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Growth in Suicide Rates Among Children During the Illicit Opioid Crisis

David Powell

ABSTRACT This article documents child suicide rates from 1980 to 2020 in the United States using the National Vital Statistics System Multiple Cause of Death database. After generally declining for decades, suicide rates among children aged 10–17 accelerated from 2011 to 2018 in an unprecedented rise in both duration and magnitude. I consider the role of the illicit opioid crisis in driving this mental health crisis. In August 2010, an abuse-deterrent version of OxyContin was introduced and the original formulation was removed from the market, leading to a shift to illicit opioids and stimulating growth in illicit opioid markets. Areas more exposed to reformulation—as measured by pre-reformulation rates of OxyContin misuse in the National Survey on Drug Use and Health—were more affected by the transition to illicit opioids and experienced sharper growth in child suicide rates. The evidence suggests that children's illicit opioid use did not increase, implying that the illicit opioid crisis engendered higher suicide propensities by increasing suicidal risk factors for children, such as increasing rates of child neglect and altering household living arrangements. In complementary analyses, I document how living conditions declined for children during this time period.

KEYWORDS Suicide rates • Mental health crisis • Illicit opioid crisis • OxyContin reformulation

Introduction

Suicide is the 10th leading cause of death in the United States (Hedegaard et al. 2021), and annual suicide rates grew continuously between 2005 and 2018 (National Institute of Mental Health 2023). Among children aged 10–17, suicide was the second leading cause of death in 2020.[1] Reducing suicide attempts and deaths among adolescents were national policy priorities even before the growth over the past decade (National Center for Health Statistics 2012). Citing the rise in child suicide rates, the American Academy of Pediatrics, the American Academy of Child and Adolescent Psychiatry, and the Children's Hospital Association declared a national state of emergency in children's mental health in 2021 (American Academy of Pediatrics et al. 2021).

[1] Author's calculation using data from https://wonder.cdc.gov/ucd-icd10.html.

ELECTRONIC SUPPLEMENTARY MATERIAL The online version of this article (https://doi.org/10.1215/00703370-11077660) contains supplementary material.

Although multiple studies have documented suicide rates for various younger age groups (e.g., Bridge et al. 2015; Bridge et al. 2018; Burstein et al. 2019; Curtin 2020; Hill et al. 2021; Marcotte and Hansen forthcoming; Price and Khubchandani 2022; Ruch et al. 2021; Ruch et al. 2019; Sheftall et al. 2016; Spiller et al. 2019), little work has recognized or studied the unprecedented and uninterrupted rise in child suicide rates beginning in 2011. This article documents child suicide rates in the United States from 1980 to 2020—placing the current incidence of suicides among children in historical context—and then examines their relationship with the opioid crisis.

The opioid crisis is itself a national emergency. In 2021, more than 100,000 Americans died by overdose, most involving opioids (Spencer et al. 2022). The opioid crisis has evolved over time (Ciccarone 2019): prescription opioids dominated the first wave (Kolodny et al. 2015), followed by a transition to a higher prevalence of heroin overdoses in the second (Mars et al. 2014), and then widespread use of fentanyl in the third (Reuter, Pardo and Taylor 2021).[2] This article explores the independent effects of the illicit opioid crisis relative to the first wave. The illicit opioid crisis is associated with use of illegal and more potent opioids, suggesting that it may induce more harmful consequences than the first wave. To date, there is little evidence that the opioid crisis is linked to the rise in child suicide rates.[3]

Little is known about why child suicide rates have increased so sharply in recent years, representing a major gap in our knowledge of a critical and developing mental health crisis. Existing research on the recent rise in child suicide rates has considered associations of time on social media with mental health issues among adolescents (Twenge et al. 2018), the possible role of antidepressant warnings (Lu et al. 2020), and other correlates (Liu et al. 2022).

More generally, it is difficult to characterize the determinants of child suicide or suicide ideation (Molina and Duarte 2006). The literature on youth suicide risk factors considers the role of family and personal relationships as well as more general environmental factors. "Connectedness" is an important protector against suicidal behaviors among adolescents (Borowsky et al. 2001; Maimon and Kuhl 2008; Mueller and Abrutyn 2016; Whitlock et al. 2014). Research has highlighted the role of familial support in deterring suicidal behavior, such as parental absence (Fu et al. 2017; Garnefski and Diekstra 1997; Liu et al. 2022; Morano et al. 1993) and family stability (Adam et al. 1982; Cutler et al. 2001). Cohen-Sandler et al. (1982) found that disruptive family events leading to loss or separation are associated with suicidal behavior in children. Notably, parental death is linked to child suicide (Burrell et al. 2018; Hiyoshi et al. 2022; Niederkrotenthaler et al. 2012), suggesting one possible role for the opioid crisis. In addition, parental substance use has been associated with behavioral and social problems among children (Smith et al. 2016), higher rates of involvement by child protective services, and lower rates of reunification (Akin et al. 2015).[4] Abuse and neglect (Angelakis et al. 2020; Brodsky and Stanley 2008; Palmer et al. 2021; Stickley et al. 2020) and adverse childhood experiences

[2] The opioid crisis is now thought to have entered a "fourth wave," defined by polysubstance use (Ciccarone 2021; Friedman and Shover 2022).

[3] Fernandez and Jayawardhana (2022) found that policies that regulate pain management clinics reduce overall suicide rates.

[4] Exposure to parental substance misuse and incarceration has been associated with all-cause mortality in longitudinal cohort studies (Beardslee et al. 1986; Jackisch et al. 2019).

(Baiden et al. 2017; Miller et al. 2013) have been strongly linked to youth suicide. Suicide rates among children in foster care are extremely high (Brown 2020; Evans et al. 2017).

Related to the importance of connectedness, bullying has been associated with youth suicide for both the victim and perpetrator (Holt et al. 2015), and anti-bullying laws have been found to reduce teenage suicide rates (Rees et al. 2022). Related research has shown that suicide rates coincide with the timing of the school year (Hansen and Lang 2011; Hansen et al. 2022), consistent with a role for bullying. Similarly, Nikolaou (2017) found evidence of a relationship between cyberbullying victimization and youth suicide.

More general environmental and economic factors have also been linked to child suicide rates (Evans et al. 2005).[5] Poverty rates are strong predictors of child suicide attempts and deaths (Bernburg et al. 2009; Dupéré et al. 2009; Hoffmann et al. 2020), and food insecurity is a suicide risk factor for adolescents (Alaimo et al. 2002; Brown et al. 2022; Koyanagi et al. 2019; McIntyre et al. 2013). Perceived neighborhood safety has been linked to adolescent distress (Goldman-Mellor et al. 2016) and suicide attempts (Allen and Goldman-Mellor 2018).[6]

Many of these risk factors have been affected by the opioid crisis, which has disrupted household and community life beyond just those misusing opioids (Maclean et al. 2022).[7] The illicit opioid crisis, in particular, has led to major changes in many of the aforementioned conditions. This article focuses on the transition of the opioid crisis from the first wave to the illicit opioid crisis, as the literature has found that this shift induced a multitude of social harms.

Prior research has shown that the introduction of an abuse-deterrent version of OxyContin and the removal of the original formulation in August 2010 spurred an increase in overdoses involving heroin and synthetic opioids (e.g., fentanyl) (Alpert et al. 2018; Evans et al. 2019; Powell and Pacula 2021). Before this reformulation, OxyContin was the most abused prescription opioid (Cicero et al. 2005) because of aggressive marketing practices by Purdue Pharma (Alpert et al. 2022; Kolodny et al. 2015). Reformulation made it more difficult to misuse OxyContin, and as access to abusable prescription opioids decreased, many individuals switched to illicit drugs (Cicero et al. 2012; Coplan et al. 2013). In response, illicit opioid markets expanded, rates of polysubstance overdoses rose, and overdose rates increased (Powell and Pacula 2021; Powell et al. forthcoming).

Although adolescents did not increase their use of illicit opioids because of reformulation (DiNardi 2021),[8] they were negatively affected by the broader consequences

[5] There is also work suggesting that relative cohort size predicts suicide rates because of increased competition for scarce resources (Freeman 1998; Holinger and Offer 1982; Mathur and Freeman 2002).

[6] This line of research suggests that perceived safety has more predictive power than official crime rates.

[7] There is research discussing associations between the geographic intensity of the opioid crisis (not the illicit opioid crisis specifically) and child outcomes. Bullinger and Ward (2021) found that areas more exposed to the opioid crisis experienced faster increases in foster care entry, while Chapman (2022) documented a strong association with child maltreatment. Ghertner et al. (2018), Quast (2018), and Quast et al. (2018) observed similar associations with child maltreatment and home removals, while Gihleb et al. (2022) estimated that the implementation of mandatory access prescription drug programs—which limit opioid access and overprescribing—reduced home removals.

[8] DiNardi (2021) constructed heroin rates using the National Survey of Drug Use and Health (NSDUH), discussed more below. While the NSDUH provides credible and widely used rates of substance use, the

of the illicit opioid crisis. Most relevant to this article, reformulation triggered increased rates of child neglect (Evans et al. 2022), a strong predictor of youth suicide and indicative of deteriorating conditions for children. Evans et al. (2022) found that states more affected by reformulation experienced faster growth in rates of child physical abuse and neglect starting in 2011. Mackenzie-Liu (2021) and Dallman (2020) estimated that states more affected by reformulation experienced sharper increases in foster care admissions. Children in foster care suffer high suicide rates (Brown 2020; Evans et al. 2017).

Although it has not been directly studied, the rise in overdose deaths due to reformulation likely increased rates of parental loss and changes in child living arrangements. The literature shows that reformulation induced a rise in criminal behavior (Chen et al. 2022; Mallatt 2022; Park 2021). Notably, opioid use in recent years has been strongly associated with incarceration (Winkelman et al. 2018), and parental loss and incarceration have been strongly associated with youth suicidal behavior (Burrell et al. 2018; Hiyoshi et al. 2022; Niederkrotenthaler et al. 2012).

