorphine patterns may provide insight into areas of need for opioid dependency treatment. Monitoring temporal and seasonal fluctuations in street buprenorphine pricing can help estimate timing of opioid overdoses. Greater contextual awareness of the geographic, demographic, and socio-economic factors that shape opioid epidemiological trends can be garnered through the examination of street buprenorphine pricing which should be used as a method of surveillance to prevent opioid abuse.

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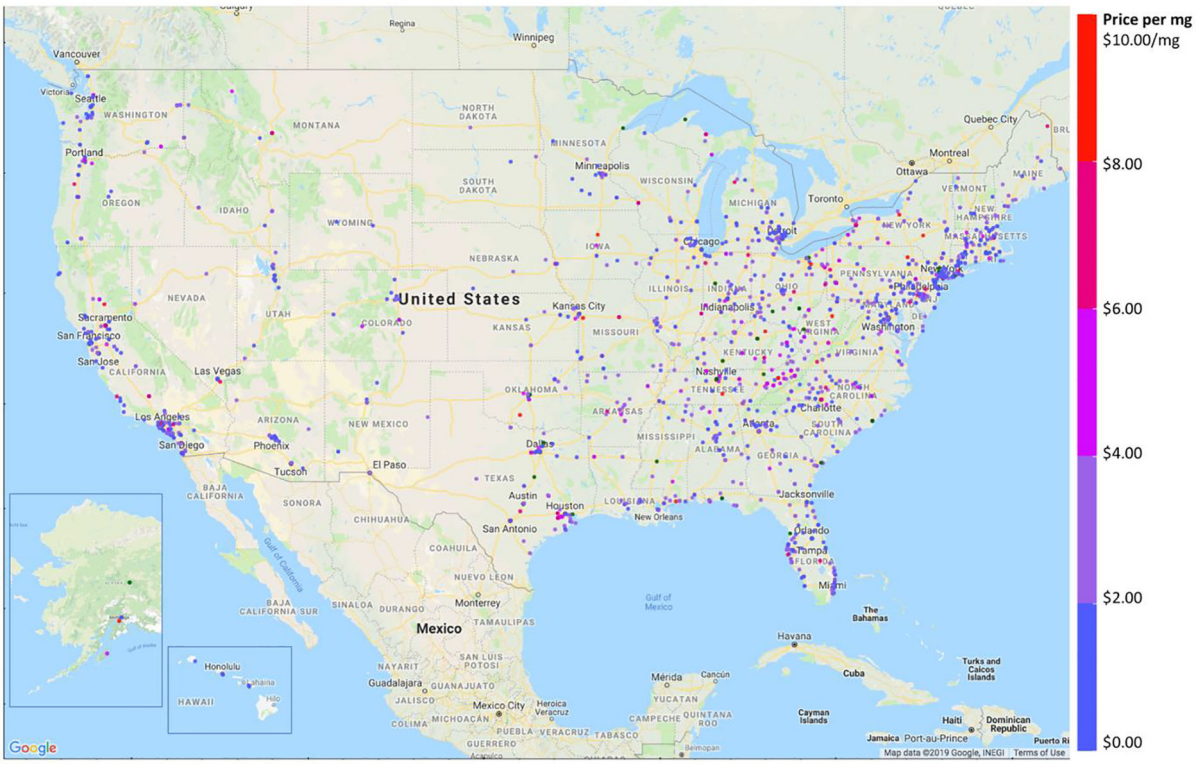

Figure 1.
US Map of StreetRx postings for buprenorphine, color coded by price per mg, 2010–2018.

Table 1.

Summary of linear mixed effects regression results.

Dependent variable	Log (Price per mg)					
Number of observations	N = 2421					
Number of groups	616					
Min, Max, Mean group size	Min = 1, Max = 63, Mean = 3.9					
	Coef	**Std err**	**z**	**P>|z|**	**95% CI**	**% effect on price**
Intercept	2.385	0.591	4.035	<0.001	[1.227, 3.544]	NA
Time (years since first post)	−0.031	0.012	−2.500	0.012	[−0.055, −0.007]	−3.05%
Winter	0.096	0.051	1.865	0.062	[−0.005, 0.197]	--
Spring	0.158	0.050	3.167	0.002	[0.060, 0.256]	+17.12%
Summer	0.201	0.052	3.884	<0.001	[0.100, 0.302]	+22.26%
Fall	*Reference group*					
Is bulk purchase	−0.111	0.048	−2.298	0.022	[−0.206, −0.016]	−10.51%
Is combination	−0.220	0.049	−4.537	<0.001	[−0.316, −0.125]	−19.75%
Is brand name	0.106	0.049	2.174	0.030	[0.010, 0.201]	+11.18%
Is film formulation	0.134	0.049	2.748	0.006	[0.038, 0.229]	+14.34%
Median income	−0.000	0.000	−1.711	0.087	[−0.000, −0.000]	--
Percent insured	−0.021	0.008	−2.693	0.007	[−0.035, −0.006]	−0.02%
Percent white	0.633	0.171	3.706	<0.001	[0.298, 0.968]	+0.64%
Percent rural	0.000	0.001	−0.292	0.771	[−0.002, 0.003]	--
Buprenorphine provider density	0.003	0.002	1.258	0.208	[−0.002, 0.007]	--
County Level Variance	0.058	0.017	NA	NA	NA	NA