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Child Mortality In The US And 19 OECD Comparator Nations: A 50-Year Time-Trend Analysis

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ABSTRACT The United States has poorer child health outcomes than other wealthy nations despite greater per capita spending on health care for children. To better understand this phenomenon, we examined mortality trends for the US and nineteen comparator nations in the Organization for Economic Cooperation and Development for children ages 0–19 from 1961 to 2010 using publicly available data. While child mortality progressively declined across all countries, mortality in the US has been higher than in peer nations since the 1980s. From 2001 to 2010 the risk of death in the US was 76 percent greater for infants and 57 percent greater for children ages 1–19. During this decade, children ages 15–19 were eighty-two times more likely to die from gun homicide in the US. Over the fifty-year study period, the lagging US performance amounted to over 600,000 excess deaths. Policy interventions should focus on infants and on children ages 15–19, the two age groups with the greatest disparities, by addressing perinatal causes of death, automobile accidents, and assaults by firearm.

Across almost every domain, the United States has poorer child health outcomes than other wealthy nations. A UNICEF report from 2013 summarized these findings by ranking the US twenty-fifth of twenty-nine developed countries with respect to overall child health and safety.[1] Compared to other high-income nations, mortality rates for US infants are higher and life expectancy at birth is lower.[2,3] Children in the US also face a morbidity disadvantage, with higher rates of injury, obesity, HIV infection, and adolescent pregnancy, compared to children from peer countries.[4]

The care of children is a basic moral responsibility of our society, both because children are inherently vulnerable and because disease can profoundly affect a child's life course.[5] The US outspends every other nation on health care per capita for children, yet outcomes remain poor.[6] The proposed budget for 2018 of the administration of President Donald Trump includes substantial cuts to the Children's Health Insurance Program, which covers seven million children, and to the Supplemental Nutrition Assistance Program, which directs three-quarters of its benefits to households with children.[7–9] In the current political climate, with the government poised to execute these and other dramatic reductions to the social safety net, it is essential to understand how well the nation has taken care of its children and to account for why indicators of children's health in the US consistently lag behind those of other wealthy nations.

In this article we report mortality rate trends in the US and nineteen similar nations for children ages 0–19 during 1961–2010. Our analyses used publicly available data from the Human Mortality Database (University of California, Berkeley, and Max Planck Institute for Demographic Research) and the World Health Organization (WHO) Mortality Database for each of the twenty

countries. Previous studies have tracked US performance over time or compared mortality to similar countries for children in specific age groups, but to our knowledge this is the first study to describe the full burden of excess mortality in the US for children and adolescents of all ages. By comparing US mortality trends to those of other wealthy nations, we gain a historical perspective for understanding when and how the US fell behind. And by disaggregating these trends by age, sex, and cause of death, we hope to direct policy interventions toward areas with the greatest disparities.

Study Data And Methods

STUDY DESIGN We conducted a repeated cross-sectional analysis of mortality rates over the fifty-year period from 1961 to 2010 among children ages 0–19 residing in the US or in one of nineteen other developed nations (listed below) in the Organization for Economic Cooperation and Development (OECD); we call this aggregation of nineteen countries the OECD19. OECD membership was used as a proxy for countries with similar levels of economic development and political structure. This approach was consistent with previous studies comparing international trends in health outcomes and policy.[10–12] All data analyses used publicly available, deidentified data sets and were deemed exempt from human subjects review by the Children's Hospital of Philadelphia.

We identified twenty-three potential countries for our comparator group: the nineteen OECD member states (other than the US) at the organization's founding, in 1960, plus the four countries that had joined by 1973. Of these, Turkey, Greece, and Portugal were excluded because of missing or low-quality data.[13,14] We excluded Luxembourg because the WHO did not compile child population and death counts by age for this country. Thus, the final group of OECD comparators consisted of the following nineteen countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, and the United Kingdom.

DATA SOURCES The Human Mortality Database (HMD) is a publicly available data source jointly created and maintained by the University of California, Berkeley, and the Max Planck Institute for Demographic Research that provides mortality and population data to investigators interested in studying human longevity in thirty-eight countries.[15] For this database, population size is collected from census data and official population estimates; death counts are collected from vital statistics reported by each country. When raw data are reported in aggregated age groups or with unknown age, HMD statisticians distribute counts proportionally across the reported age range. In the HMD, population counts are also adjusted for each year, with a small correction to reflect the timing of death during that year.[16] The database does not contain information on cause of death. Mortality data were available for just twelve of the OECD19 countries after 2010, so 2010 was the final year in our analysis.

The WHO Mortality Database compiles data on mortality and cause of death by age and sex for 144 member states from 1950 to the present.[17] These data are reported by the civil registration systems of member countries. Cause-of-death data are included in the database only for countries that reported medically certified causes of death using *International Classification of Diseases* (ICD) codes; all twenty countries in our analysis met this requirement. WHO population estimates are derived from data submitted by member countries, when available, and otherwise are derived from the United Nations Population Division.