Reformulation also had an impact on environmental factors. The shift to illicit opioids increased rates of infectious diseases (Beheshti 2019; Powell et al. 2019) and food insecurity (Heflin and Sun 2022) while prompting a decline in work capacity, household income, and health insurance rates (Cho et al. 2021; Park and Powell 2021). Food insecurity and neighborhood poverty rates have been associated with higher child suicide propensities (Alaimo et al. 2002; Brown et al. 2022; Koyanagi et al. 2019; McIntyre et al. 2013), while the rise in criminal behavior may have diminished the perception of safety, further heightening suicide risk.

In this article, I document child suicide rates from 1980 to 2020 to study recent growth in suicides and the relative magnitudes compared with historical rates, and consider the role of the opioid crisis and its transition to illicit opioids in explaining this unprecedented rise. I compare changes in suicide rates in areas more exposed to the shift to illicit opioids with growth in less exposed areas. Although the illicit opioid crisis has had an impact on the entire country, some areas have been more affected than others because of higher pre-reformulation rates of OxyContin misuse. I leverage this geographic variation in exposure to study how child suicide rates responded. These results reflect additional suicides relative to the first wave of the opioid crisis.[9]

I also evaluate possible intermediate mechanisms by examining which conditions worsened for children nationally during this period, focusing on factors that the literature has suggested were affected by reformulation. The illicit opioid crisis has altered life in numerous ways, and it is difficult to isolate specific pathways affecting suicide rates. Instead, this article tests whether there is a foundational relationship between two ongoing crises that are generally considered independent, while also discussing possible intermediate mechanisms.

Many suicidal risk factors for children have different associations by sex, age, race, and ethnicity (Brent et al. 1999; Garnefski and Diekstra 1997; Opara

heroin use rates specifically have been questioned (Midgette et al. 2019; Reuter, Caulkins and Midgette 2021). In the following, I will examine overdose death rates among children as a correlate for use.

[9] Although the first wave of the opioid crisis may itself have affected child suicide rates, this article does not speak to this relationship. It only establishes *changes* in child suicide rates due to the transition to the illicit opioid crisis.

et al. 2020), suggesting the importance of studying heterogeneous effects among demographic groups. For example, reformulation increased reported rates of child neglect; if the association between neglect and suicide varies by demographic group, then we might expect the effects of reformulation to vary as well. Additionally, the opioid crisis has had a disproportionate impact on certain demographic groups and these trends have changed considerably in recent years (see Cano 2021; Friedman et al. 2022; Friedman and Hansen 2022; Gibbons et al. 2023; Hedegaard et al. 2022; Om 2018; Rudd et al. 2016; Townsend et al. 2022). The reasons behind these recent demographic shifts are generally unexplained. Given the uncertainty of the reasons driving the recent differential growth in overdose deaths across demographic groups, we may expect that the association with child suicide rates might also vary.

This article explores a potential critical mechanism for the surprising and adverse upturn in child suicides. Moreover, it speaks to the broader impact of the opioid crisis for understanding the effects of the crisis on children (Winstanley and Stover 2019).

Data Sources

Overdose and Suicide Mortality Rates

My primary data source is the National Vital Statistics System (NVSS) Multiple Cause of Death database, the census of deaths in the United States, which I use to construct the universe of annual deaths by suicide and overdose from 1980 to 2020. I use restricted, geocoded data to access state identifiers and categorize deaths on the basis of state of residence. The 1980–1998 data use ICD-9 codes to classify underlying causes of deaths, whereas the 1999–2020 data use ICD-10 codes; however, this switch had little effect on the classification of suicide deaths (Anderson et al. 2001). Because it is difficult to establish intent at younger ages, I focus on ages 10–17 (Crepeau-Hobson 2010). Death by "intentional self-harm" is categorized in the NVSS as E950–E959 with ICD-9 codes and X60–X84 and Y87.0 with ICD-10 codes. I code deaths as drug poisonings ("overdoses") using ICD-9 codes E850–E858, E950.0–E950.5, E962.0, and E980.0–E980.5 and ICD-10 external cause of injury codes X40–X44, X60–X64, X85, and Y10–Y14. ICD-10 codes T40.1 and T40.4 designate heroin and synthetic opioid deaths, respectively.

The NVSS includes information on age and sex. "Bridged" race designations provided by the NVSS can be consistently categorized into four groups: American Indian and Alaska Native (AI/AN), Asian American and Pacific Islander (AAPI), Black, and White. I scale deaths by population size for the relevant demographic group using data from the Surveillance, Epidemiology, and End Results (SEER) program.

Differential Exposure to Reformulation

To measure nonmedical use (misuse) of OxyContin and pain relievers, I use aggregated, state-level data from the National Survey on Drug Use and Health (NSDUH), a nationally representative household survey of individuals aged 12 or older. NSDUH is the country's largest survey on substance use, including self-reported "nonmedical

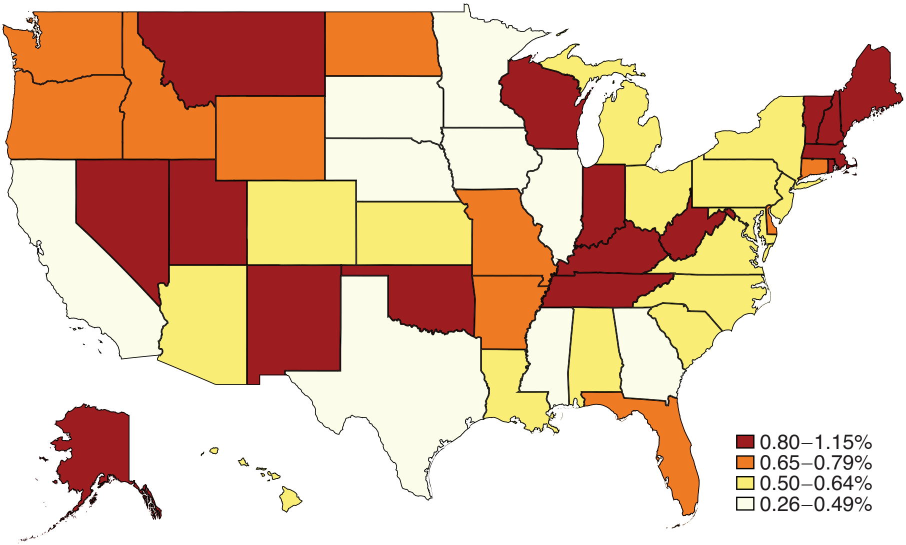

Fig. 1 Geographic variation in rate of OxyContin misuse, 2004–2009. *Source:* 2004–2009 National Survey of Drug Use and Health.

OxyContin use" and "nonmedical pain reliever use" within the past year. Nonmedical use is defined as use by individuals who were not those originally prescribed the medication or who used it "only for the experience or feeling it caused."

The NSDUH began asking about nonmedical OxyContin use in 2004. To reduce measurement error concerns, I aggregate 2004–2009 data as the measure of exposure to OxyContin reformulation. The NSDUH has two important advantages for this analysis. First, it specifies OxyContin. Second, it specifies nonmedical use—the relevant dimension given that reformulation did not affect medical use of OxyContin. Although self-reported,[10] nonmedical use has been validated as predictive of major shifts in the opioid crisis and correlated with administrative measures of pre-reformulation OxyContin supply and prescribing (Alpert et al. 2018; Powell and Pacula 2021). Measurement error would attenuate the results. If people were misreporting which substance they were misusing, I would instead observe a relationship between nonmedical pain reliever use and suicide rates, but I do not.

Figure 1 shows the geography of the nonmedical OxyContin use variable. To illustrate the geographic variation, I calculate the average nonmedical OxyContin use rate for each state's neighbors and then regress (excluding Hawaii and Alaska) each state's rate on this average rate. The estimate is negative, implying considerable variation even among neighboring states.

States likely do not properly reflect local drug markets, and this unit of analysis is primarily chosen for data availability reasons. The use of states—instead of substate

[10] NSDUH uses techniques designed to elicit accurate and honest answers from respondents. These methods—such as showing pictures of OxyContin—reduce concerns that the "OxyContin misuse" measure reflects misuse of other opioids. NSDUH provides respondents with a highly private and confidential method for responding to questions to increase honest reporting.

areas—may reduce power but should not meaningfully bias the analysis. More granular units would provide additional variation to exploit, but the literature has not found power to be an issue with state-level analyses. Purdue Pharma's early marketing strategies were often based on state-level policies, leading to large and enduring differences in misuse rates across states (Alpert et al. 2022).

The public NSDUH suppresses rates that are further stratified by other characteristics, such as race. For the same reasons that these rates are suppressed, demographic-specific rates in the restricted data would likely be too noisy to be useful. The literature has generally suggested that the nonmedical OxyContin use variable proxies for the broader effects of the transition to illicit opioid markets, so more targeted measures would miss some of these effects.

Additional Predictors

I use nonmedical pain reliever use as an additional exposure variable to verify the stability of the results to other factors correlated with opioid misuse. Pre-reformulation rates of OxyContin misuse may predict adoption of specific policies, changes in underlying economic conditions, or other factors forecasting secular growth in child suicide rates. These factors would likely be related to the more general rate of nonmedical use of pain relievers. Accounting for the independent effects of nonmedical pain reliever use over time helps isolate outcome growth unique to OxyContin and reformulation. The nonmedical pain reliever use variable may also be mismeasured, but it should be less prone to measurement error concerns than the OxyContin misuse variable, suggesting that unobserved confounders should load onto the broader misuse variable rather than the OxyContin misuse variable.[11]

In addition, I control for state-level demographic shares—White and Black—constructed using the SEER data. I also control for the state minimum wage (expressed in 2020 dollars) given evidence that adult suicide rates respond to the minimum wage (Dow et al. 2020; Gertner et al. 2019; Kaufman et al. 2020) such that we might expect child suicide rates to respond as well.[12] Furthermore, I include an indicator for whether a state had a Prescription Drug Monitoring Program (PDMP) and a separate indicator for having a "mandatory access" PDMP (Horwitz et al. 2021) given that the literature has found this dimension specifically to have disproportionate effects on prescribing behavior (Alpert et al. forthcoming; Buchmueller and Carey 2018). Finally, I include an indicator for whether the state had an anti-bullying policy (Rees et al. 2022).

