Supplemental Online Content

Schlüter B, Alburez-Gutierrez D, Bibbins-Domingo K, Alexander MJ, Kiang MV. Youth experiencing parental death due to drug poisoning and firearm violence in the United States, 1999-2020. *JAMA.* Published online May 4, 2024. doi:10.1001/jama.2024.8391

This supplemental material has been provided by the authors to give readers additional information about their work.

eMethods. Details of the data sources, Matrix Kinship Model, assumptions, limitations, and incorporating uncertainty.

This modeling analysis did not require review by the Stanford University Institutional Review Board, as it does not meet the criteria for human subjects research. Specifically, this analysis uses publicly available, secondary, deidentified data with no risk of reidentification. Here, we provide more information about the data sources, Matrix Kinship Model, assumptions and limitations of the model, and how uncertainty was incorporated.

Data sources

In order to estimate parental death by cause of death, we required (a) population estimates, (b) death counts by cause of death, and (c) fertility rates for both females and males. While 1999 through 2020 is our period of interest, we used data from 1990 through 1998 to initialize the projection model with more accurate estimates of parental age.

Population estimates. This modeling analysis used population estimates from the US Census Bureau for the period 1990 through 2020. These population estimates are stratified by age, race, ethnicity, and sex, and serve as the denominators for mortality and fertility rates.

Mortality data. We used the publicly available Multiple Cause-of-Death Records from the National Center for Health Statistics (NCHS) (1). These files include data from January 1990 through December 2020 and contain individual-level information for all deaths that occur in the US including decedents' cause of death, month and year of death, age, sex, race, and ethnicity.

Female fertility data. The NCHS provides publicly available Birth Files, which contain information for all births that occur in the US including mothers' age, race, and ethnicity. We used fertility data from 1990 through 2020 from the NCHS "Health, United States" series, which summarizes the Birth Files to calculate mothers' birth and fertility rates (2, 3) by age, race, and ethnicity.

Male fertility data. Age-, race-, and ethnicity-specific fertility rates for males in the US are not available. We used male fertility for the total population from the Human Fertility Collection (HFC) (4), to model age-, race-, and ethnicity-specific fertility for males (described below).

In addition to the total population, non-Hispanic Black, non-Hispanic White, and Hispanic subgroups were examined. These groupings were selected because they were consistent with the NCHS bridged-race categories (5), were consistent across both the mortality and fertility data sets, and had sufficient sample size when using the required one-year age groupings.

Tabulating death counts

We tabulated death counts for (a) all causes of death (which includes firearm-related deaths and fatal drug poisonings), (b) fatal drug overdoses only, (c) firearm-related deaths only, and (d) all other causes of death excluding fatal drug poisonings and firearm-related deaths. Death counts were generated for each of these causes of death groupings by racial/ethnic group and sex in one-year age bins (i.e., <1, 1, 2, …, 85+ years old). All cause death counts were tabulated starting from an earlier period, from January 1, 1990 through December 31, 2020, to initialize the demographic projection model and obtain more accurate estimates of the number of children per individual. Fatal drug overdose deaths, firearm-related deaths, and all other causes of death were tabulated for the period of interest for this study, January 1, 1999 through December 31, 2020.

Defining fatal drug poisonings. Consistent with consensus recommendations (5), we defined fatal drug overdoses deaths as meeting two conditions. First, drug-related deaths must have one of the following ICD-10 codes as an underlying cause of death: X40-X44 (unintentional), X60-X64 (intentional), X85 (assault), or Y10-Y14 (undetermined intent). In addition, a drug overdose death also must have a drug-related T-code (T36-T50.9) in one of the twenty contributing cause of death columns.

Defining fire-arm related deaths. Firearm-related deaths were defined as having ICD-10 codes: *U01.4 (terrorism); W32-W34 (accidental); X72-X74 (suicide); X93-X95 (homicide); Y22-Y24 (undetermined); and Y35.0 (legal intervention), consistent with previously published research (6).

Defining all other causes. We defined "all other causes" as deaths that were not fatal drug poisonings or firearms-related drugs as defined above.

Estimating male fertility rates

While there exists national-level data on male fertility, data on rates by race and ethnicity do not exist. As this is an essential input component of the model, we obtain estimates of age-, race- and ethnicity-specific fertility rates for males using a relational regression-based model. Specifically, for a specific race and ethnicity r and age a, we model the ratio of this race-ethnicity-specific fertility rate to the national fertility rate over time using a linear function over time:

$$Ratio_{a,r,t} \quad = \alpha_{a,r} + \beta_{a,r}t \tag{1}$$

We then use the estimates of $\hat{\alpha}$ and $\hat{\beta}$ to obtain an estimate of the ratio of male age-, race- and ethnicity-specific fertility rates to the national-level male fertility rates. In particular we estimate the male fertility rate for race/ethnicity group r, age a, and year t, $f_{r,a,t}$, as

$$\hat{f}_{r,a,t} = \left(\widehat{\alpha_{a,r}} + \hat{\beta}_{a,r}t\right) \times F_{a,t} \times TFR_{r,,t} \times \frac{TFR_{M,t}}{TFR_{F,t}} \tag{2}$$

where $F_{a,t}$ is the national male age-specific fertility rate, standardized such that $\sum_a \quad F_{a,t} = 1$, $TFR_{r,t}$ is the female total fertility rate (TFR) for race/ethnicity r and year t, and $TFR_{M,t}$and $TFR_{F,t}$ are the national TFRs for males and females in year t, respectively. The last term of the above equation accounts for the fact that male TFRs may be systematically lower than females, which is usually the case in Western countries (7). Note that as male fertility data is only available up to the year 2015, obtain estimates of both the national male fertility rate and the ratio of male to female TFR for years 2016-2020 assuming a linear trend, were extrapolated from the years 2010-2015.

Matrix Kinship Model

In order to estimate parental deaths by cause of death, we used a two-sex time-variant kinship matrix projection model approach developed by (8, 9, 10). Broadly, using the matrix based projection approach, for every year we estimate the number of living children (aged below 18) an average individual has at every age in year t. The estimates of surviving children are based on the race-, ethnicity-, age- and sex-specific survival probabilities of children up to age 18, and also the race-, ethnicity-, age- and sex-specific fertility rates of the parents. The projection model is estimated separately for both males and females. The estimates of surviving children are then combined with race/ethnicity-, age- sex-, and cause-specific death counts to estimate the implied parental deaths by cause.

Specifically, the projection model for the expected number of living children of an individual can be expressed as follows:

$$\begin{pmatrix} a^f \\ a^m \end{pmatrix}(x+1, t+1) = \begin{pmatrix} U_t^f & 0 \\ 0 & U_t^m \end{pmatrix}\begin{pmatrix} a^f \\ a^m \end{pmatrix}(x,t) + \begin{pmatrix} \bar{\alpha}F_t^f & \bar{\alpha}F_t^m \\ \alpha F_t^f & \alpha F_t^m \end{pmatrix}\begin{pmatrix} \phi^f \\ \phi^m \end{pmatrix}(x,t) \quad (3)$$

where the vectors a^f and a^m are of dimension ($\omega \times 1$) and contains the estimated average number of female and male children living at every age, in year t when a parent is aged x; ω=86 is the total number of ages considered. Note the subscripts f and m always refer to females and males, respectively. The matrix U_t of dimension ($\omega \times \omega$) contains the survival probabilities by age on its main diagonals, which is applied to the living children. These survival probabilities were obtained from age-, race-, and ethnicity-specific life tables that were constructed based on all-cause mortality rates using standard life tables techniques (11). The matrix F_t of dimension ($\omega \times \omega$) contains age-specifc fertility rates, which represents the fertility of parents. The scalars α and $\bar{\alpha}$ are the fraction of males and females at birth respectively, which are set as 0.51 and 0.49, based on standard assumptions about the sex ratio at birth (11). Finally, the vectors ϕ^f and ϕ^m of dimension ($\omega \times 1$) indicate the age of a mother and father, respectively.

In the model in Equation 3, the first term on the right-hand side projects the expected number of children living over time, as their parents age. The second term reflects that children are the result of the reproduction of parents. Note that the youth's ages considered here are from birth to 18 years old. At the start of the projection (at birth of a parent), a parent has no children, i.e., $a(0,t) = 0$. The model is estimated for each race/ethnic group separately, thus assuming no births to interracial couples.

