Proceedings of ICMMGH 2027 Symposium: Transforming Nutrition for Public Health Across the Life Course
DOI: 10.54254/2753-8818/2027.KL38074

Estimating the Economic Cost of the Fentanyl Shock: A Cost-of-Illness Analysis of Opioid Overdose in West Virginia and Pennsylvania

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Abstract. After fentanyl displaced prescription opioids as the primary driver of overdose fatalities, the U.S. opioid crisis entered the so-called "fourth wave." However, most existing state-level illness cost estimates remain anchored to circa 2017. This study extends these estimates to 2022 and 2023 using the illness-cost framework developed by Florence et al. To our knowledge, this study is the first to place Pennsylvania and West Virginia within the same framework. This study uses the human capital approach to calculate two types of costs, fatal overdose and non-fatal opioid use disorder, drawing on data from the CDC WONDER mortality database, the SAMHSA NSDUH prevalence surveys, and the official annual VSL/VSLY estimates released by HHS. The results indicate that the total economic burden in both states rose by approximately 133% between 2017 and 2023, far outpacing the increase in overdose fatalities; this growth is primarily driven by a substantial expansion in OUD prevalence cases. The composition of the burden has also shifted from being dominated by fatal costs toward a larger share of nonfatal costs. West Virginia's criminal justice costs could only be estimated using scenario analysis, due to the lack of publicly released annual arrest data, reflecting a gap in public health data infrastructure between the two states.

Keywords: opioid overdose, cost of illness, fentanyl, economic burden, opioid use disorder

1. Introduction

In the United States, the opioid crisis has three stages: prescription drugs, heroin, and fentanyl, which is increasingly combined with xylazine and stimulants. The national-level cost estimates also keep pace with this change. The White House Council of Economic Advisers' 2025 report estimates that the opioid crisis caused approximately 2.7 trillion US dollars in economic losses in 2023 [1]. State-level benchmarks, however, have not kept up. Most existing state-level analyses still rely on 2017-vintage cost estimates.

While national estimates have been updated accordingly, state-level cost benchmark data remain confined to the prescription opioid- and heroin-dominated era.

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This state-level benchmark is derived from a body of studies that collectively established the current illness cost estimation framework.

In 2016, Florence et al. estimated the economic costs of prescription opioid overdose, abuse, and dependence; however, the analysis was restricted exclusively to prescription opioids and limited to 2013 data [2].

In 2020, the scope was expanded to all opioids by Florence, Luo, and Rice, and the national cost in 2017 was found to total $1.02 trillion; they were the first to put quality-of-life loss and the value of statistical life (VSL) into the same framework, and the resulting unit-cost estimates were subsequently widely adopted as a benchmark [3]. The following year, these national unit costs were applied to state-level case counts by Luo, Li, and Florence in the CDC's Morbidity and Mortality Weekly Report to produce state-level estimates [4]. West Virginia had the highest per capita cost in the United States, while Pennsylvania was excluded because its mortality data did not meet the drug-specificity requirement, and this state-level benchmark has not been updated since 2017. So far, there is no research indicating whether there have been any changes in state-level costs and cost structure during the fentanyl-dominated phase. This study extends the aforementioned framework to the 2022-2023 period, incorporates Pennsylvania into the analytical scope, and focuses on structural shifts in economic cost composition.

2. Methodology

Mortality data were from CDC WONDER [5], with opioid-involved overdose deaths identified using a combination of underlying-cause and multiple-cause ICD-10 codes. The prevalence data come from SAMHSA's NSDUH [6-8]. The unit cost was not re-estimated; we used the national benchmark established by Florence et al. [3], and inflation was adjusted according to the BLS's CPI-U [9]. The VSL and VSLY parameters were updated to reflect the latest official estimates published in HHS reports [10]. For criminal justice costs, Pennsylvania has complete year-by-year arrest data [11], while West Virginia does not.

This study employs the framework derived from the human capital approach developed by Florence et al. [2, 3], in which costs are divided into two categories: fatal overdose and opioid use disorder (OUD). The total economic burden (TB) for a given state and year is calculated as:

$$TB = D \times (HC_f + LP_f + VSL) + N \times (HC_o + TX + CJ + LP_o + HRQOL) \quad (1)$$

where D is the number of fatal overdoses and N is the number of OUD cases. HC_f and HC_o are the per-case health care costs for fatal and nonfatal cases, respectively. LP_f and LP_o are the corresponding lost-productivity costs; TX is treatment cost; CJ is criminal justice cost; VSL is the value of a statistical life; and HRQOL is the health-related quality-of-life loss, calculated as:

$$HRQOL = w \times VSLY \quad (2)$$

where w is the health-state weight (0.354) and VSLY is the value per statistical life year [3].