Methods

I exploit variation in states' differential exposure to the reformulation of OxyContin due to differences in their initial prevalence of OxyContin misuse. The main outcome

[11] The questionnaire involves surveying respondents about a large set of specific pain relievers. These drugs are listed (and pictures are often provided) for the respondent. If respondents are mistaken about which pain reliever they misused, it will not affect the pain reliever misuse variable, suggesting less scope for measurement error.

[12] I use the minimum wage information from University of Kentucky Center for Poverty Research (2022) to construct this variable.

is suicide deaths per 100,000 children, but I also show results for suicides excluding overdoses. I examine whether states with higher rates of OxyContin misuse before reformulation experienced larger changes in suicides rates by estimating the specification

$$Y_{gsrt} = \alpha_{gs} + \gamma_{grt} + \mathbf{X}'_{\mathbf{st}}\boldsymbol{\beta} + \delta_t \times OxyRate_s^{Pre} + \varepsilon_{gsrt}, \tag{1}$$

where Y_{gsrt} is the number of suicide deaths per 100,000 children (aged 10–17) in state s and census region r at year t for group g. "Groups" are defined by the interaction of race (AI/AN, AAPI, Black, White), age, and sex. $OxyRate_s^{Pre}$ is the fixed rate of OxyContin misuse in state s in the pre-reformulation (2004–2009) period and is interacted with a full set of year indicators (as denoted by the t subscript on the coefficient). I control for state–group fixed effects α_{gs} to account for fixed cross-sectional differences across states and allow these differences to vary by the interaction of race, age, and sex. I also include year fixed effects γ_{grt} to account for national trends, changes in federal policies, and other common factors. These effects are permitted to vary by race, age, and sex. The time fixed effects also vary by census region, given that the opioid crisis affected regions of the country differentially (Abouk et al. 2021; O'Donnell et al. 2017). $\mathbf{X}_{\mathbf{st}}$ represents a vector of predictors, discussed above.

A traditional difference-in-differences design accounts for state and year fixed effects. Given the richness of the demographic information in the data, I interact these fixed effects to flexibly account for changing demographics. The fixed effects nonparametrically account for differences generated from changes in demographics over time and differences due to preexisting variation in demographics. The state fixed effects (interacted with demographic group indicators) nonparametrically account for the independent relationship between nonmedical OxyContin use and child suicide rates.

The main variables of interest are the full set of δ_t estimates, which I present graphically, normalizing the 2009 coefficient to zero. These δ_t estimates identify *changes* in the differences in suicide rates across states with higher and lower initial rates of OxyContin misuse in each year, relative to the 2009 difference. The assumption is that in the absence of the reformulation, states with different OxyContin misuse rates would have continued along the same trends. This condition can be partially assessed by studying pretreatment estimates. I also estimate Eq. (1) for overdose death rates to test whether child mortality appears to have been directly affected by the shift to illicit opioids.

I summarize the suicide findings by estimating one "post" parameter for 2011–2020 relative to 2006–2009 using

$$\begin{aligned} Y_{gsrt} = \alpha_{gs} + \gamma_{grt} + \mathbf{X}'_{\mathbf{st}}\boldsymbol{\beta} + \delta \times OxyRate_s^{Pre} \times 1(\text{Year} > 2010) \\ + \theta \times PainRelieverRate_s^{Pre} \times 1(\text{Year} > 2010) + \varepsilon_{gsrt}. \end{aligned} \tag{2}$$

Results from this specification are shown with and without the $PainRelieverRate_s^{Pre}$ variable. This variable is the pre-reformulation (2004–2009) rate of nonmedical pain reliever use, excluding OxyContin. Including this variable helps δ to isolate changes in suicide rates that are unique to pre-reformulation OxyContin misuse and not correlated with opioid misuse more generally.

The nonmedical OxyContin use variable does not vary within states. The hypothesis is that children in states more affected by reformulation experienced sharper growth in suicide rates because of deteriorating social and familial conditions. Misuse rates specific to children would not be useful for this analysis. All regressions are population-weighted, and I use robust variance estimation accounting for state-level clustering.

Results

Sample Description

I observe 48,063 deaths designated as suicides for the 10–17 population from 1980 to 2020. Comparing states with below-median pre-reformulation OxyContin misuse rates to above-median states in Table 1, I do not observe preexisting differences (for 2004–2009) in child suicide rates. There are some differences in demographics and overdose rates for this population, motivating the use of methods that account for initial differences. There is little evidence of any preexisting differences in policies or economic conditions.

Given that reformulation occurred near the beginning of the Great Recession, I examine changes in four economic metrics between 2007 and 2009. First, I study the employment-to-population ratio using data from the U.S. Bureau of Labor Statistics' Local Area Unemployment Statistics. Second, I examine the overall poverty rate using data from the U.S. Census Bureau Small Area Income and Poverty Estimates. Third, I study child food insecurity rates by aggregating data from the Current Population Survey (CPS) annual Food Security Supplements, collected from IPUMS (Flood et al. 2022).[13] Fourth, I examine the state housing price index, which is indexed to 100 in each state in the first quarter of 1991, using data from the Federal Housing Finance Agency.[14] For all four outcomes, there is little evidence that states with high OxyContin misuse were disproportionately exposed to the effects of the Great Recession.

Overall Suicide and Overdose Rate Trends

Figure 2 provides suicide and overdose rates for those aged 10–17 for 1980 to 2020. Prior to reformulation, suicides for this age group peaked at 4.66 per 100,000 in 1988. From 1988 to 2010, the suicide rate declined by 36%. The decline in 2010 was followed by eight consecutive years of increases—resulting in an 83% increase in child suicide rates. The duration of this growth and the overall magnitude of the increase were unprecedented when placed in historical context. In 2019 and 2020, there were modest declines in the suicide rate, but it remained above its pre-reformulation peak.

[13] I use the household-level variables on whether there is low or very low food security among children in the household.

[14] I include housing prices given the importance of the housing market to the Great Recession.

Table 1 State characteristics at baseline (2004–2009)

	Below Median	Above Median	Difference	*p* Value
Deaths (per 100,000), Ages 10–17				
Suicides	2.707	3.228	0.520	.167
Overdoses	0.775	1.176	0.401	.001
Heroin overdoses	0.053	0.027	–0.027	.181
Natural/semisynthetic opioid overdoses	0.175	0.352	0.177	<.001
Synthetic opioid overdoses	0.039	0.068	0.029	.055
Demographics, Ages 10–17				
% Black	18.49	12.87	–5.62	.098
% White	74.46	81.90	7.44	.005
% American Indian/Alaska Native	1.44	2.25	0.82	.301
% Asian American/Pacific Islander	5.61	2.97	–2.64	.090
% male	51.25	51.33	0.08	.001
% ages 10–12	36.58	36.44	–0.14	.391
% ages 13–15	37.83	37.79	–0.04	.467
% ages 16–17	25.59	25.78	–0.19	.133
State population size (ages 10–17)	5,763,358	2,316,514	–3,446,844	.008
Economic Conditions (full population)				
Employment-to-population ratio	62.13	62.19	0.07	.942
Poverty rate (%)	13.50	12.92	–0.58	.438
Child food insecurity rate (%)	11.45	10.69	–0.76	.370
Housing price index	206.15	219.60	13.45	.266
Change in employment-to-population ratio (2007 to 2009)	–3.537	–4.004	–0.467	.391
Change in poverty rate (2007 to 2009)	1.32	1.49	0.17	.635
Change in child food insecurity rate (2007 to 2009)	3.61	1.66	–1.95	.180
Change in housing price index (2007 to 2009)	–32.97	–37.25	–4.28	.817
Policies				
Prescription drug monitoring programs (%)[a]	13.93	14.77	0.86	.922
Anti-bullying laws (%)[a]	27.40	34.89	7.48	.651
Minimum wage (in 2020 $)	7.90	7.95	0.05	.889
Pain Reliever Misuse (per 100), Ages 12+				
Nonmedical OxyContin use (%)	0.475	0.865	0.402	<.001
Nonmedical pain reliever use, excluding OxyContin (%)	3.921	4.579	0.496	.059

Notes: Below-median states are those with 2004–2009 OxyContin misuse rates below the median, and above-median states have rates above the median. The "Difference" column is the "Above Median" rate minus the "Below Median" rate. PDMPs with mandatory access are not included because no states had mandatory access requirements during 2004–2009. The housing price index is normalized to 100 in each state for the first quarter of 1991.

[a] Percentage of the population in 2004–2009 in states with these policies.