Quantities of interest

Two metrics — obtained using outputs from the projection model — were of particular interest. The first metric of interest is the number of children aged less than 18 years old losing a parent by cause in year t. We were also interested in the percentage of children aged less than 18 years old experiencing a parental death by cause in year t. In what follows, we describe how these two quantities were derived.

First, we only consider the first 18 entries of $a^f(x,t)$ and $a^m(x,t)$ reflecting the expected number of living children less than 18 years old of an individual aged x in year t, and sum these entries over both child sexes. Define this quantity to $a_{<18}\ (x,t)$. In any given year, we can estimate the number of children losing a parent as

$$\mathit{Number\ of\ children\ } < 18\ \mathit{yo\ experiencing\ parental\ death} = \sum_{x=0}^{\omega} a_{<18}\ (x,t) \times D(x,t) \quad (4)$$

where $D(x,t)$ reflects the death counts of individuals aged x, in year t, from a given cause. This term can be computed by sex, giving the number of children who lost a mother (father).

The probability for youth aged less than 18 years old experiencing a parental death by cause in year t, can be expressed as the ratio

$$p^{g}(t) = \frac{Number\ of\ children < 18\ yo\ experiencing\ parental\ death}{Number\ of\ children < 18\ yo} = \frac{\sum_{x=0}^{\omega} a_{<18} \quad (x,t) \times D(x,t)}{\sum_{x=0}^{\omega} a_{<18} \quad (x,t) \times N(x,t)} \qquad (5)$$

where $g \in \{f, m\}$ reflects either mothers or fathers, respectively, and $N(x, t)$ reflects the population of individuals aged x, in year t. Making the assumption that mother and father deaths are independent, the probability of losing at least one parent by cause is

$$p(t) = 1 - \left(\left(1 \quad - p^{f}(t)\right) \times \left(1 \quad - p^{m}(t)\right)\right). \qquad (6)$$

These two metrics were computed separately for each racial/ethnic group.

In order to validate the model against survey data on parental deaths by all causes, we also estimated the prevalence of children experiencing a parental death. The probability for a child of any age n of not experiencing a parental death by cause in year t can be expressed as

$$S(t) = 1 - \frac{Number\ of\ children\ aged\ n\ yo\ experiencing\ parental\ death}{Number\ of\ children\ aged\ n} = 1 - \left(\frac{\sum_{x=0}^{\omega} a_{n} \quad (x,t) \times D(x,t)}{\sum_{x=0}^{\omega} a_{n} \quad (x,t) \times N(x,t)}\right) \qquad (7)$$

Calculating the cumulative product of these probabilities as a cohort of children ages allows to estimate the probability that a youth still has their mother or father alive in year t. Using Equation 6, we convert these probabilities into the probability of having lost at least one parent at all ages between 0 and 18 years old. Taking the weighted sum of these probabilities at all ages between 0 and 18 years old in year t — where the weights correspond to the fraction aged x in the population aged less than 18 years old — estimates the prevalence of youth in year t that have lost at least one parent.

The table below summarizes the inputs of the model, the corresponding variable name, and the source of data.

Input	**Variable**	**Source of data/estimates**
Survival probabilities of children	U_t	NCHS death counts from a census of all deaths in the US; observed with no sampling error.
Cause-specific death counts by age	$D(x,t)$	NCHS death counts from a census of all deaths in the US; observed with no sampling error.
Female age- and race/ethnicity specific fertility rates	$F^{f}(t)$	NCHS birth counts from a census of all births in the US, and USCB population estimates, but assume to be observed with no sampling error

Male age- and race/ethnicity specific fertility rates	$F^m(t)$	Estimated using national male fertility rates (from the Human Fertility Collection) and female fertility rates (as described above). Variability comes from error in the estimation process.
Population counts	$N(x,t)$	Population counts from USCB, observed with no sampling error

Assumptions of the model

There are several assumptions underlying the modeling process to obtain estimates of the number and percent of youth experiencing parental death. Firstly, the model assumes that, conditional on age, sex, and race/ethnicity, those who die from drugs or firearms have the same fertility as those who die from other causes. We discuss this assumption in more detail in eAppendix 2, including sensitivity analyses to different assumptions about fertility rates for different population groups.

Secondly, to obtain the most reasonable estimates of the number of living children per individual, given the data available, we started the projection in 1990. In that year, an individual could be any age between 0 and 85 years old. As it is commonly done in these models (12), before 1990, we assumed that the earliest available vital rates have been operating for a long time (stable population assumption).

Thirdly, the modeling process does not produce multiracial estimates. As multiracial fertility rates are not available, we only produced estimates by single-race groupings and ethnicity. Relatedly, the model assumes that the racial and ethnic identity of the child matches that of the parents, and when combining estimates of both mothers and fathers lost, we are assuming that the racial and ethnic identity of both parents is the same. These assumptions do not reflect the reality of many Americans.

A fourth assumption of the model is the independence of mortality risk across generations and parents. Put another way, this means that if a parent dies at a young age, for example, this has no impact on the likelihood of death for their child. This assumption is also common in demographic microsimulation models (13). From the point of view of surviving children, Ruggles (13) showed that intergenerational correlations of mortality does not impact the expected number of children surviving for a mother of a particular age, but rather the distribution or spread of children surviving across families within a population. As we are interested in youth, the impact of the independence assumption will be not as great as if we were considering children surviving to older ages; however it should be noted that this assumption may lead to less variation in the extent of parent death that is truly present in a population.

Further, as described above, we estimated male fertility rates by race/ethnicity as data were not available. In doing so, we made several assumptions. Firstly, we assumed that the ratio between the fertility for a particular race/ethnicity to the overall national fertility is similar in the male population to the female population. We also assumed that this ratio is changing linearly over time, as is the national male total fertility rate (TFR), and the ratio of male to female TFRs. The linear specifications were chosen based on observing past trends in these quantities over the period 2010-2015, which are well-captured using a linear model.

Finally, we assume that race and ethnicity recording on death certificates is accurate, but this may not be the case. However, an analysis by the NCHS suggests that misclassification for the racial and ethnic groupings examined in this study was low, ranging from 5% for Hispanic decedents in the 1990s, which improved over time, to 0% among White and Black decedents from 1990 through 2011.

Sources of variation and incorporating uncertainty

Unlike regression models, the Matrix Kinship Model is a deterministic model where the parameters do not have distributional assumptions of probabilistic uncertainty. There is also no model-based uncertainty. In addition, both the mortality and female fertility data represent a census of all deaths and births that occur in the US and do not have sampling error. We thus incorporate uncertainty into our estimates through two areas: (1) stochasticity from deaths and births and (2) uncertainty when modeling male fertility.

Firstly, while the deaths and births used in the data are a census of observations and do not have sampling error, one can consider deaths and births to be observations from a latent stochastic process which has natural variability. It is important to consider stochasticity in vital rates, even when the underlying data are taken from the whole population of interest, because often we are interested in comparing groups and inferring whether differences are larger than some level of natural fluctuations (14).

We incorporate this natural variability by modeling both births and deaths as realizations from an underlying probability distribution. Specifically, for the fertility component of the model, for each race/ethnicity group and year, we simulated an i-th series of birth counts as follows:

$$Births_{x,c,i} \sim Negative\ Binomial\big(f_x \cdot N_x \cdot \alpha_c, \phi_{x,}\big), \tag{8}$$

where $Births_{x,c,i}$ is the i simulated birth count at age x for those who die from cause c for $c \in \{drug, firearm, other\}$, f_x is the observed fertility rate at age x, N_x is the observed population aged x, and α_c is the proportion of the total population who die from cause c. The scaling factor $\alpha_c$is included in the simulation process to account for the additional variability across populations who die from different causes. The overdispersion parameter ϕ_x allows for extra variability in the observed births (compared to a Poisson distribution) and is estimated separately for each race/ethnicity, sex, and age group. The simulated birth counts are then used to calculate fertility rates, which are used as an input to the model.

Similarly for deaths, for each race/ethnicity group and year we simulated an i-th series of death counts as follows:

$$Deaths_{x,c,i} \sim Negative\ Binomial\big(m_{x,c} \cdot N_x, \phi_x\big), \tag{9}$$

where $Deaths_{x,c,i}$ is the i simulated death count at age x for those who die from cause c for $c \in \{drug, firearm, other\}$, $m_{x,c}$ is the observed mortality rate at age x for cause c, and N_x is the observed population aged x. Similarly to births, we use a negative binomial to simulate realizations of deaths to allow for overdispersion. Again the overdispersion parameter ϕ_x is estimated separately for each race/ethnicity, sex, and age group.