CAUSE OF DEATH Across the fifty-year study period, countries recorded causes of death using ICD-7, ICD-8, ICD-9, and ICD-10 codes. The WHO database translated those codes to basic tabular list alphanumeric codes. We assigned these WHO codes to nine categories: infectious diseases, perinatal conditions, cardiovascular diseases, congenital anomalies, malignant neoplasms, neuropsychiatric conditions, other noncommunicable diseases, intentional injuries, and unintentional injuries. (Look-up tables for the basic tabular list codes to cause-of-death category assignments are in online appendix A1.)[18]

We also identified the leading specific causes of death from 2001 to 2010 for each age subgroup. During this decade the US and sixteen of the OECD19 submitted data to the WHO Mortality Database using ICD-10 codes. Austria, Ireland, and Italy used ICD-9 codes during some years in this decade, so we excluded them from this ICD-specific cause-of-death analysis.

STATISTICAL ANALYSIS The primary set of analyses contrasted childhood mortality rates in the US and those in the OECD19. All-cause mortality rates were calculated as the ratio of death counts to population counts in the HMD. For the most part, they are reported here as deaths per 10,000 population in each age group. Age-specific rates were estimated for the groups younger than than age 1 and ages 1–19. Mortality rates for the older age group were age-adjusted using the US as the standard population. Where rates were calculated across decades, the age distribution for a given decade

was used for weighting. For cause-specific analyses, where the available WHO data varied between one- and five-year granularity, the coarser five-year granularity was used for all countries. We used bootstrap estimates (1,000 resamples) to compute 95% confidence intervals for mortality rate ratios.

Using data from the HMD, we computed excess childhood deaths in the US by applying the OECD19 age-standardized rates for each year of the study to the US population. We then subtracted this product (an expected number of deaths) from the actual number of deaths.

To assess whether each nation's death rates significantly differed from the overall mean of the US and OECD19 (a total of twenty countries), we conducted linear mixed-model analyses of age-adjusted mortality rates from 2001 to 2010. These analyses used the logarithm of country-specific mortality rate as the outcome, country as a random effect, and year as a fixed effect. This approach assumed that children from each country represented samples from a larger distribution—specifically, the population of all children in developed nations. The country-specific random effects from these models correspond to a percentage difference from the mean rate: Negative values indicate rates lower than average, and positive values higher than average.

We performed all analyses in R, version 3.4.0. We used the ddplyr and readr packages for data loading and pooling, the lme4 package for estimating linear mixed models, the sjPlot package to generate random effects plots, and the ggplot2 package to produce graphics.[19–21]

LIMITATIONS Our study had several limitations. First, our analysis relied on country-specific reporting systems for population counts, death counts, and cause-of-death data. Cause-of-death statistics from civil registration data have varying degrees of accuracy and comparability over time and across countries.[22,23] Despite these concerns, more recent data have shown that these inconsistencies are concentrated in less-developed nations. Of the twenty OECD countries in our analysis, eleven (including the US) are classified as having "high quality" cause-of-death statistics, with at least 90 percent completeness and less than 10 percent ill-defined codes, while eight are classified as "medium–high quality," with at least 70 percent completeness and less than 15 percent ill-defined codes (data from the remaining country, France, are characterized as "medium–low quality").[24]

Second, as noted above, over the fifty years of our analysis, the US and OECD19 used four different versions of the ICD coding system to categorize causes of death. This introduced potential discontinuities in cause-of-death analyses when nations switched coding systems. For example, there is no ICD-8 code for cerebral palsy, so the US mortality rate from neuropsychiatric conditions increased by about 0.05 deaths per 10,000 population when the US switched to ICD-9 in 1979. We attempted to mitigate this problem by using broad cause-of-death categories. To further limit inaccuracies, our analysis of the leading individual causes of death relied solely on ICD-10 data in the period 2001–10.

By the 1990s and into the 2000s, the US ranked lowest of all twenty nations in terms of child mortality rates.

Third, several studies have shown that international comparisons of mortality rates are confounded by the various ways in which countries classify preterm infants near the threshold of viability.[25–28] This could artificially increase the disparities between the US and the OECD19 since the US classified certain babies born before twenty-two weeks as viable, while some other countries did not.[28] Nevertheless, two recent studies found that these reporting inconsistencies could not fully explain the US mortality disadvantage.[2,28] A more detailed analysis of preterm births could not be completed because neither of the two databases we used compiled this information for the twenty countries we examined.

Fourth, reporting delays from various countries allowed us to extend our analysis only through 2010. As more recent data become available, we suggest that our study be replicated to monitor trends and progress annually.