Figure 2 also includes the trend for suicides but excluding those jointly designated as overdoses. Overdoses are relatively uncommon for this age group, so this does not appear to be a fundamental mechanism explaining the increase in suicides. Figure 2 further shows that overdose death rates did not generally increase for this population until 2020. The 2020 increase in overdose deaths is consistent with broader increases in overdose rates during the COVID-19 pandemic (Imtiaz et al. 2021). These trends are not

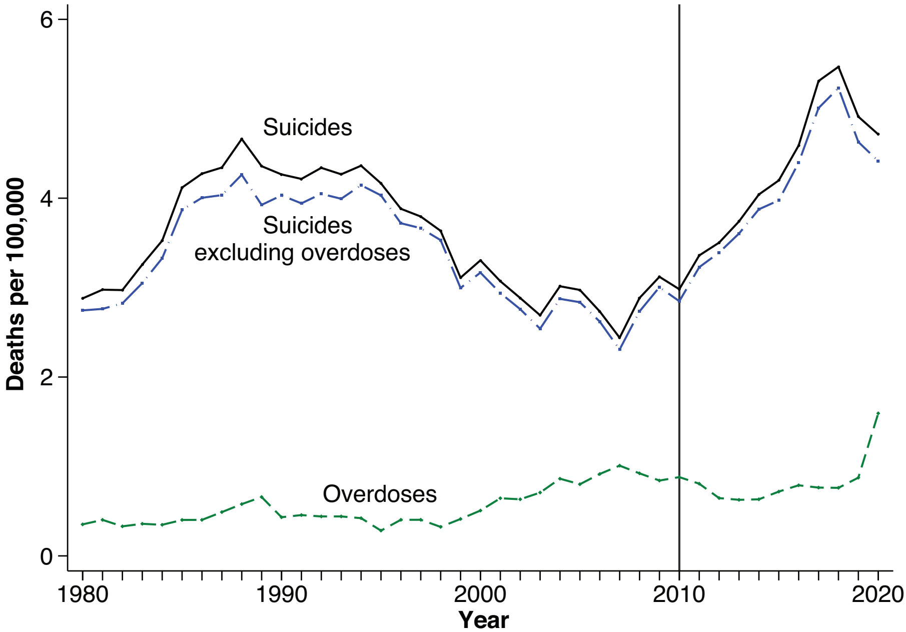

Fig. 2 Suicide and overdose deaths per 100,000 for ages 10–17 for 1980–2020. Data represent national time series for 1980–2020 for suicides, suicides excluding those jointly designated as overdoses, and overdoses per 100,000 for ages 10–17. OxyContin reformulation is indicated by a vertical line in 2010.

sensitive to including suicides and overdose deaths among children aged 0–9 (see Figure A1, shown in the online appendix, along with all other figures designated with an "A").

There is some evidence that the upturn in child suicide rates began prior to reformulation, though it is difficult to draw conclusions from just two years of increasing rates, which were then interrupted by a decline. The difference-in-differences analyses below isolate the role of reformulation beyond other nationwide factors affecting child suicide rates. For the remainder of the analysis, I focus on 1999–2020, the years in which the NVSS reports ICD-10 codes.

Demographic-Specific Suicide Rate Trends

In Figure 3, I present child suicide rates for different demographic groups given that overdose trends have varied substantially across groups during this period (Friedman et al. 2022). Suicide rates increased for both males and females after reformulation (Figure 3, panel a). White children experienced the starkest increases immediately after reformulation, but increases occurred across all racial groups (panel b).

The increase in suicides affected all age groups (Figure 3, panel c). The rise was more modest for the 10–12 age group, which also had a much lower baseline rate. Overall, Figure 3 shows evidence of heterogeneity across demographic groups, but it also suggests that every group experienced some magnitude of rising suicide rates since 2010, after years of stagnant or declining rates.

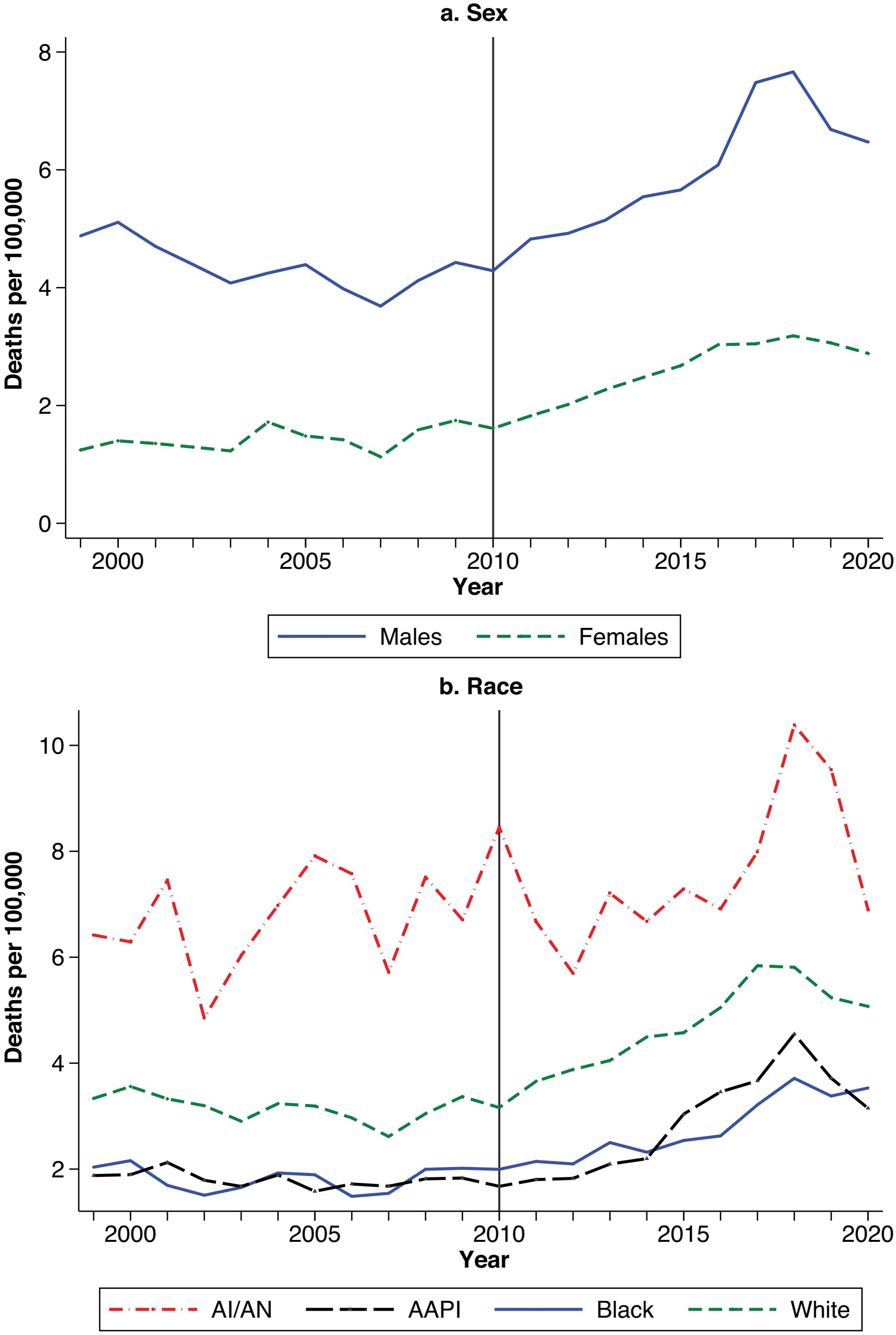

Fig. 3 Suicides per 100,000 for ages 10–17 for 1999–2020 by sex, race, and age. Suicides per 100,000 are plotted over time for different demographic groups. OxyContin reformulation is indicated by a vertical line in 2010. AI/AN = American Indian and Alaska Native. AAPI = Asian American and Pacific Islander.

(continued)

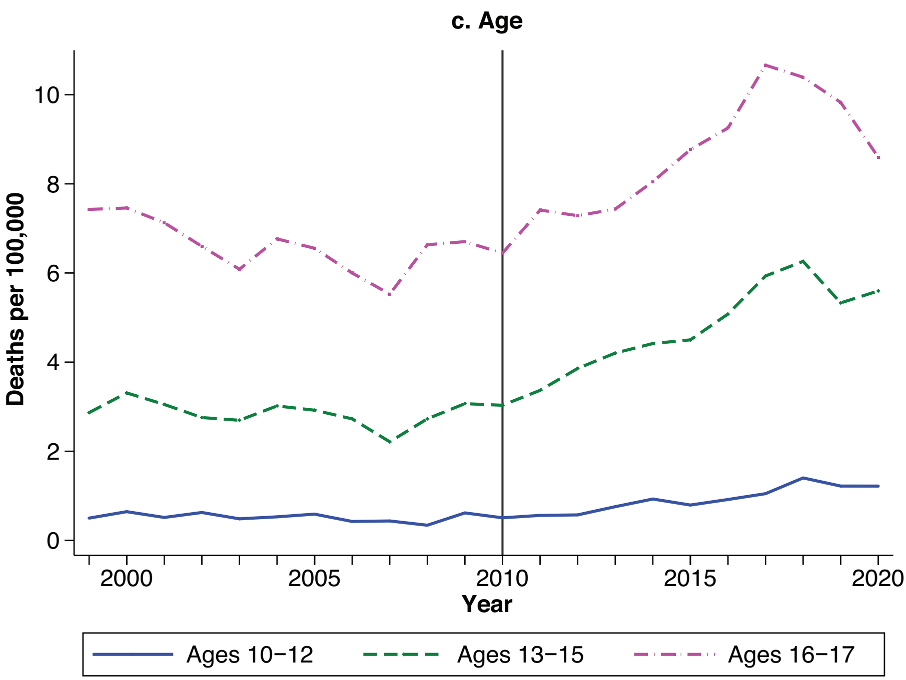

Fig. 3 (continued)

Difference-in-Differences Analyses

There are many reasons that child suicide rates may have increased after reformulation. By comparing states more exposed to reformulation to states less exposed, the difference-in-differences analyses can isolate the role of the shift to illicit opioids from other nationwide factors. Before proceeding to the main results, it is illustrative to extend prior work on the overdose mortality effects associated with exposure to reformulation for the full population. I include these results in Figure A2. I find little evidence of preexisting trends, followed by differential growth in deaths involving heroin or synthetic opioids. Although not a perfect measure, changes in these deaths likely reflect illicit opioids during this period. I observe a statistically significant increase beginning immediately in 2011. This effect was primarily driven by heroin at first but later transitioned to synthetic opioids.