In addition to simulating stochastic variability, as mentioned above, age-, race-, and ethnicity-specific male fertility rates are not available in the US. As such these were estimated based on available national data, and utilizing known relationships between race-, and ethnicity-specific fertility rates and the overall fertility in the female population, as well as known relationships between overall male and female fertility. As estimates of age-, race-, and ethnicity-specific male fertility rates were obtained using a regression framework, we incorporated this model uncertainty by drawing from a uniform distribution bounded by the 95% CI of male fertility rates to simulate a set of male fertility rates; specifically for each race/ethnicity group and year we simulated as follows:

$$f_{x,i} \sim U(\widehat{f_x} - 1.96 s_x \ , \widehat{f_x} + 1.96 s_x \ ), \qquad (10)$$

where $\widehat{f_x}$ is the mean estimate for the male age-specific fertility rate and s_x is the standard error of the prediction. Drawing from uniform distributions can be seen as a conservative representation of variability. Once a simulated fertility rate is obtained, we use this to further simulate a birth count, using the process described in Equation 8.

We repeated each simulation procedure 1,000 times obtaining 1,000 associated sets of fertility rates and death counts for both sexes which were then used as inputs in the Matrix Kinship Model and to estimate parental loss. We thus obtained 1000 realizations of the different outputs of interest. The medians and 2.5 and 97.5 quantiles of these distributions provided point estimates and 95% confidence intervals for our estimates.

eAppendix 1. Reproducible code and data

Reproducible code is available at: https://github.com/benjisamschlu/parental_deaths. This online code repository includes the code necessary to download the publicly available multiple cause of death mortality files from the NCHS. Smaller files, such as the female fertility rates, also from the NCHS, are available directly from the repository. Lastly, for full reproducibility, large files generated from our analysis are available via the Open Science Framework (OSF) and instructions for downloading these files from OSF are available on the repository.

eAppendix 2. Assessing the sensitivity of our results to differences in fertility rates.

The results of this study are estimated using demographic projections based on vital statistics. An important assumption of the model is that, after adjusting for age, sex, race, and ethnicity, those who died from drugs and firearms have the same fertility levels as those who died of other causes. Fertility rates by cause of death are not available and the extent and direction of this potential bias is difficult to ascertain.

To our knowledge, no research is available on fertility rates among US firearm-owners compared to non-firearm-owners. However, a recent study found that among households with children, the average number of children in firearm-owning households was comparable to the average number of children in non-firearm-owning households (1.9 vs 1.8) (15), which would imply the same fertility rate between people who are likely to die from firearms as those who are not. Importantly, this estimate does not take into account the potentially different distribution of households without children among firearm-owners and non-firearm-owners. Similarly, research on the relationship between illicit drug use and fertility is limited and indirect. Some studies suggest illicit substance use reduces male fertility (16, 17), which would imply lower fertility rates among people who are more likely to die from fatal drug poisoning. However, other studies suggest the use of some illicit substances (such as cocaine) is associated with a shorter time to conception (18) and that contraceptive use is lower among women with substance use disorder (19), which would imply higher fertility rates among people who are more likely to die from fatal drug poisonings.

To investigate family size of those who use drugs, we used data from the National Survey on Drug Use and Health (NSDUH), which is a nationwide, annual survey designed to track the prevalence of tobacco, alcohol, and drug use in the US. Specifically, we used the 2020 public-use file to tabulate the proportion of households with no children under the age of 18 among those who have ever used an illicit substance except marijuana compared to those that have never used an illicit substance or only used marijuana. We used the NRCH17_2 variable which asks, "How many people in their household are the respondent's children younger than age 18?" Responses are coded as 0, 1, 2, and "3 or more". We also used the binary ILLEMFLAG variable which asks, "Ever in their life, had they used an illicit drug other than marijuana?" We subset the data to only those ages 12 through 49 to more closely match our study population. This approach has several limitations. For example, those who use illicit substances may be less likely to be included in the NSDUH sampling frame, even if they are included, they may be less inclined to answer truthfully, and those who use illicit substances may be less likely to have children living in the same household (19-21). Despite these limitations, we found that across race, ethnicity, and sex, those who ever used illicit substances reported similar prevalence of children compared to those who never used. For example, the proportion (SE) of those with no children was 0.65 (0.01) for both groups, those with one child or two children in the household were 0.13 (0.01) for those who have never used and 0.14 (0.01) for those who ever used (eTable 1, eFigure 1). Comparisons with the 2002-2014 NSDUH survey found similar results (not shown), suggesting this pattern is stable over the study period.

Given the complex interplay of social, behavioral, and biological factors on the potential association between fertility and cause of death (specifically, firearms and fatal drug poisonings), we conducted a sensitivity analysis to quantify how altering the fertility rate of those who died from firearms of drugs may impact our results. Based on our analysis of the NSDUH data stratified by race, ethnicity, sex, and age, we set bounds of 25% lower and higher fertility among those who died of drugs or firearms relative to those who did not die of drugs or firearms within the same age, sex, race, and ethnic group. Based on the NSDUH data, we believe these bounds represent extreme but plausible ranges of fertility differences by cause of death. We then reran our primary model where we changed the fertility rate of those who died from drugs or guns (independently) to be ±25%, ±20%, ±15%, ±10%, and ±5% higher or lower than that of the baseline fertility rate (noting that a 0% deviation represents our primary results).

Even in our most pessimistic scenario of -25% fertility among both people who died of drugs and those who died of firearms, we estimated 895,000 (95% CI: 879,000 to 912,000) youth experienced parental death over the study period. In more plausible, conservative scenarios, such as -15% lower fertility among those who died of drugs or firearms, we still estimate over 1 million youth experienced parental death over the study period. All sensitivity results are shown in eFigure 5.

While scant, the existing literature suggests the assumption of the same fertility rate across causes of death, after adjusting for age, sex, race, and ethnicity is plausible. Even so, the results of these sensitivity analysis suggest our overall findings are robust to violations of this assumption.

eAppendix 3. Validation of the model with empirical data on the prevalence of parental death from all causes.

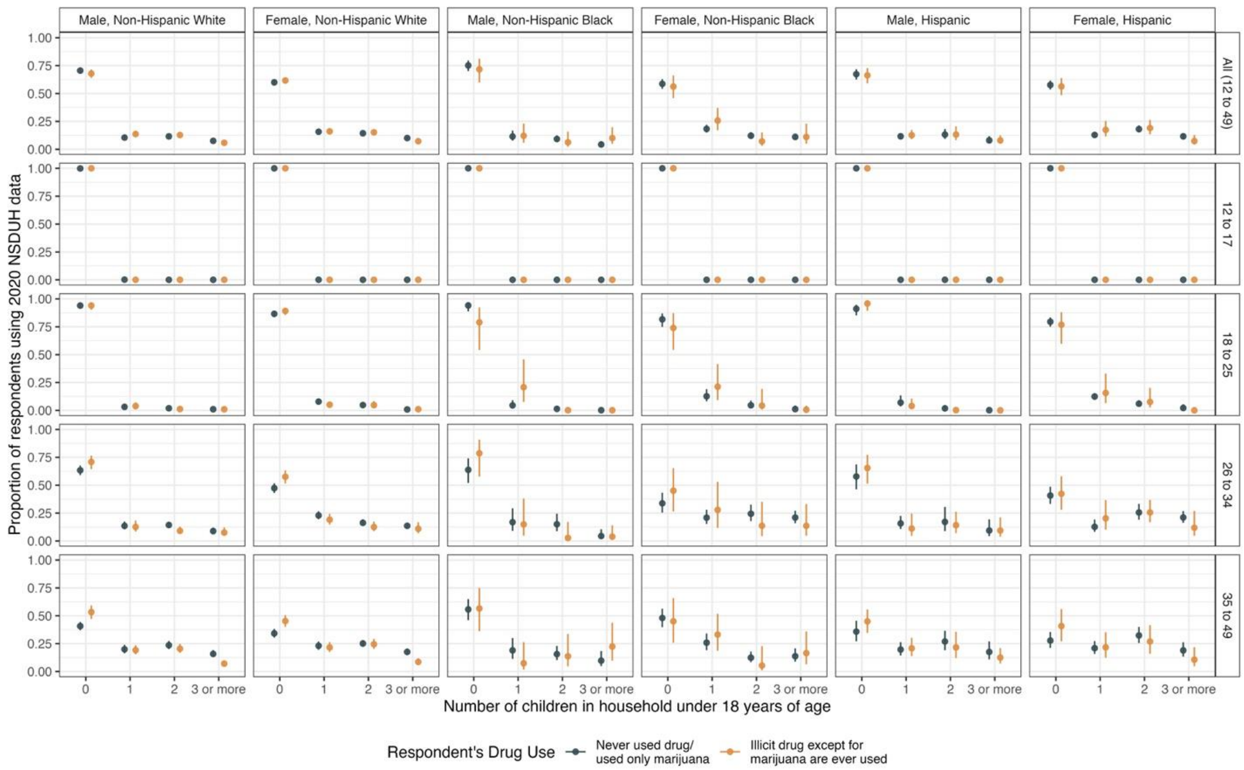
To validate our method, we compared our estimated prevalence of parental death from all causes of death to observed prevalence obtained from a national survey.