Given Pennsylvania's comprehensive annual arrest records, its criminal justice costs were estimated as precise point estimates. For West Virginia, by contrast, we adopted a three-tier scenario analysis framework (low, medium, and high scenarios).

Polysubstance data, primarily on xylazine and stimulant co-detection, are not incorporated directly into the cost formula above. Instead, after identifying the detection rate using multiple cause-of-death coding, we use it to help explain the shifts in cost composition.

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3. Result

This section presents the results in four parts: mortality trends and the changing drug landscape, the overall growth in economic burden and its drivers, structural shifts in cost composition, and the uncertainty surrounding criminal justice costs.

3.1. Mortality trends and the changing drug landscape

Overdose deaths in both Pennsylvania and West Virginia rose between 2017 and 2022-2023 [5]. In Pennsylvania, the number of Overdose deaths increased from 2,548 in 2017 to 3,960 in 2022, then dropped to 3,576 in 2023. The overdose death rate rose from 19.9 per 100,000 in 2017 to 30.5 in 2022, then fell back to 27.6 in 2023. In West Virginia, the number of overdose deaths rose from 833 in 2017 to 1,146 in 2022 and then to 1,184 in 2023; the overdose death rate climbed from 45.9 to 64.6 and then 66.9 per 100,000, one of the highest mortality rates among states. The 2017-2023 period examined in this study corresponds to the "fourth wave" of the crisis, when fentanyl replaced prescription opioids as the main lethal drug and was often used in combination with sedatives such as xylazine. Using SUDORS data spanning January 2021 to June 2022, Kariisa et al. reported that 23.3% of fentanyl-related deaths in Pennsylvania involved xylazine, ranking the state third nationally [12]. West Virginia was not named in that article, but the study's classification map places it in the same highest range as Pennsylvania, 20.0% to 27.7% of fentanyl-related deaths, with fentanyl-related deaths as the denominator. A separate West Virginia-based study found xylazine detection increased from 1% in 2019 to 5% in mid-2021, where the denominator for this proportion was all drug-involved deaths [13]. These two figures use different denominators and are not directly comparable, but both indicate that xylazine detection in West Virginia is rising. The authors also found that fentanyl was detected in 98% of xylazine-related deaths as shown in Table 1.

Table 1. Fentanyl-xylazine co-involvement: background data sources

Source	State	Time Window	Denominator	Xylazine Co-Involvement
Kariisa et al. [12]	Pennsylvania	Jan 2021-Jun 2022	Fentanyl-related deaths	23.3% (3rd highest state)
Kariisa et al. [12]	West Virginia	Jan 2021-Jun 2022	Fentanyl-related deaths	20.0%–27.7% (same bracket)
Sibbesen et al. [13]	West Virginia	2019-mid-2021	All drug-related deaths	1% (2019) to 5% (mid-2021)

Note: The two sources use different denominators and only partially overlapping time windows; the percentages are not directly comparable to one another and are cited here as background context only, not as inputs to the cost model. Sibbesen et al. [13] also found that 98% of xylazine-involved deaths in West Virginia also involved fentanyl.

3.2. Overall economic burden and its drivers

Table 2 shows the economic burden rose by approximately 133% in both states between 2017 and 2023, an increase far exceeding the growth in overdose fatalities (Pennsylvania: +40.3%; West Virginia: +42.1%). The expansion in OUD case counts constitutes the primary driver of total economic burden: West Virginia's OUD case count increased 2.25-fold under a consistent combined definition applied across the full period. Pennsylvania's OUD case count rose 1.88-fold, but the 2017 figure was based on pain reliever use disorder alone, while the 2022 and 2023 figures used the

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combined definition. These two figures are not directly comparable, and the existing data cannot separate how much of Pennsylvania's apparent increase reflects real growth versus the broadening of the survey definition. Because of this definitional issue, Pennsylvania's 132.7% total burden increase is itself questionable. If Pennsylvania's 2017 OUD case count is replaced with the estimate of about 98,667, extrapolated from West Virginia's same-period ratio as shown in Table 2, the total burden increase shrinks from 132.7% to 107.9%, lower than West Virginia's 132.7% over the same period. The composition of the burden has also shifted as shown in Table 3: the share of fatal costs in total burden has declined in both states, while the share of nonfatal OUD-related costs has correspondingly risen.