Panel a of Figure 4 presents the conditional relationship between pre-reformulation OxyContin misuse and child suicide rates for 1999–2020. There is little evidence of systematic differences in child suicide trends based on nonmedical OxyContin misuse prior to 2010. However, notably, the 2009 estimate (which is normalized to 0) is the smallest in the preperiod but, as discussed in the following, this transitory decrease does not explain the subsequent large increases.

The relationship between pre-reformulation OxyContin misuse and child suicide rates strengthens immediately in 2010, followed by further growth over time and peaking in 2018. Although 2010 was a partially treated year (reformulation

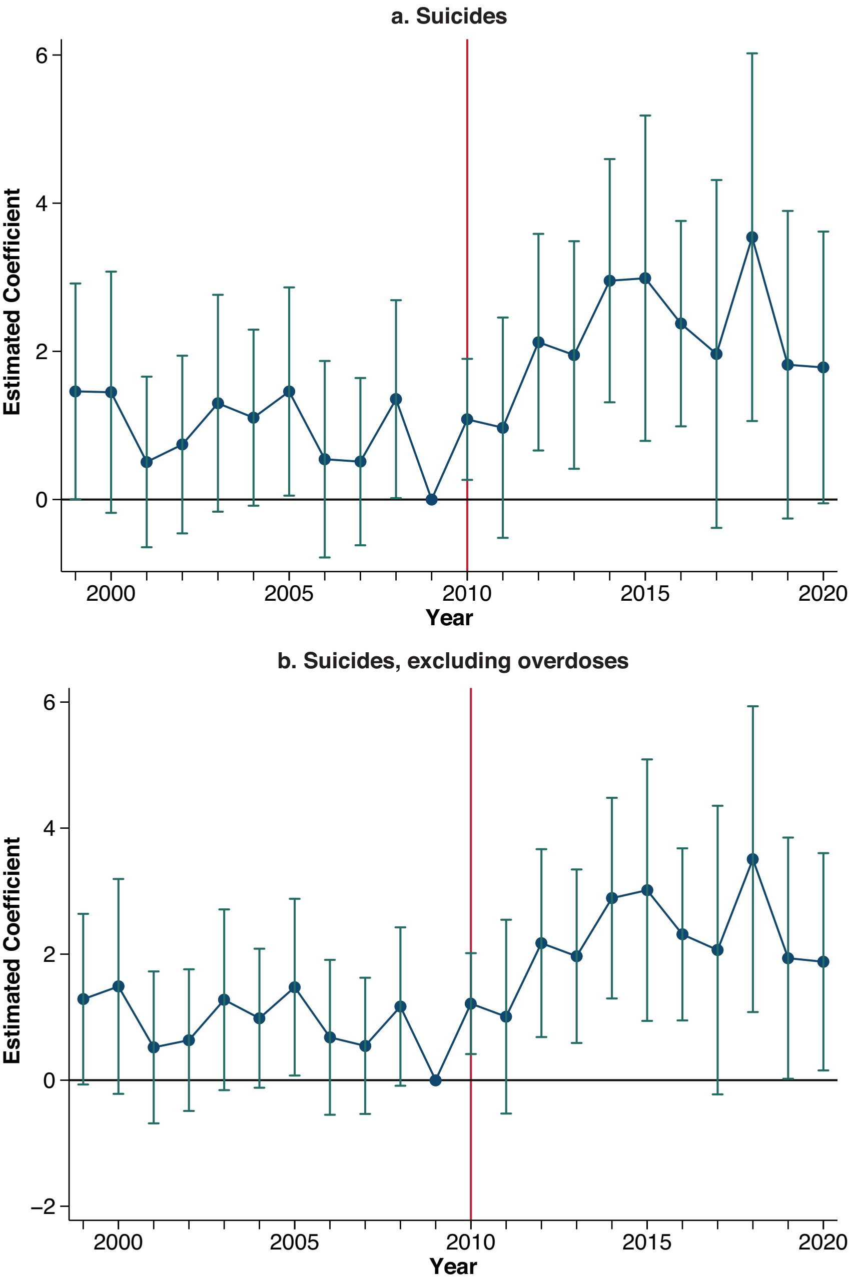

Fig. 4 Difference-in-differences estimates for suicide and overdose deaths per 100,000, ages 10–17. 95% confidence intervals were adjusted for clustering at the state level. The 2009 estimate is normalized to zero. The estimated specification included state × race × age × sex fixed effects and year × race × age × sex × census region fixed effects and was weighted by population size. Specification also included controls for fraction of the population that is White, fraction that is Black, the minimum wage, anti-bullying laws, PDMPs, and "mandatory access" PDMPs. The outcome was suicides or overdoses per 100,000 for ages 10–17. Each point estimate represents the coefficient for the year on the pre-reformulation nonmedical OxyContin misuse (%) variable. OxyContin reformulation is indicated by a vertical line in 2010.

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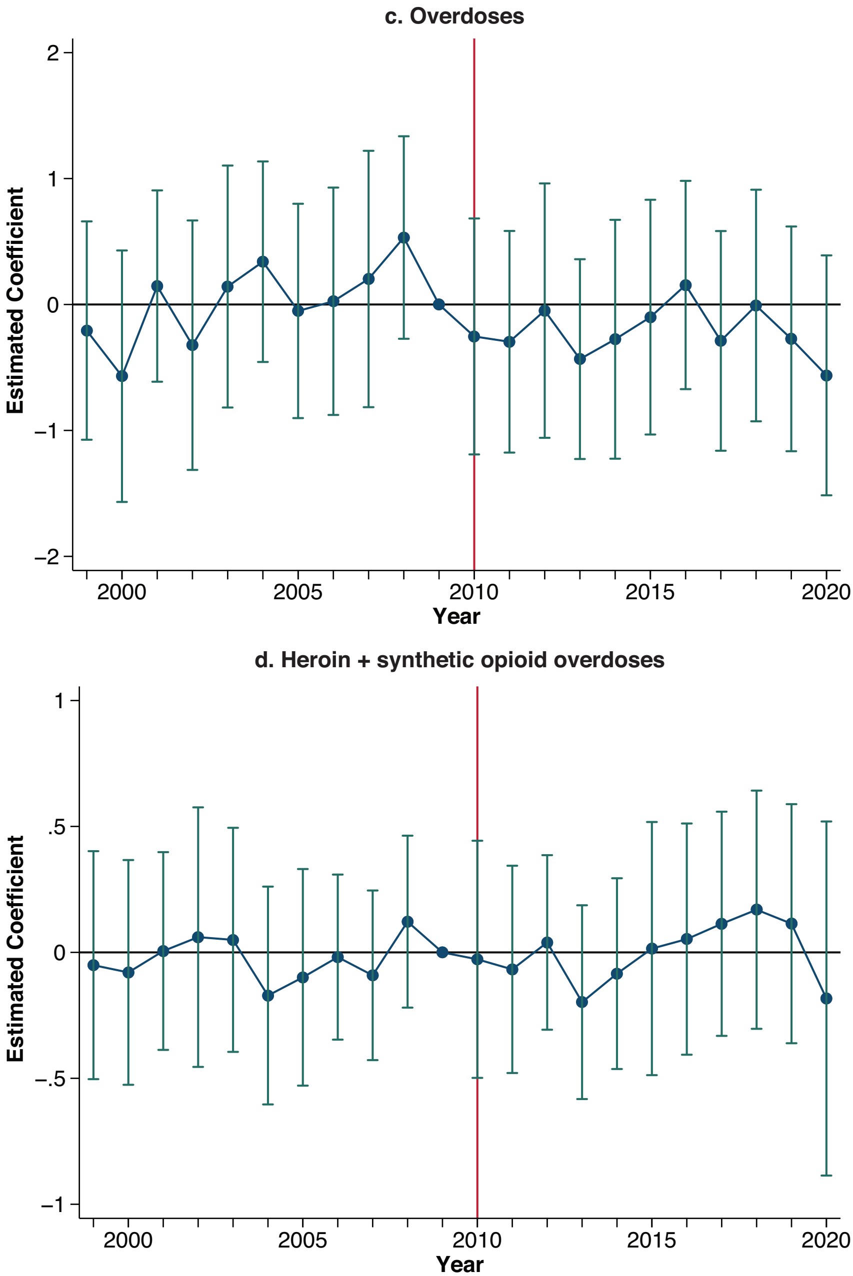

Fig. 4 (continued)

occurred in August), we observe a large 2010 effect relative to 2009, suggesting that the removal of the abusable formulation may have been immediately disruptive and potentially had outsized short-term behavioral effects. This response would be consistent with especially harmful effects resulting from people entering illicit markets and accessing more potent opioids for the first time.[15] This immediate increase was not transitory. The relationship increases substantially as the opioid crisis worsens and illicit markets further develop and innovate.

The overall estimated pattern is similar when suicides also designated as overdoses are excluded (Figure 4, panel b). I exclude overdoses to consider the possibility of a mechanical increase in suicides because of an increase in overdose deaths; however, the results do not appear to be driven by this mechanism.

I observe no relationship between exposure to reformulation and overdose rates for those aged 10–17 (Figure 4, panel c) or overdoses involving heroin or synthetic opioids (panel d). These results are consistent with this age group not increasing illicit opioid use and suggest that the illicit opioid crisis has not affected children directly by increasing misuse and overdoses.