The National Survey of Children's Health (NSCH) has been conducted yearly since 2016. The NSCH is designed to be representative of all non-institutionalized children under 18 years old and the sample size ranges from 21,599 (2017) to 50,212 (2016) with an average response rate of about 40%. One of the questions asks if the surveyed child's parent or guardian died. The NSCH provides a warning that missing values for this variable are greater than the 2% missingness typically observed in the data; however, they still provide prevalence estimates. The impact of missingness is unknown but if respondents with children who experienced parental mortality are more likely to skip questions about the death of a child's parent, the results presented below may be underestimated.

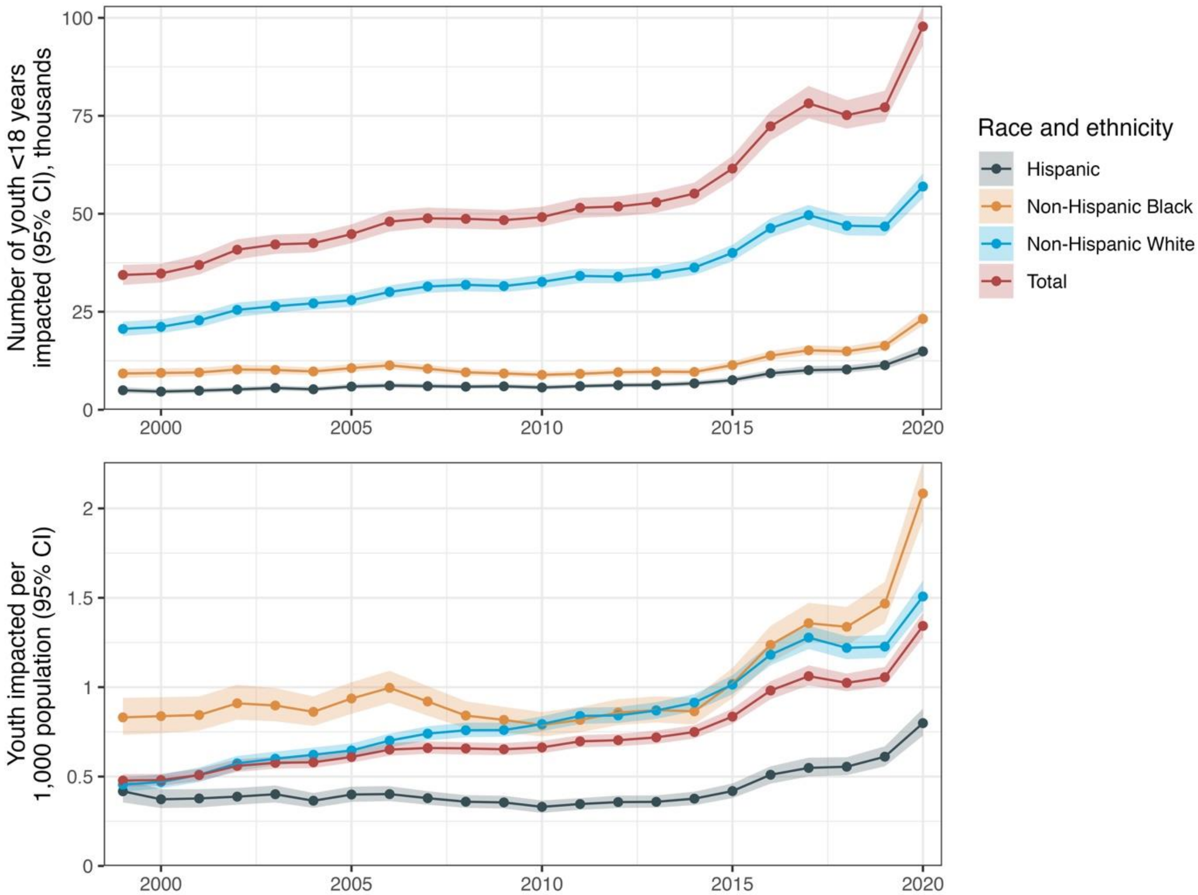
In the eFigure 6, we compare the estimated percentages of children that ever experienced parental death from any causes from the Matrix Projection Model to the survey's estimates for each racial and ethnic group. The model's estimates are generally near or within the 95% confidence intervals of the NSCH survey's estimates, except for the non-Hispanic Black population over the years 2016 and 2017 and the non-Hispanic White population, which is consistently overestimated relative to the survey results . It is unclear if the elevated prevalence observed in 2016 and 2017 (compared to 2018-2020) are statistical artifacts, due to methodological changes (e.g., data collection for the NSCH switched to online and over the phone in 2016), or true values. Likewise, it is unclear if differences in the non-Hispanic White population reflect underlying differences in the target population, self-identified race and ethnicity of parents and respondents, or reflect true differences.

Assuming the survey results are accurate, this suggests our results for non-Hispanic Black youth may be too conservative (low) and conversely that our estimates non-Hispanic White youth are too high — though it is not clear if this impact is uniform across causes of death or limited to just 'all other causes'. Further study is required.

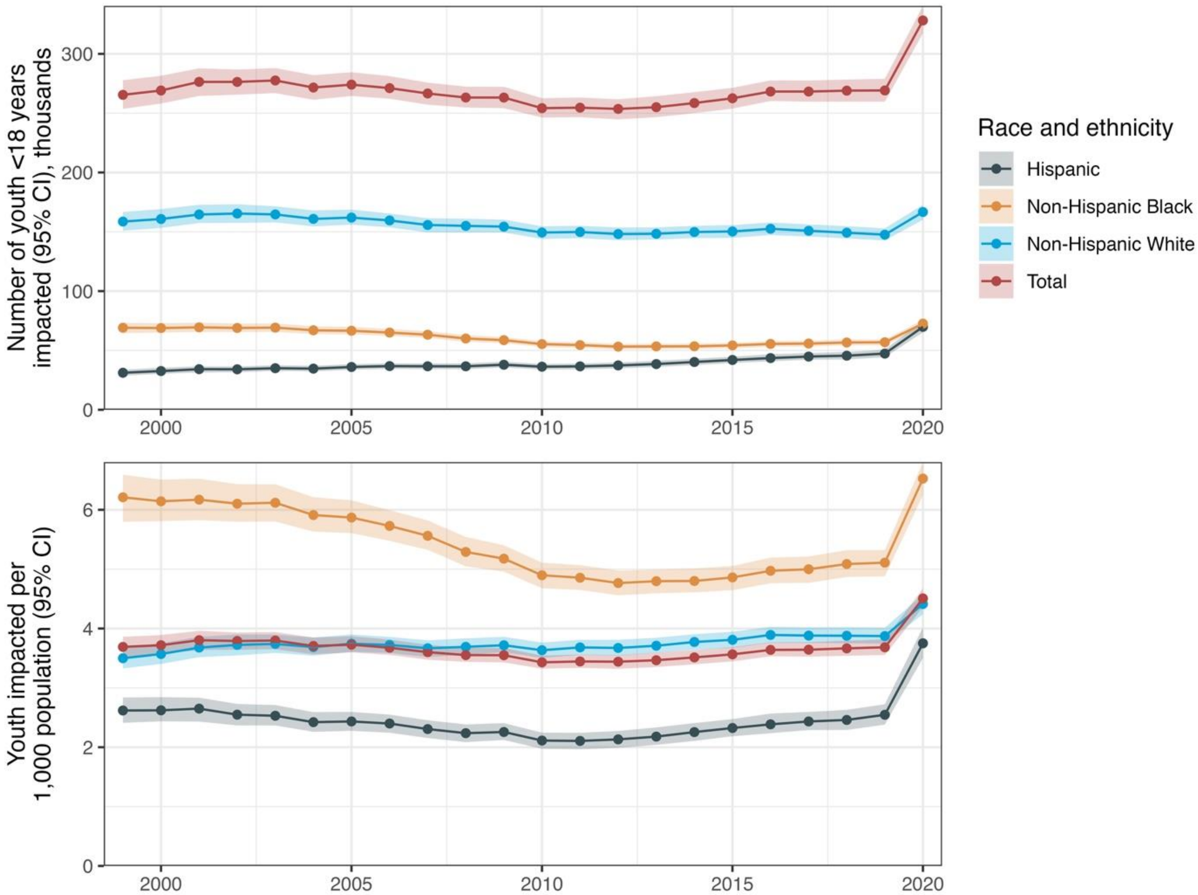
eFigure 1. Number (95% CI) of children under 18 years old in the same household as the respondent among 2020 National Survey on Drug Use and Health respondents who have ever used an illicit substance except marijuana and those who have never used an illicit substance except marijuana, by race/ethnicity, sex, and age.