Table 2. Economic burden of opioid overdose in Pennsylvania and West Virginia, 2017-2023

Year	State	Deaths	Fatal Cost ($ billion)	OUD Cases	OUD Cost ($ billion)	Total Burden ($ billion)	Per Capita Burden ($)	Fatal Share (%)
2017	Pennsylvania	2,548	29.43	74,000	16.37	45.80	3,576	64.3
2017	West Virginia	833	9.62	16,000	3.54	13.16	7,247	73.1
2022	Pennsylvania	3,960	55.80	256,000	61.43	117.23	9,038	47.6
2022	West Virginia	1,146	16.15	54,000	12.96	29.11	16,397	55.5
2023	Pennsylvania	3,576	52.93	213,000	53.65	106.58	8,222	49.7
2023	West Virginia	1,184	17.52	52,000	13.10	30.62	17,299	57.2

Note: Fatal Cost, OUD Cost, and Total Burden are expressed in 2017, 2022, and 2023 dollars respectively (not inflation-adjusted to a common year). Fatal Share is the share of Total Burden attributable to fatal overdoses.

Table 3. Sensitivity of Pennsylvania's 2017 OUD case definition

Case Definition	OUD Cases	2017 Total Burden ($B)	Increase to 2022	Increase to 2023
Low (PRUD only)	74,000	45.80	+156.0%	+132.7%
High (extrapolated, combined definition)	98,667	51.25	+128.7%	+107.9%

Note: PRUD = pain reliever use disorder. Pennsylvania's 2017 NSDUH report published only PRUD as a standalone measure. The combined definition (heroin + PRUD), used elsewhere in this study, is not available for Pennsylvania in 2017. The high estimate (~98,667) extrapolates West Virginia's PRUD-to-combined-definition ratio (16,000/12,000 = 1.333) onto Pennsylvania's PRUD figure (74,000).

3.3. Cost composition and structural shifts

Table 4 shows the composition of the cost per case. Both OUD and fatal overdose are rising due to the CPI-U inflation and annual adjustments to two official HHS parameters, VSL and VSLY [10]. HRQOL remains the largest component of the per-case OUD cost, at over 80%, but it is also the only component whose share has shrunk over this period, from 82.8% to 81.2%, because VSLY has grown more slowly than the other CPI-U-adjusted components. For fatal overdose, the VSL share increased from 87.5% to 87.8%, because VSL itself has grown faster than CPI. Therefore, the economic burden of fatal overdose is mostly not the medical bills but the social value assigned to the deceased's lost life expectancy. Combining Table 2 and Table 4, it can be seen that the composition of the total burden of the two states is also different: fatal overdose accounts for 57.2% of West Virginia's total burden but only 49.7% of Pennsylvania's.

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Table 4. Per-case cost composition by category, 2017-2023 (US$)

Panel A. Nonfatal Opioid Use Disorder (OUD)						
Year	Health Care	Treatment	Criminal Justice	Lost Productivity	HRQOL	Total
2017	$14,705 (6.6%)	$1,660 (0.7%)	$6,961 (3.1%)	$14,707 (6.6%)	$183,186 (82.8%)	$221,219
2022	$17,557 (7.3%)	$1,982 (0.8%)	$8,311 (3.5%)	$17,559 (7.3%)	$194,559 (81.1%)	$239,967
2023	$18,279 (7.3%)	$2,064 (0.8%)	$8,653 (3.4%)	$18,282 (7.3%)	$204,593 (81.2%)	$251,871

Panel B. Fatal Overdose				
Year	Health Care	Lost Productivity	VSL	Total
2017	$5,462 (0.05%)	$1,443,000 (12.5%)	$10,100,000 (87.5%)	$11,548,462
2022	$6,521 (0.05%)	$1,722,837 (12.2%)	$12,362,409 (87.7%)	$14,091,767
2023	$6,790 (0.05%)	$1,793,755 (12.1%)	$13,000,000 (87.8%)	$14,800,544

Note: Percentages in parentheses denote each component's share of the per-case total for that year. HRQOL = health-related quality of life loss (health-state weight x VSLY). VSL = value of statistical life.

3.4. Criminal justice cost uncertainty

Data on criminal justice costs are the weakest of all categories in this analysis. The Pennsylvania State Police have released relatively complete annual data on opioid-related arrests [11], which increased from 1,174 in 2013 to a peak of 3,053 in 2021, and then dropped back to 1,908 in 2023. However, we still rely on the national unit cost to estimate Pennsylvania's criminal justice costs because of the absence of a model for converting arrest counts into a per-case criminal justice cost. West Virginia does not have publicly released annual data on opioid-related arrests; the only available figure from BJS is static: drug offenders accounted for 11.7% [14] of the state's sentenced inmates. This study therefore applies three coefficients, 0.7, 1.0, and 1.3, to construct low, medium, and high scenarios around the national criminal justice unit cost (Table 5). Criminal justice costs account for only about 3% of the per-case OUD cost (Table 4). As a result, although the criminal justice unit cost itself ranges from $6,057 in the low scenario to $11,249 in the high scenario ($8,653 in the medium scenario), a swing of nearly 90%, the resulting fluctuation in total burden is only about ±0.4% to 0.5%.