I summarize the relationship between pre-reformulation OxyContin misuse and child suicide rates in the first column of Table 2. I do not include any time-varying controls and estimate that each percentage point of pre-reformulation misuse is associated with an additional 1.642 annual suicides per 100,000 children after 2010. When I add controls, this estimate is relatively stable, increasing to 1.672, statistically different from zero at the 1% level. A one-percentage-point difference in misuse is large, so it is helpful to express this response in terms of a one-standard-deviation-higher pre-reformulation misuse rate, which is equal to 0.23. The estimate then implies that each standard deviation of misuse is associated with an additional 0.38 annual suicides per 100,000 children after 2010.

Methodological Concerns and Sensitivity Analyses

I find a strong relationship between pre-reformulation OxyContin misuse and growth in suicide rates beginning immediately after reformulation. There is little evidence of confounding trends, and child suicide rate *levels* were also similar prior to reformulation—a useful property when evaluating the validity of difference-in-differences designs (Kahn-Lang and Lang 2020). The differential growth in suicides surpasses any previous magnitude of variation across states, implying that it does not reflect mean reversion or natural fluctuations.

States may be different in unobserved ways that predict growth in suicide rates beginning in 2010. In the third and fourth columns of Table 2, I add the pain reliever misuse variable (interacted with post-2010). The main estimate is not meaningfully affected by the inclusion of this variable, and suicide rate growth is not statistically associated with pre-reformulation pain reliever misuse rates. This result implies that the growth in suicide rates is unique to OxyContin. Many policies addressed opioid

[15] There is less evidence of an immediate impact on overdose deaths for the full population (Figure A2); however, the harmful effects of shifts to illicit opioid markets may occur even without an increase in overdose deaths.

Table 2 Aggregate difference-in-differences estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
OxyContin Misuse	1.642*	1.672**	1.444*	1.442*	1.558*	1.283*	1.763**	1.628*
	(0.651)	(0.627)	(0.694)	(0.647)	(0.606)	(0.573)	(0.649)	(0.661)
Pain Reliever Misuse			0.163	0.206				
			(0.184)	(0.175)				
Pre-Period	2006–2009	2006–2009	2006–2009	2006–2009	2006–2010	1999–2009	2006–2009	2006–2009
States	All	All	All	All	All	All	No FL	No WV
Time-Varying Controls	No	Yes	No	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses are adjusted for clustering at the state level. The outcome is suicides per 100,000 for ages 10–17 by demographic group. The post-period is 2011–2020. The pre-reformulation suicide rate (2006–2009) is 2.794 per 100,000. The estimated specification included state × race × age × sex fixed effects and year × race × age × sex × census region fixed effects and was weighted by population size. Time-varying controls included fraction of the population that is White, fraction that is Black, the minimum wage, anti-bullying laws, PDMPs, and "mandatory access" PDMPs. Columns 3 and 4 include an additional control for the pre-reformulation pain reliever misuse rate (excluding OxyContin) interacted with an indicator equal to 1 for 2011–2020. Each point estimate represents the coefficient on the nonmedical OxyContin misuse (%) variable for 2011–2020, except for the point estimate related to the pain reliever misuse rate. FL = Florida, WV = West Virginia.

*$p < .05$; **$p < .01$

use and misuse, but they rarely targeted OxyContin specifically, except for reformulation. Although there are concerns about differences across states that might predict differential *growth* in suicide rates, these confounding factors should load onto the pain reliever misuse variable.

Moreover, states more exposed to reformulation were not disproportionately affected by the Great Recession. The Great Recession would be unlikely to explain such a persistent effect because the growth in suicides outlasted the recession. Other state or local policies may also have independently mattered. Such policies (or other factors) would confound the main estimates only if they were correlated with OxyContin misuse, these correlations emerged immediately after reformulation, and the correlations are unique to OxyContin misuse and not broader pain reliever misuse. Similarly, although classifying deaths as suicides can be problematic (Crepeau-Hobson 2010; Schmidt et al. 2002), it is unlikely that pre-reformulation rates of OxyContin misuse would be correlated with quality changes in suicide classification and only became correlated exactly at the time of reformulation.

To assess the importance of the choice of preperiod, in column 5 of Table 2, I include 2010 as part of the preperiod. This is a conservative choice given that 2010 was partially treated. The estimate decreases (relative to column 2), as expected, but not to a meaningful extent. In column 6, I use the full preperiod available, 1999–2009. The estimate is relatively unaffected by choice of preperiod. I also study whether the results are driven by Florida, given that Florida cracked down on pill mills around the same time as reformulation (Kennedy-Hendricks et al. 2016). In column 7, I exclude Florida. In column 8, I exclude West Virginia, as it had the highest overdose rate for much of the post-reformulation period (Warfield et al. 2019). Results are similar whether Florida or West Virginia is excluded.

I further evaluate the assumptions of my analysis in the online appendix. I find that the results are similar when demographic and policy adjustments are excluded (see Figure A3). While I discussed the merits of including the flexible interaction terms, instead of just state and time fixed effects, the results are similar when these additional terms (and the control variables) are excluded. This implies coefficient stability and suggests that the OxyContin misuse variable is not correlated with other factors driving child suicide growth.

I also provide results for the full 0–17 population, and the findings are similar (Figure A4). In the main analysis, I use a continuous exposure variable. Alternatively, I can compare above-median misuse states to below-median states. I find similar results using this approach (Figure A5). Results are also similar when I account for state-specific trends (Figure A6). Finally, recent literature has discussed concerns with difference-in-differences methods (De Chaisemartin and D'Haultfoeuille 2022). I find that these critiques are not important in this context (Figure A7).

Extrapolation Exercise

In this section, I use the main estimates to extrapolate the implications of reformulation and the subsequent shift to illicit opioids on national child suicide rates. Extrapolations are necessarily "out of sample," so the usual caveats about such exercises apply. If we are willing to extrapolate the across-state findings to explain national

Table 3 Difference-in-differences estimates by demographic group

	Males	Females	AI/AN	AAPI	Black	White	Ages 10–12	Ages 13–15	Ages 16–17
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
OxyContin									
Misuse	2.355*	0.953**	−0.604	2.457*	−0.306	1.961**	0.520**	2.588**	1.980
	(1.006)	(0.336)	(2.873)	(1.105)	(0.518)	(0.693)	(0.181)	(0.901)	(1.224)
Pre-Reformulation									
Mean	4.053	1.469	6.877	1.762	1.757	2.996	0.455	2.683	6.213

Notes: Standard errors in parentheses are adjusted for clustering at the state level. The outcome is suicides per 100,000 for ages 10–17 by demographic group. The pre-reformulation mean uses the 2006–2009 pre-period. The estimated specification included state × race × age × sex fixed effects and year × race × age × sex × census region fixed effects and was weighted by population size. Specification also included controls for fraction of the population that is White, fraction that is Black, the minimum wage, anti-bullying laws, PDMPs, and "mandatory access" PDMPs. Each point estimate represents the coefficient on the nonmedical OxyContin misuse (%) variable for 2011–2020. AI/AN = American Indian and Alaska Native. AAPI = Asian American and Pacific Islander.

*$p < .05$; **$p < .01$

growth, then the estimate of 1.672 annual child suicides per 100,000 should be multiplied by the national pre-reformulation of OxyContin misuse rate of 0.475, implying that the shift to illicit opioids induced an additional 0.79 annual suicides per 100,000 children. Comparing 2011–2020 with 2006–2009, the annual child suicide rate increased by 1.59 per 100,000. Thus, this exercise suggests that the reformulation of OxyContin can explain 49% of the rise in child suicides.

A similar exercise for 2018—the highest estimated coefficient in Figure 4, panel a—implies that reformulation increased child suicides in 2018 by 1.68 per 100,000. The 2018 child suicide rate was 2.68 per 100,000 higher than the 2006–2009 rate, suggesting that reformulation accounted for 63% of the increase in child suicides at its peak.

Subgroup Analyses

The illicit opioid crisis has affected different demographic groups than the first wave of the opioid crisis, suggesting that we may observe differential effects of reformulation. Table 3 explores this possibility. I find positive effects for most subgroups, consistent with a broad impact on the population. I estimate larger effect sizes for males than females, although both effects are large and statistically significant from zero at the 5% level. I also find that reformulation disproportionately affected AAPI and White children; I estimate negative but small and statistically insignificant effects for AI/AN and Black children.

The largest effects across all subgroups are estimated for those aged 13–15. The lack of associations for some groups does not imply that the illicit opioid crisis did not affect them. Instead, it suggests that the predictor of growth in illicit opioid markets used in this analysis does not predict growth in suicide rates for those groups. Consequently, the analysis may simply not be able to isolate all subgroup effects due to differential demographic exposure to the first wave of the opioid crisis.

Possible Pathways

The literature on child suicides has identified a host of risk factors, but there is limited evidence about the causal nature of these associations given the difficulties in independently varying such factors as neglect and food insecurity. This article provides evidence of the importance of a large and broad social change—the illicit opioid crisis—as a driving force behind the recent unexplained increase in child suicides. The transition to the illicit opioid crisis has altered households and society in several documented ways and likely on countless unstudied dimensions.

In this section, I document changes in the conditions faced by children during the period. I plot time series trends for possible intermediate factors, relying on the literature exploring the effects of OxyContin reformulation. If the illicit opioid crisis were increasing child suicide rates because it harmed economic conditions, adding a potential stressor to the lives of children, then we would expect to observe the relevant economic metrics to have similar national trends as the child suicide rate.