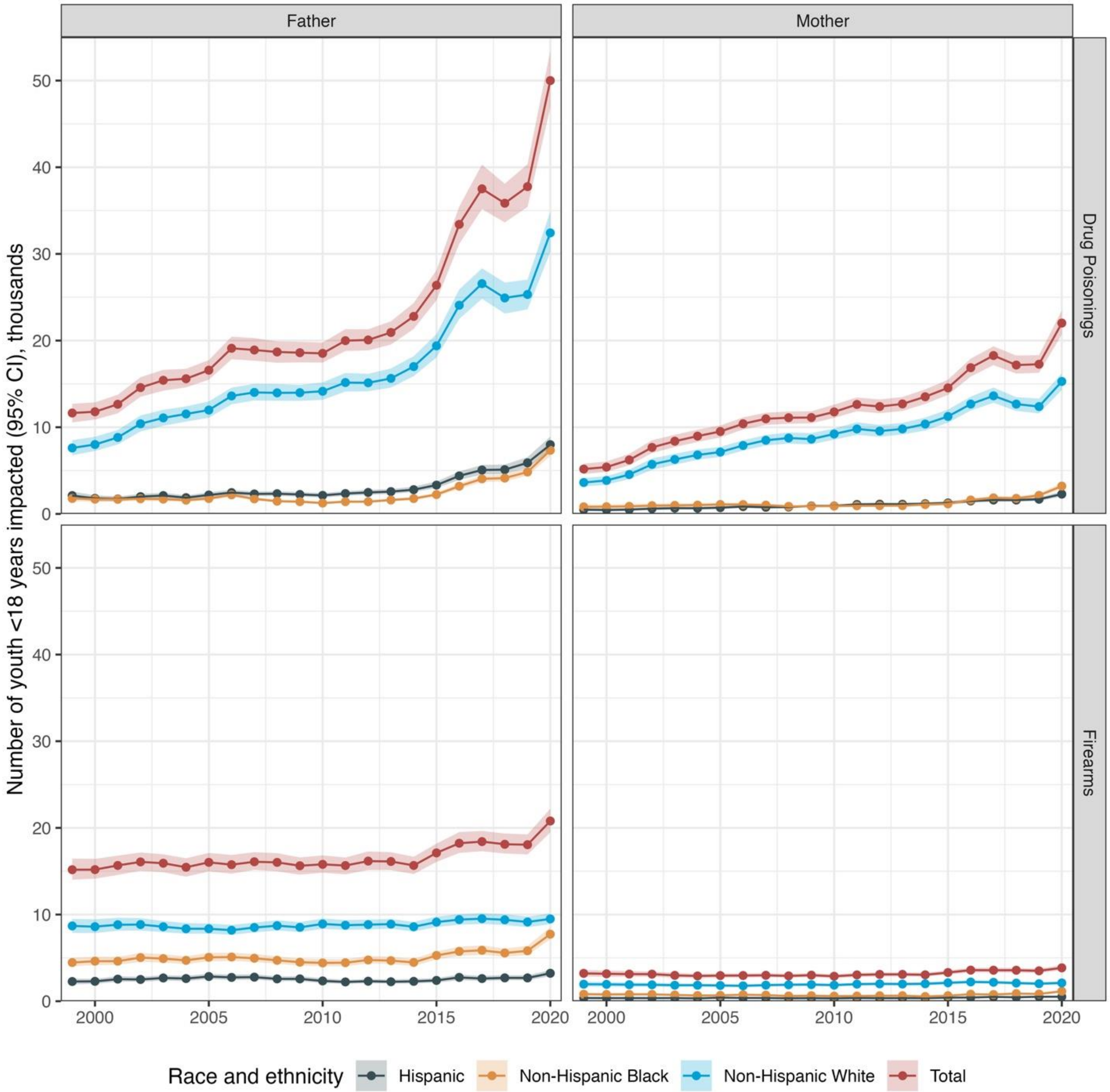
eFigure 2. A, Number (95% CI) of youth under 18 years old impacted by parental death due to drugs or firearms combined by race and ethnicity, 1999-2020. B, Youth (95% CI) under 18 years old impacted by parental death due to drug or firearms combined per 1,000 population by race and ethnicity, 1999-2020.



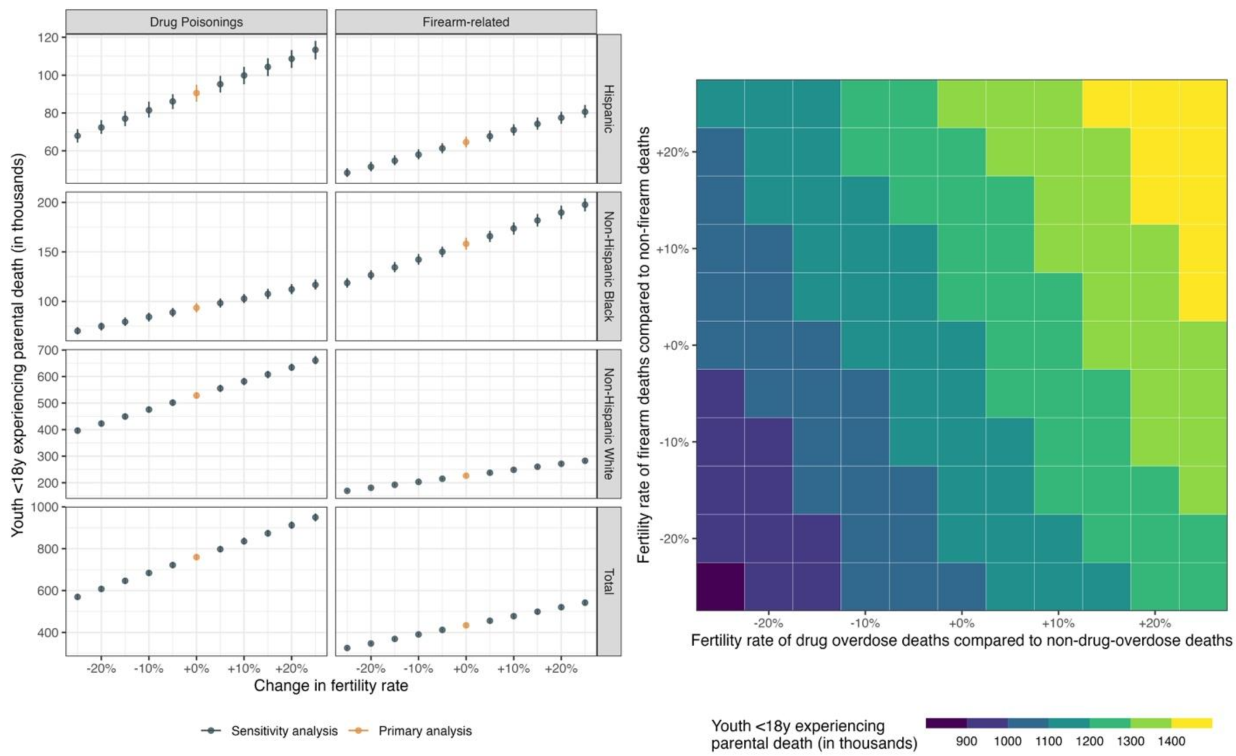
eFigure 3. A, Number (95% CI) of youth under 18 years old impacted by parental death due to all other causes (except drugs and firearms) by race and ethnicity, 1999-2020. B, Youth (95% CI) under 18 years old impacted by parental death due to all other causes (except drugs and firearms) per 1,000 population by race and ethnicity, 1999-2020.