Table 5. West virginia criminal justice cost scenarios, 2022-2023 (per-case, US$)

Year	Low (x0.7)	Medium (x1.0, baseline)	High (x1.3)
2022	$5,818	$8,311	$10,804
2023	$6,057	$8,653	$11,249

Note: Low/Medium/High scenarios apply multipliers of 0.7/1.0/1.3 to the national criminal justice unit cost, reflecting the absence of publicly released annual arrest data for West Virginia. The medium scenario is the baseline used elsewhere in this study. The resulting

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swing in West Virginia's total burden is approximately +/-0.4%-0.5%.

4. Discussion

The shift in both states' economic burden from fatal costs toward nonfatal OUD costs has direct implications for the allocation of policy resources. If funding priorities continue to be determined solely by death counts or mortality rates, this approach may underestimate the strain that nonfatal OUD imposes on healthcare, treatment, and criminal justice systems. One point worth highlighting is that West Virginia's criminal justice cost had to be estimated using scenario analysis rather than a point estimate. This is mainly because West Virginia lacks both publicly released annual data on opioid-related arrests and a model for converting arrest counts into criminal justice costs. Although the Pennsylvania State Police have released complete annual opioid-related arrests data, no model yet exists to convert those figures into a per-case cost. This cross-state disparity in data infrastructure reflects more than merely a limitation of the present study's analytical approach. Instead, it indicates meaningful disparities in state-level public health surveillance capacity, which directly constrain the accuracy with which policymakers can assess their state's economic burden.

This study also has several limitations. First, Pennsylvania's 2017 OUD case count relied solely on pain-reliever use disorder, which is inconsistent with the combined diagnostic criterion applied for 2022, 2023, and for West Virginia. The second limitation concerns several simplifying assumptions in estimating VSL, VSLY, and HRQOL; there were no official direct release figures for VSL and VSLY in 2022. In this study, we infer the figures using HHS's official 1.0% real income growth rate [10], combined with the CPI-U. This calculation is based on the official method but not on officially measured figures. We also assume the HRQOL weight (0.354) is fixed across years and only updated annually by VSLY. The sensitivity tests show that this assumption leads to a meaningful degree of estimation difference. Third, all unit costs in this study are based on the national benchmark values from Florence et al. [2, 3], updated annually via CPI-U or VSL/VSLY. Neither medical prices nor wage levels were adjusted for either state. Criminal justice costs are likely the most sensitive to this simplification, since incarceration and enforcement costs tend to vary more by region than medical costs do. Fourth, this study cites the trend of fentanyl combined with sedatives such as xylazine only as background information [12, 13]; it was not incorporated into the model as a quantitative attribution adjustment. Both cited studies also have their own limitations, including different denominators and incomplete time windows.

5. Conclusion

Building on Florence et al.'s disease-cost framework [2, 3], this study extends the cost calculation to 2022 and 2023 for both Pennsylvania and West Virginia. To our knowledge, this is the first time Pennsylvania and West Virginia have been compared within the same framework. This study addresses two questions raised in this study: How the economic burden scale changed under the fentanyl impact between the two states, and whether the composition of costs underwent a structural shift. The results show that the economic burden in both states increased by approximately 133% between 2017 and 2023, far exceeding the growth in the death toll itself. This growth is driven mainly by the expansion in nonfatal OUD cases. At the same time, the composition of the burden also shifted from being dominated by fatal costs toward a larger share of nonfatal OUD costs. This finding implies that the government may need to reconsider resource allocation accordingly. The calculation process also exposed a clear gap in data infrastructure between the two states,

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particularly in criminal justice costs for West Virginia. Due to the lack of publicly released annual arrest data, this study relies on Scenario analysis rather than a point estimate for that category.

This study also has several limitations, including Pennsylvania's inconsistent OUD case definition in 2017 and reliance on official methods to estimate several key parameters, as discussed above. Future research could extend this state-level framework to additional states, building a more complete picture of how the economic burden of opioid overdose has evolved across the country during the fentanyl era. As data on polysubstance involvement and state-specific cost parameters become more complete, future studies could incorporate these factors directly into the cost model rather than treating them as background context.

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