Of course, the absence of such a trend does not indicate that the illicit opioid crisis had no impact on the metric itself. For example, the reformulation of OxyContin increased food insecurity rates (Heflin and Sun 2022), but national food insecurity rates (discussed below) decreased for most of the post-reformulation period as economic conditions improved during the recovery from the Great Recession. Thus, the findings in the literature imply that food security rates would have recovered even faster in the absence of reformulation, but the lack of a similar national trend in child food insecurity rates suggests that food insecurity rates themselves are not a primary factor linking the illicit opioid crisis with child suicide rates.[16]

In Figure 5, I plot the national trends for a subset of household- and society-level conditions experienced by children that the literature on the reformulation of OxyContin has studied (or outcomes related to those studied). In the most related work to this article, Evans et al. (2022) found that reformulation increased rates of child neglect claims. Panel a plots the national trend in substantiated abuse claims per 1,000 children for 2006–2019 using restricted data from the National Child Abuse and Neglect Data System (NCANDS).[17] The NCANDS represents a census of referrals to state child protective services agencies.[18] The post-reformulation rise in child neglect rates mirrors the one observed for suicide rates, suggesting a shared set of

[16] However, food insecurity may independently affect suicide rates (i.e., child suicide rates increased despite improvements in food security).

[17] I use the 2006–2020 data—which provide cases for each fiscal year—to construct rates for calendar years 2006–2019. I follow the method and code used in Evans et al. (2022), which reported rates for 2006–2017. See their article for more details on construction of these rates and on difficulties in harmonizing these data with earlier years.

[18] The data were acquired through an agreement with the National Data Archive on Child Abuse and Neglect.

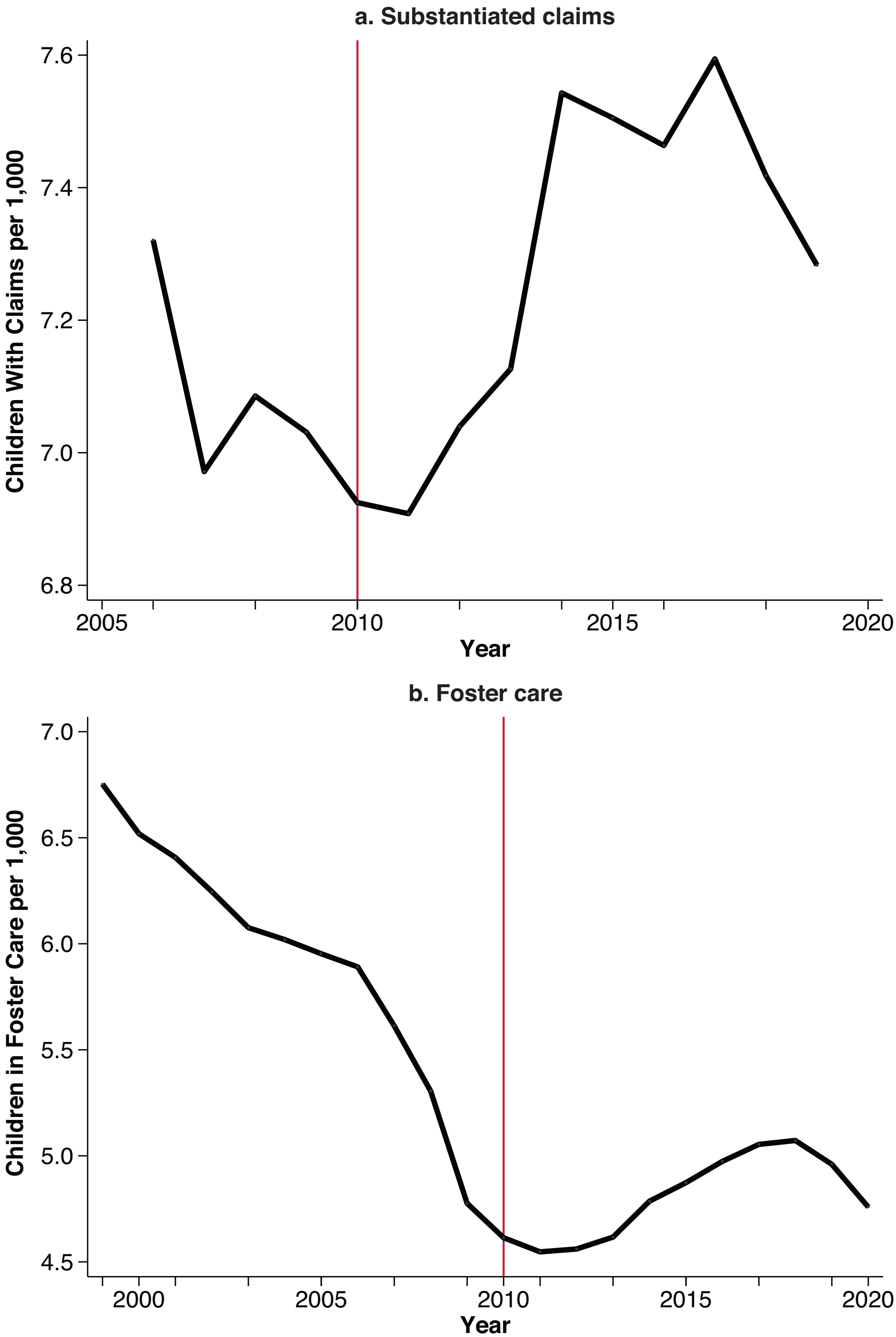

Fig. 5 National time series trends for possible pathways. National trends in measures were impacted by reformulation. OxyContin reformulation is indicated by a vertical line in 2010. See text for discussion of data sources.

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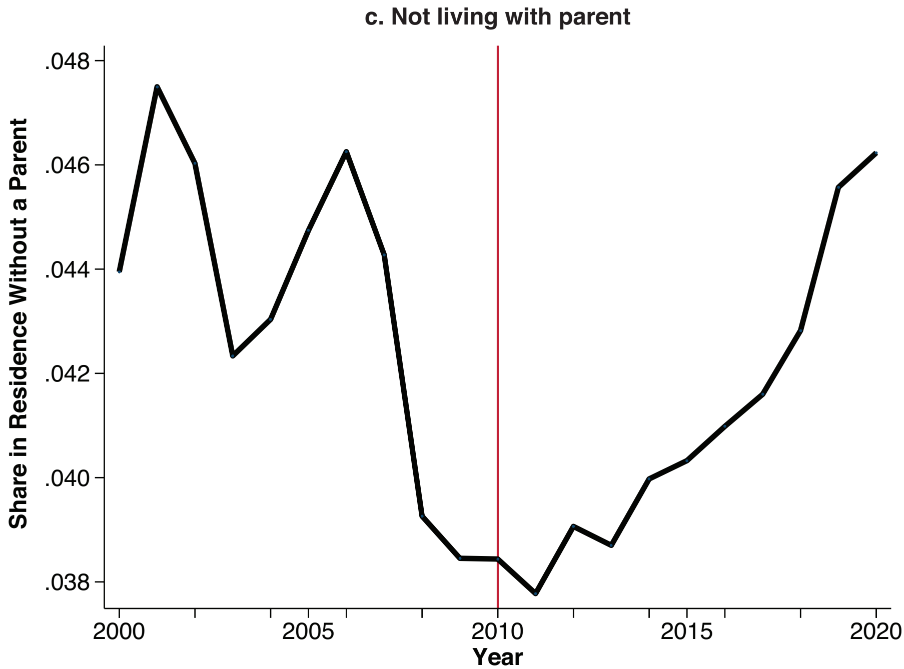

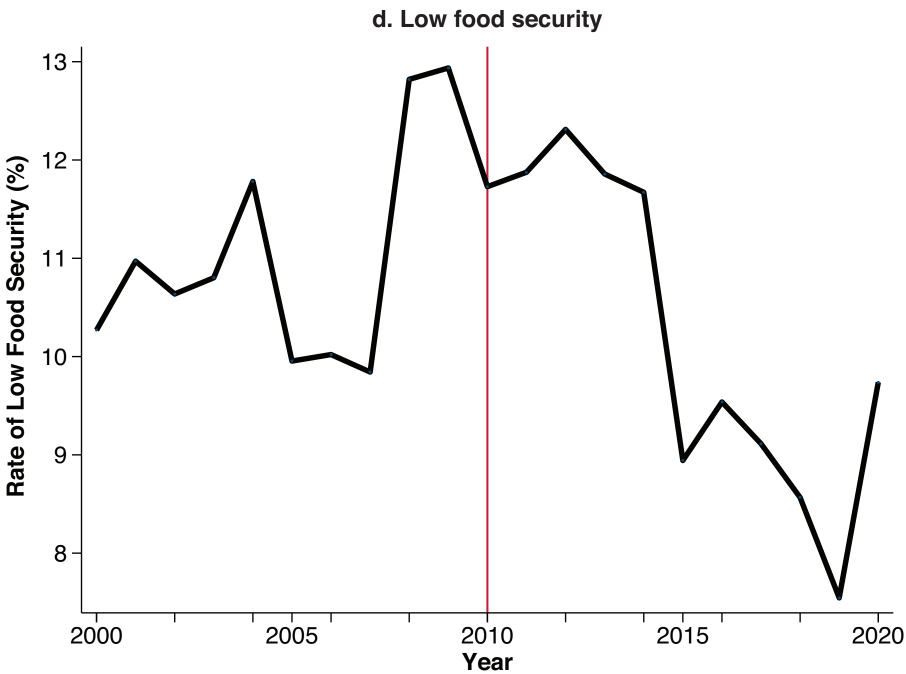

Fig. 5 (continued)