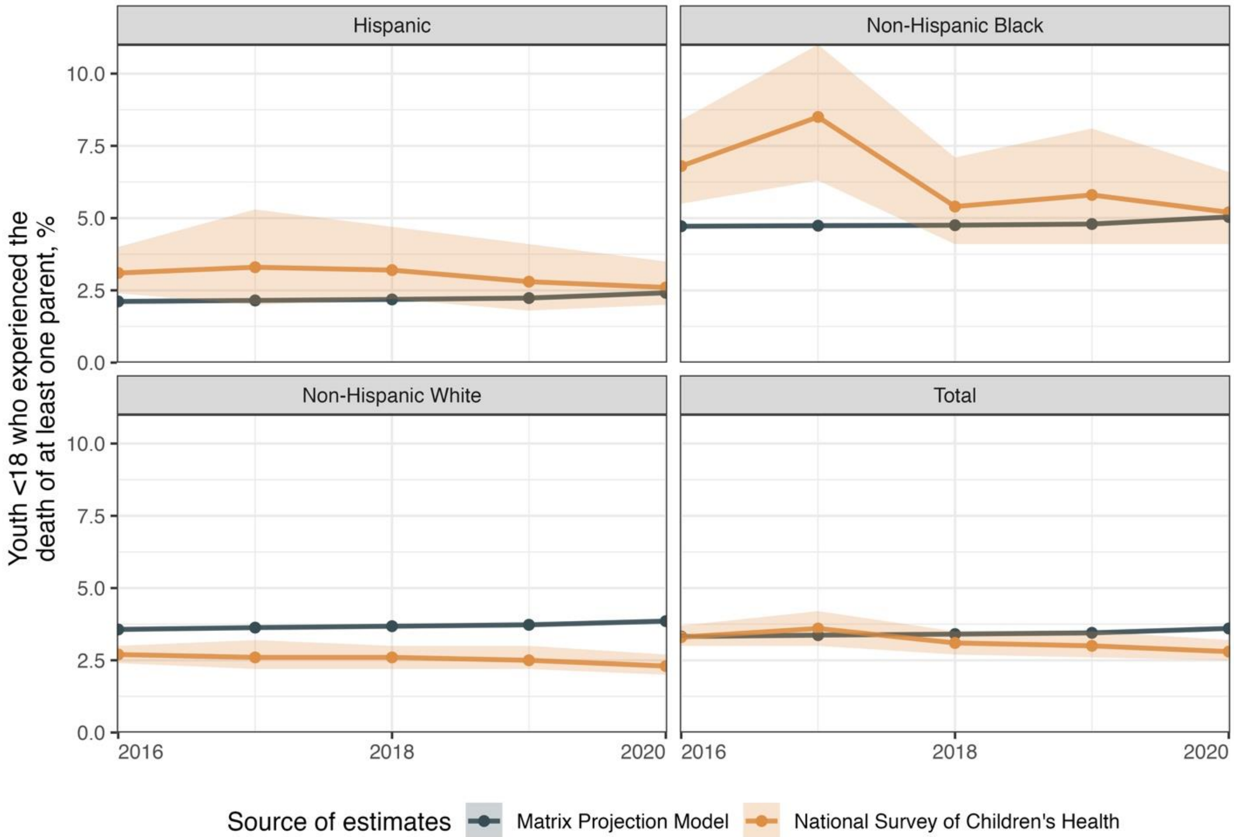
eFigure 4. Number (95% CI) of youth under 18 years old impacted by parental death due to drug poisoning (top row) or firearms (bottom row) by parent and race and ethnicity, 1999-2020.



eFigure 5. Results of sensitivity analysis to changing fertility rates of those who die by drugs or firearms. Left panels show the number of youth experiencing parental death (y-axis) by cause of death (columns) and race and ethnicity (rows) as the fertility rate of those who die from the cause of interest change relative to those who do not. 0% represents the results of the primary analysis (i.e., no difference in fertility). The right panel shows the total number of youth who experienced parental death from both drugs and firearms combined as either the fertility rate among those who died of firearms (y-axis) or those who died of drugs (x-axis) changed relative to those that did not. The coordinates (0%, 0%) represent our primary result.



eFigure 6. Validation of our estimates (blue line) or the prevalence of youth experiencing parental deaths from anycause to estimates from National Survey on Children's Health (orange) by race and ethnicity, 2016-2020.



eTable 1. Number of children under 18 years of age in the same household as the respondent of the National Survey on Drug use and Health 2020 among those who have ever used an illicit substance except marijuana and those who have never used an illicit substance or only marijuana.

	Proportion (SE)			Raw count, N		Weighted count, N	
Number of children under 18 y/o in the household	**Respondents who never used illicit substances**	**Respondents who ever used illicit substances**	**Difference in proportion (SE)**	**Respondents who never used illicit substances**	**Respondents who ever used illicit substances**	**Respondents who never used illicit substances**	**Respondents who ever used illicit substances**
0	0.648 (0.007)	0.650 (0.010)	0.004 (0.013)	13,270	4,924	70,217,134	28,698,105
1	0.132 (0.005)	0.140 (0.010)	0.013 (0.010)	1,949	870	14,250,039	6,380,965
2	0.134 (0.005)	0.140 (0.010)	0.002 (0.008)	2,004	874	14,470,278	5,960,528
3 or more	0.087 (0.004)	0.070 (0.010)	-0.019 (0.007)	1,255	411	9,385,454	2,990,580

eTable 2. Youth experiencing parental death due to drugs or firearms. Table 1 presents information about youth experiencing parental deaths due to drugs, firearms, or all other causes. eTable 2 shows the same information for drugs and firearms combined.

Race and ethnicity	1999			2020			Change in youth impacted 1999 to 2020		Cumulative youth impacted 1999 to 2020	
	Youth[a] impacted (95% CI)[b], thousands	Total youth[a], thousands	Youth impacted per 1,000 population (95% CI)[b]	Youth[a] impacted (95% CI)[b], thousands	Total youth[a], thousands	Youth impacted per 1,000 population (95% CI)[b]	Absolute increase (95% CI)[b], thousands	Percent increase (95% CI)[b]	Youth impacted (95% CI)[b], thousands	Youth impacted per 1,000 person-years (95% CI)[b]
Estimated youth impacted by parental deaths[c] due to fatal drug poisonings and firearms combined										
Hispanic	5 (4.2 to 5.8)	11,901.6	0.42 (0.36 to 0.49)	14.9 (13.6 to 16.4)	18,631.8	0.80 (0.73 to 0.88)	9.9 (9.3 to 10.6)	199.5 (183.8 to 221.2)	154.9 (139.5 to 171.6)	5.07 (4.57 to 5.62)
Non-Hispanic Black	9.3 (8.2 to 10.5)	11,131.4	0.83 (0.73 to 0.94)	23.2 (21.5 to 25.1)	11,123.7	2.08 (1.93 to 2.26)	13.9 (13.3 to 14.7)	150.5 (140.2 to 163.3)	251.3 (229.8 to 275.1)	11.29 (10.32 to 12.36)
Non-Hispanic White	20.6 (18.8 to 22.5)	45,335.1	0.45 (0.41 to 0.50)	56.9 (53.9 to 60.3)	37,778.4	1.51 (1.43 to 1.60)	36.3 (35.1 to 37.8)	176.1 (168.0 to 187.0)	754.9 (712.7 to 799.2)	9.08 (8.58 to 9.62)
Total	34.4 (31.8 to 37)	71,946	0.48 (0.44 to 0.51)	97.8 (93 to 103)	72,822.1	1.34 (1.28 to 1.41)	63.4 (61.1 to 66.1)	184.3 (178.8 to 192.0)	1,193 (1,131.1 to 1,259.7)	8.24 (7.81 to 8.70)

Notes: [a] youth is defined as a person under 18 years old; [b] 95% CI are the confidence intervals obtained from 1,000 Monte Carlo simulations and taking the 2.5th and 97.5th percentiles; [c] parental deaths are defined as the death of at least one parent

eTable 3. Youth experiencing the death of a father due to drugs, firearms, and all other causes. The Table in the primary text shows data on youth experiencing parental death of at least one parent. eTable 3 shows the same results for youth experiencing the death of the father alone.

Race and ethnicity	1999			2020			Change in youth impacted 1999 to 2020		Cumulative youth impacted 1999 to 2020	
	Youth[a] impacted (95% CI)[b], thousands	Total youth[a], thousands	Youth impacted per 1,000 population (95% CI)[b]	Youth[a] impacted (95% CI)[b], thousands	Total youth[a], thousands	Youth impacted per 1,000 population (95% CI)[b]	Absolute increase (95% CI)[b], thousands	Percent increase (95% CI)[b]	Youth impacted (95% CI)[b], thousands	Youth impacted per 1,000 person-years (95% CI)[b]
Estimated youth impacted by the death of a father due to fatal drug poisonings										
Hispanic	2.1 (1.7 to 2.6)	11,901.6	0.169 (0.138 to 0.206)	8 (7.2 to 8.9)	18,631.8	0.457 (0.411 to 0.512)	5.9 (5.5 to 6.3)	277.8 (246.8 to 313.5)	67.2 (59.5 to 75.9)	2.20 (1.95 to 2.49)
Non-Hispanic Black	1.8 (1.5 to 2.1)	11,131.4	0.197 (0.161 to 0.238)	7.3 (6.7 to 8)	11,123.7	0.814 (0.740 to 0.892)	5.6 (5.2 to 5.9)	311.8 (276.1 to 357.4)	52 (46.3 to 58.1)	2.34 (2.08 to 2.61)
Non-Hispanic White	7.6 (6.8 to 8.5)	45,335.1	0.158 (0.140 to 0.176)	32.4 (30.2 to 34.9)	37,778.4	0.821 (0.766 to 0.885)	24.8 (23.4 to 26.4)	326.2 (310.3 to 346.2)	354.8 (329.5 to 381.4)	4.27 (3.96 to 4.59)
Total	11.6 (10.6 to 12.7)	71,946	0.159 (0.144 to 0.175)	50 (46.9 to 53.4)	72,822.1	0.699 (0.656 to 0.748)	38.4 (36.3 to 40.7)	329.5 (320.1 to 344.2)	496.8 (464.3 to 531.4)	3.43 (3.21 to 3.67)
Estimated youth impacted by the death of a father due to firearms										
Hispanic	2.3 (2 to 2.6)	11,901.6	0.182 (0.154 to 0.209)	3.2 (2.9 to 3.6)	18,631.8	0.184 (0.165 to 0.206)	1.0 (0.9 to 1.0)	41.8 (37.7 to 47.8)	56.3 (50.1 to 63)	1.84 (1.64 to 2.06)
Non-Hispanic Black	4.5 (4 to 5)	11,131.4	0.495 (0.438 to 0.557)	7.7 (7.1 to 8.5)	11,123.7	0.858 (0.792 to 0.947)	3.3 (3.1 to 3.5)	73.3 (70.7 to 77.9)	111.5 (101.7 to 122.6)	5.01 (4.57 to 5.51)
Non-Hispanic White	8.7 (7.9 to 9.5)	45,335.1	0.180 (0.163 to 0.199)	9.5 (8.9 to 10.1)	37,778.4	0.241 (0.225 to 0.257)	0.8 (1.0 to 0.6)	9.3 (6.7 to 12.6)	194.4 (181.2 to 208.6)	2.34 (2.18 to 2.51)
Total	15.2 (14 to 16.5)	71,946	0.208 (0.192 to 0.226)	20.8 (19.5 to 22.2)	72,822.1	0.291 (0.272 to 0.312)	5.6 (5.5 to 5.8)	37.0 (35.0 to 38.9)	363.2 (339.9 to 387.9)	2.51 (2.35 to 2.68)
Estimated youth impacted by the death of a father due to other causes										
Hispanic	23.1 (21 to 25.5)	11,901.6	1.851 (1.652 to 2.043)	46.8 (42.9 to 51)	18,631.8	2.679 (2.446 to 2.925)	23.7 (21.9 to 25.5)	102.3 (99.9 to 104.4)	606.5 (555.3 to 661)	19.86 (18.19 to 21.65)

Race and ethnicity	1999			2020			Change in youth impacted 1999 to 2020		Cumulative youth impacted 1999 to 2020	
	Youth[a] impacted (95% CI)[b], thousands	Total youth[a], thousands	Youth impacted per 1,000 population (95% CI)[b]	Youth[a] impacted (95% CI)[b], thousands	Total youth[a], thousands	Youth impacted per 1,000 population (95% CI)[b]	Absolute increase (95% CI)[b], thousands	Percent increase (95% CI)[b]	Youth impacted (95% CI)[b], thousands	Youth impacted per 1,000 person-years (95% CI)[b]
Non-Hispanic Black	37.2 (34.6 to 40)	11,131.4	4.129 (3.794 to 4.466)	38.6 (36.5 to 40.9)	11,123.7	4.291 (4.045 to 4.553)	1.4 (1.9 to 0.9)	3.8 (2.3 to 5.6)	692.5 (650.9 to 736.3)	31.12 (29.25 to 33.08)
Non-Hispanic White	114.6 (108 to 121.8)	45,335.1	2.377 (2.226 to 2.537)	115.1 (109.9 to 120.7)	37,778.4	2.920 (2.774 to 3.059)	0.5 (1.8 to -1.1)	0.4 (-0.9 to 1.7)	2,402.4 (2,286 to 2,525.5)	28.90 (27.50 to 30.39)
Total	181.8 (171.7 to 192)	71,946	2.494 (2.349 to 2.641)	216.1 (206.8 to 226.1)	72,822.1	3.020 (2.887 to 3.166)	34.3 (35.1 to 34.1)	18.8 (17.8 to 20.5)	3,917.5 (3,737.2 to 4,102.6)	27.06 (25.82 to 28.34)

Notes: [a] youth is defined as a person under 18 years old; [b] 95% CI are the confidence intervals obtained from 1,000 Monte Carlo simulations and taking the 2.5th and 97.5th percentiles

eTable 4. Youth experiencing the death of a mother due to drugs, firearms, and all other causes. The Table in the primary text shows data on youth experiencing parental death of at least one parent. eTable 4 shows the same results for youth experiencing the death of the mother alone.