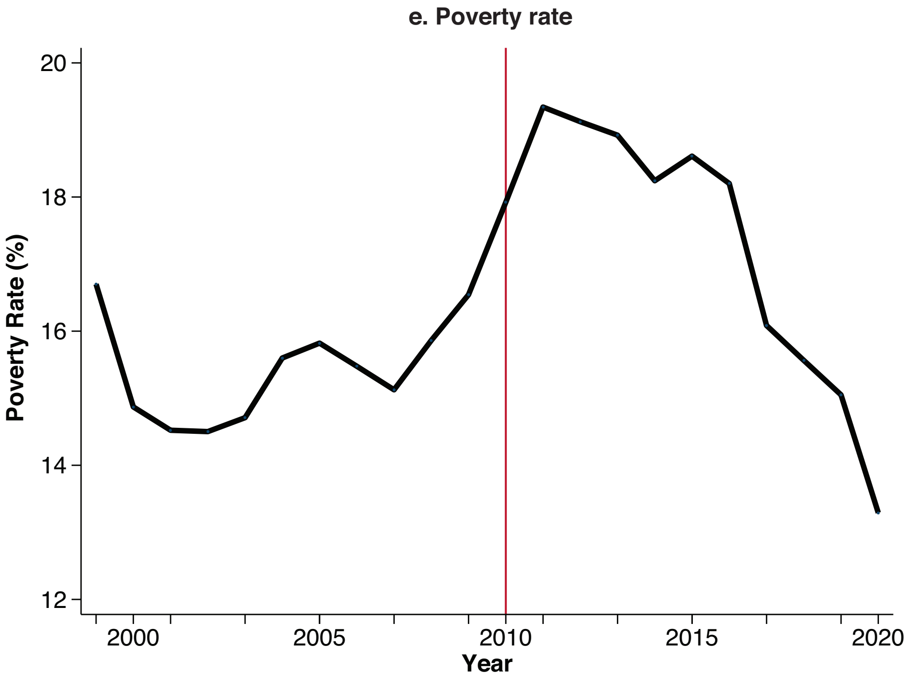

Fig. 5 (continued)

underlying causes. Neglect itself may lead to suicide or the conditions leading to child neglect may predict child suicide rates. These patterns suggest that the illicit opioid crisis is affecting child suicide rates through adverse effects on parents and caretakers. Although the determinants of child maltreatment are complicated and numerous (Bullinger et al. 2021), parental opioid use has been associated with child neglect (Bullinger and Ward 2021; Romanowicz et al. 2019), and that association may have worsened because of the shift to illicit opioids.

To further understand the conditions leading to higher rates of suicide and neglect, I study living arrangements given evidence that reformulation increased foster care admissions (Dallman 2020; Mackenzie-Liu 2021).[19] The rise in overdose deaths (Powell and Pacula 2021) and rise in criminal behavior (and, likely, incarceration) (Mallatt 2022) could affect whether a child lives with a parent. I use data from the Adoption and Foster Care Analysis and Reporting System to plot trends in foster care rates for 1999–2020. As a complementary measure, I calculate the share of children aged 10–17 not living in a residence with at least one parent, using the intrahousehold relationship variables constructed from the American Community Survey by IPUMS

[19] Most child neglect cases do not result in child removal (Testa and Smith 2009), and, at the state level, foster care rates and child neglect rates have a surprisingly low correlation (Doyle and Aizer 2018). Thus, it is useful to analyze both factors separately.

(Ruggles et al. 2023). For both outcomes, there are large declines prior to reformulation followed by increases after reformulation (Figure 5, panels b and c).

Although child suicide rates after reformulation far surpass their pre-reformulation rates, the increases in foster care rates and share of children not living in a household with a parent do not. It could be that the reasons behind the changes in living arrangements since reformulation are important mechanisms that increase suicide rates, but living arrangements themselves are not primary determinants. For example, living arrangement changes since reformulation may have become increasingly related to parental death and incarceration, which are important child suicide risk factors. The trends in panels b and c of Figure 5 suggest that living arrangements may be contributing factors in worsening the conditions of children but are not the main factors.

Lastly, I examine broader economic conditions as proxies for possible household-level stressors that might predict neglect. Specifically, I consider the rate of food insecurity for children aged 10–17, constructed using CPS supplement data (discussed earlier). I also look at child poverty rates given that the literature has found that reformulation decreased household income (Park and Powell 2021) and poverty rates are associated with child suicide attempts and deaths. Child poverty rates were constructed using the CPS Annual Social and Economic Supplement “official poverty” variable. These trends are shown in panels d and e of Figure 5. These economic metrics were generally improving after reformulation, given the recovery from the Great Recession. Reformulation slowed this recovery but did not impede it. This evidence suggests that worsening economic conditions were not the reason that the illicit opioid crisis increased child suicide rates.

Overall, this analysis suggests that conditions for children have worsened since reformulation by increasing child neglect rates and for reasons related to changing living arrangements. Overdose death rates have increased, suggesting roles for bereavement and the harmful effects associated with parental death. There is less evidence that economic conditions have caused suicide rates to rise, given that they have improved since reformulation for reasons unrelated to the opioid crisis. These metrics suggest that the spillovers of the illicit opioid crisis that are affecting child welfare predominantly originate with effects on families and caretakers. There is less evidence of impacts on children through broader social conditions. Of course, this conclusion is reached after analyzing only a small set of possible pathways and should only be considered suggestive.

Discussion

Child suicides rates began rapidly increasing after the 2010 reformulation of OxyContin. This growth was uniquely long in duration and large in magnitude relative to annual suicide rates back to 1980. Child suicide rates reached record highs and, even after modest reductions in 2019 and 2020, are still well above pre-reformulation rates.

Reformulation affected the entire country; however, I observe a strong association between differential exposure to reformulation and growth in child suicide rates. States that experienced a stronger transition to illicit opioids as a result of reformulation suffered disproportionate growth in child suicide rates. This differential growth began only after reformulation.

I find little evidence of changes in overdose rates—overall or by type—for those aged 10–17, suggesting little change in illicit opioid use for this population. The results are consistent with growth in illicit opioid access and use among the adult population generating worsening conditions for children by increasing rates of child neglect (Evans et al. 2022), changing living arrangements (Mackenzie-Liu 2021), increasing crime (Mallatt 2022), and reducing household income (Park and Powell 2021); other mechanisms are also likely. A brief analysis of national trends in some of these conditions suggests that child neglect is itself a critical mechanism linking the illicit opioid crisis with child suicide rates or it shares common underlying determinants. Trends in living arrangements also share some common properties with national trends in child suicide rates, although they would not themselves explain the magnitude of the rise in child suicides.

The results do not rule out that other factors related or unrelated to the opioid crisis may have played independent or complementary roles in the growth of child suicide rates. Other opioid-specific policy changes and broader reductions in opioid supply (Stein et al. 2022) may have played independent roles. Lack of treatment access (Davis and Carr 2019), nonopioid policies affecting opioid use and misuse (Bradford and Bradford 2020; Venkataramani and Tsai 2020), and social factors (O'Brien et al. 2022) may have played complementary roles. Reformulation itself was not the sole factor in shifting people to illicit opioids. However, this analysis does not require fully explaining the transitions in the opioid crisis. Instead, it uses reformulation and its differential geographic effects to understand the relationship between these transitions and child suicide rates.

The results also suggest substantial heterogeneity across demographics. Groups suffering disproportionately faster growth in suicide rates were often found to have been more affected by reformulation. I estimated larger effects of reformulation for males. From 2009 to 2020, males experienced a faster rise in suicide rates of 2.0 per 100,000 compared with 1.1 per 100,000 for females. Similarly, I found large differences by age, with the largest effects for the 13–15 age group. This is also the age group that experienced the largest increase in suicide rates from 2009 to 2020 (2.5 per 100,000 vs. 0.6 per 100,000 for those aged 10–12 and 1.9 per 100,000 for those aged 16–17).

Stratifying by race, the effects were largest for AAPI and White children. The latter experienced the largest increase in suicides from 2009 to 2020 (1.7 per 100,000), while suicide rates for AAPI children also grew substantially (1.3 per 100,000). However, Black children also experienced fast growth during this time period (1.5 per 100,000), but I did not find evidence that reformulation was driving this growth, possibly because the exposure variable used in this article is not representative of the exposure to the illicit opioid crisis experienced by this population, although other explanations are also possible.

Conclusions

OxyContin reformulation induced transformative growth in illicit opioid markets. Nationally, at the same time, suicide rates of children increased sharply and rose unabated for an unprecedented eight consecutive years, ushering in a new mental health crisis. Child suicide rates remain at historically high levels, yet there is limited research on the determinants of this crisis. Although the overdose rate and child mental health are both considered national crises, they have generally been considered independent. This article establishes a critical link between the two. I find that the transition of the opioid crisis to illicit opioids that accompanied reformulation is associated with the growth in child suicide rates. States more exposed to the illicit opioid crisis have experienced markedly sharper growth in child suicide rates. The literature has previously shown strong evidence that reformulation has led to worsening conditions for children (Evans et al. 2022; Mackenzie-Liu 2021), but this study is the first to show a link with child suicide rates. This growth is uniquely associated with pre-reformulation OxyContin misuse and is not related to pain reliever misuse more broadly.

Overall, I find that each percentage-point difference in pre-reformulation OxyContin misuse predicted an additional 1.7 annual suicides per 100,000 children between 2011 and 2020. This estimate implies that a one-standard-deviation-higher pre-reformulation misuse rate was associated with an additional 0.38 annual suicides per 100,000 after 2010. A simple extrapolation exercise suggests that OxyContin reformulation can explain about half of the growth in child suicide rates since 2010.

As the opioid crisis continues to transition to illicit and synthetic opioids, the destructive exposure of children to this social environment will only worsen. The damage and suffering caused by the opioid crisis are not reserved to those misusing opioids. The results of this study suggest additional gains in addressing the harms associated with the opioid crisis, such as improving treatment access (Larney and Hall 2019; Saloner and Barry 2018) or investing in alternative pain management therapies (U.S. Food and Drug Administration 2022). For example, Ali and Ghertner (2022) found that improvements in buprenorphine treatment availability decrease substantiated child maltreatment cases. As policymakers consider the benefits of these interventions relative to their costs, there is growing evidence that the returns of these investments are even larger than previously anticipated. Unfortunately, effective policy options in response to the growing opioid crisis are limited (Rao et al. 2021), suggesting that some pessimism about the future of child suicide rates is warranted. ■

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David Powell
dpowell@rand.org

RAND, Arlington, VA, USA