Race and ethnicity	1999			2020			Change in youth impacted 1999 to 2020		Cumulative youth impacted 1999 to 2020	
	Youth[a] impacted (95% CI)[b], thousands	Total youth[a], thousands	Youth impacted per 1,000 population (95% CI [b]	Youth[a] impacted (95% CI)[b], thousands	Total youth[a], thousands	Youth impacted per 1,000 population (95% CI	Absolute increase (95% CI)[b], thousands	Percent increase (95% CI)[b]	Youth impacted (95% CI)[b], thousands	Youth impacted per 1,000 person-years (95% CI)[b]
Estimated youth impacted by the death of a mother due to fatal drug poisonings										
Hispanic	0.5 (0.3 to 0.7)	11,901.6	0.038 (0.026 to 0.054)	2.3 (2 to 2.6)	18,631.8	0.128 (0.112 to 0.146)	1.8 (1.7 to 1.9)	367.8 (276.1 to 496.0)	22.7 (19.2 to 27)	0.75 (0.63 to 0.88)
Non-Hispanic Black	0.8 (0.6 to 1.1)	11,131.4	0.070 (0.051 to 0.092)	3.2 (2.9 to 3.6)	11,123.7	0.301 (0.272 to 0.334)	2.4 (2.3 to 2.5)	292.2 (228.6 to 379.0)	27 (23.1 to 31.3)	1.21 (1.04 to 1.41)
Non-Hispanic White	3.6 (3.2 to 4.2)	45,335.1	0.076 (0.066 to 0.087)	15.3 (14.3 to 16.2)	37,778.4	0.392 (0.367 to 0.416)	11.7 (11.1 to 12.1)	321.9 (290.7 to 351.7)	198.4 (183.9 to 213.9)	2.39 (2.21 to 2.57)
Total	5.2 (4.6 to 5.8)	71,946	0.068 (0.059 to 0.076)	22 (20.7 to 23.5)	72,822.1	0.300 (0.283 to 0.320)	16.8 (16.1 to 17.7)	325.6 (304.5 to 350.9)	264.1 (246.8 to 282.7)	1.82 (1.70 to 1.95)
Estimated youth impacted by the death of a mother due to firearms										
Hispanic	0.4 (0.3 to 0.5)	11,901.6	0.029 (0.021 to 0.038)	0.5 (0.4 to 0.6)	18,631.8	0.029 (0.024 to 0.036)	0.2 (0.2 to 0.1)	40.7 (29.8 to 62.2)	8.6 (6.8 to 10.7)	0.28 (0.22 to 0.35)
Non-Hispanic Black	0.8 (0.6 to 1)	11,131.4	0.069 (0.054 to 0.085)	1.1 (1 to 1.3)	11,123.7	0.108 (0.095 to 0.122)	0.3 (0.4 to 0.3)	41.8 (30.7 to 57.0)	16 (13.6 to 18.7)	0.72 (0.61 to 0.84)
Non-Hispanic White	2 (1.7 to 2.3)	45,335.1	0.041 (0.035 to 0.048)	2.1 (1.9 to 2.3)	37,778.4	0.054 (0.050 to 0.059)	0.1 (0.2 to 0.1)	7.6 (2.6 to 14.4)	43.3 (39.1 to 47.7)	0.52 (0.47 to 0.57)
Total	3.2 (2.9 to 3.6)	71,946	0.042 (0.037 to 0.047)	3.9 (3.6 to 4.2)	72,822.1	0.052 (0.049 to 0.057)	0.6 (0.7 to 0.6)	19.7 (15.6 to 24.5)	70 (64.2 to 76)	0.48 (0.44 to 0.52)
Estimated youth impacted by the death of a mother due to other causes										
Hispanic	9.9 (9 to 10.9)	11,901.6	0.769 (0.690 to 0.850)	19.1 (17.7 to 20.8)	18,631.8	1.071 (0.990 to 1.167)	9.2 (8.7 to 9.9)	93.1 (90.8 to 96.3)	269.5 (248 to 292.4)	8.83 (8.12 to 9.58)

Race and ethnicity	1999			2020			Change in youth impacted 1999 to 2020		Cumulative youth impacted 1999 to 2020	
	Youth[a] impacted (95% CI)[b], thousands	Total youth[a], thousands	Youth impacted per 1,000 population (95% CI [b]	Youth[a] impacted (95% CI)[b], thousands	Total youth[a], thousands	Youth impacted per 1,000 population (95% CI	Absolute increase (95% CI)[b], thousands	Percent increase (95% CI)[b]	Youth impacted (95% CI)[b], thousands	Youth impacted per 1,000 person-years (95% CI)[b]
Non-Hispanic Black	24.5 (22.7 to 26.3)	11,131.4	2.089 (1.901 to 2.265)	23.9 (22.5 to 25.3)	11,123.7	2.244 (2.116 to 2.380)	-0.7 (-0.2 to -1.0)	-2.7 (-3.9 to -0.7)	461.3 (433.4 to 490.1)	20.73 (19.47 to 22.02)
Non-Hispanic White	53.7 (50.7 to 57)	45,335.1	1.123 (1.048 to 1.202)	58.5 (55.7 to 61.1)	37,778.4	1.498 (1.432 to 1.572)	4.7 (4.9 to 4.1)	8.8 (7.1 to 9.7)	1,190.8 (1,135.5 to 1,248.8)	14.33 (13.66 to 15.03)
Total	91.3 (86.9 to 96.1)	71,946	1.196 (1.129 to 1.272)	109.4 (104.7 to 114.2)	72,822.1	1.491 (1.427 to 1.556)	18.1 (17.8 to 18.1)	19.9 (18.8 to 20.5)	2,036.2 (1,948.1 to 2,128.1)	14.07 (13.46 to 14.70)

Notes: [a] youth is defined as a person under 18 years old; [b] 95% CI are the confidence intervals obtained from 1,000 Monte Carlo simulations and taking the 2.5th and 97.5th percentiles

eReferences

1. National Center for Health Statistics. Data access—vital statistics online (mortality multiple cause files). Electronic resource.

2. Martin, J., Hamilton, B., Osterman, M., and Driscoll, A. (2021). Births: Final data for 2019. National Vital Statistics Reports; vol 70 no 2. https://dx.doi.org/10.15620/cdc:100472.

3. Osterman, M., Hamilton, B., Martin, J., Driscoll, A., and Valenzuela, C. (2022). Births: Final data for 2020. National Vital Statistics Reports; vol70 no 17. https://dx.doi.org/10.15620/cdc:112078.

4. Human Fertility Collection. Max Planck Institute for Demographic Research (Germany) and Vienna Institute of Demography (Austria). Available at https://www.fertilitydata.org (data downloaded on 25 March 2024).

5. Centers for Disease Control and Prevention (2021). US census populations with bridged race categories. Electronic resource.

6. Injury Surveillance Workgroup 7. Consensus recommendations for national and state poisoning surveillance. The Safe States Alliance. Atlanta, GA. 2012. April 2012.

7. Schoumaker, B. (2019). Male fertility around the world and over time: How different is it from female fertility?. *Population and Development Review*, 459-487.

8. Caswell, H. (2019). The formal demography of kinship. *Demographic Research* 41:679–712

9. Caswell, H. and Song, X. (2021). The formal demography of kinship III. *Demographic Research* 45:517–546.

10. Caswell, H. (2022). The formal demography of kinship IV. *Demographic Research* 47:359–396.

11. Preston, S. H., Heuveline, P., and Guillot, M. (2001). Demography: measuring and modeling population processes. Blackwell Publishers, Malden, MA.

12. Alburez-Gutierrez, D., Williams, I. and Caswell, H., 2023. Projections of human kinship for all countries. *Proceedings of the National Academy of Sciences*, 120(52), p.e2315722120

13. Ruggles, Steven. "Confessions of a microsimulator: problems in modeling the demography of kinship." Historical Methods: *A Journal of Quantitative and Interdisciplinary History* 26.4 (1993): 161-169.

14. Brillinger, D. R. (1986). A biometrics invited paper with discussion: the natural variability of vital rates and associated statistics. *Biometrics*, 693-734.

15. Miller M, Azrael D. Firearm Storage in US Households With Children. *JAMA Netw Open*. 2022;5(2):e2148823. doi:10.1001/jamanetworkopen.2021.48823

16. Fronczak CM, Kim ED, Barqawi AB. The Insults of Illicit Drug Use on Male Fertility. *J Androl*. 2012;33(4):515-528. doi:10.2164/jandrol.110.011874

17. Alghobary M, Mostafa T. Addiction and human male fertility: A systematic review and a critical appraisal. *Andrology*. 2022;10(6):1073-1095. doi:10.1111/andr.13196

18. Joesoef MR, Beral V, Aral SO, Rolfs RT, Cramer DW. Fertility and use of cigarettes, alcohol, marijuana, and cocaine. *Ann Epidemiology*. 1993;3(6):592-594. doi:10.1016/1047-2797(93)90080-n

19. Terplan M, Hand DJ, Hutchinson M, Salisbury-Afshar E, Heil SH. Contraceptive use and method choice among women with opioid and other substance use disorders: A systematic review. *Prev Med*. 2015;80:23-31. doi:10.1016/j.ypmed.2015.04.008 Hser YI, Anglin MD, Wickens TD, Brecht ML, Homer J. Techniques for the estimation of illicit drug-use prevalence: Overview of relevant issues. National Institute of Justice Research Report. Published online 1992. https://www.ojp.gov/pdffiles1/Digitization/133786NCJRS.pdf

20. Hickman M, Taylor C, Chatterjee A, et al. Estimating the prevalence of problematic drug use: A review of methods and their application. *Bulletin on Narcotics*. Published online February 1, 2002. https://research-information.bris.ac.uk/en/publications/estimating-the-prevalence-of-problematic-drug-use-a-review-of-met

21. Sanmartin MX, Ali MM, Meinhofer A. Parental Drug Use and Family Reunification. *Psychiatr Serv*. 2021;72(6):728-728. doi:10.1176/appi.ps.202000388