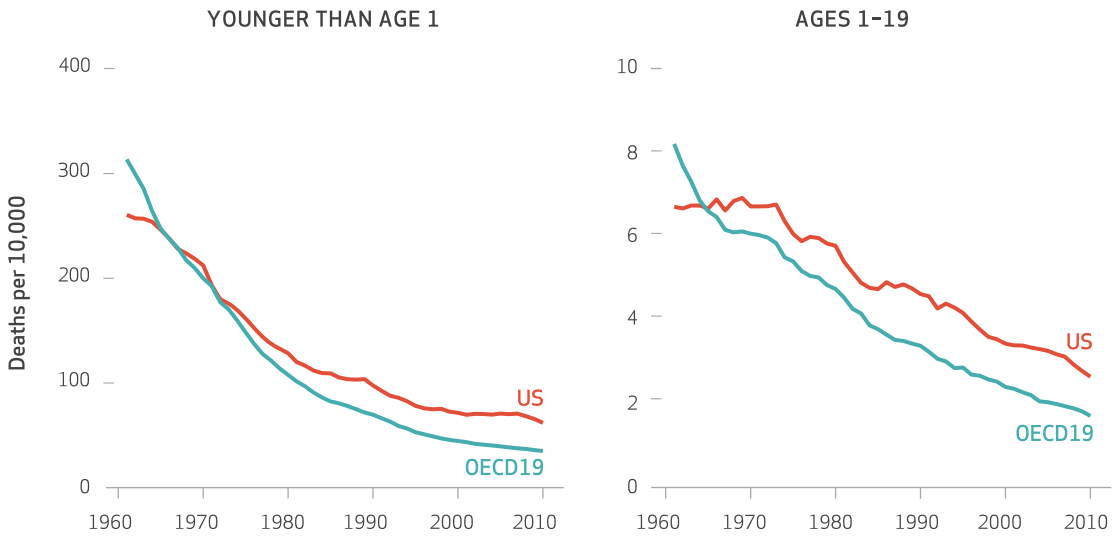
Finally, our analysis did not account for mortality disparities within countries that were attributable to socioeconomic status, geographic residence, or race/ethnicity, since our data sources did not collect demographic or social information.

Study Results

In 1961 the population of children ages 0–19 in the OECD19 was double that of the US: 144 mil-

EXHIBIT 1

Child mortality in the US and the OECD19, by age group, 1960–2010



SOURCE Authors' analysis of data from the Human Mortality Database (University of California, Berkeley, and Max Planck Institute for Demographic Research). **NOTES** The OECD19 is a group of nineteen developed nations other than the US in the Organization for Economic Cooperation and Development. Results for children in the 1–19 age group are age-adjusted.

lion versus 71 million. By 2010 the population of children in the OECD19 was just one-third greater than in the US: 112 million versus 83 million. Mortality rates using the HMD differed by less than 15 percent from WHO mortality rates for each year in our analysis.

ALL-CAUSE CHILDHOOD MORTALITY Childhood mortality rates declined progressively from 1961 to 2010 for both the US and the OECD19 (exhibit 1). Although infant mortality rates exceeded those for children ages 1–19 by a factor of 36 in the 1960s, the ratio declined to 21 by the 2000s. The US childhood mortality rate fell at a slower pace than the OECD19 rate over these fifty years. The US rate began to exceed the OECD19 rate in the late 1960s.

Mortality rates for children younger than age 1 and ages 1–19 did not significantly differ between the US and OECD19 in the 1960s (exhibit 2). US rates became significantly higher than OECD19 rates in the 1980s for children younger than age 1 and in the 1970s for those ages 1–19. These differences accounted for over 600,000 excess deaths in the US, with equal distribution of these excess deaths between the two age groups. Of the 314,000 excess deaths in the older age group,

EXHIBIT 2

All-cause, age-adjusted childhood mortality rates per 10,000 population, rate ratios, and excess deaths for the US and the OECD19, by decade

	Under age 1			Ages 1–19			
	Mortality rate			Mortality rate			
Decade	US	OECD19	Rate ratio	US	OECD19	Rate ratio	Excess deaths
1961–70	240.7	250.3	0.96	6.7	6.7	1.00	–32,500
1971–80	157.4	147.1	1.07	6.2	5.3	1.17****	95,900
1981–90	107.9	83.6	1.29****	4.9	3.8	1.29****	163,000
1991–2000	79.8	53.7	1.49****	3.9	2.7	1.44****	189,000
2001–10	68.8	39.0	1.76****	3.1	2.0	1.55****	207,300

SOURCE Authors' analysis of data from the Human Mortality Database (University of California, Berkeley, and Max Planck Institute for Demographic Research). **NOTES** The OECD19 is a group of nineteen developed nations other than the US in the Organization for Economic Cooperation and Development. During 1961-70 the US had fewer deaths per 10,000 population, corresponding to a negative value for excess deaths. There were 622,700 excess deaths in the period 1961–2010. Significance refers to difference from 1.00, based on 99.9% confidence intervals. ****$p < 0.001$

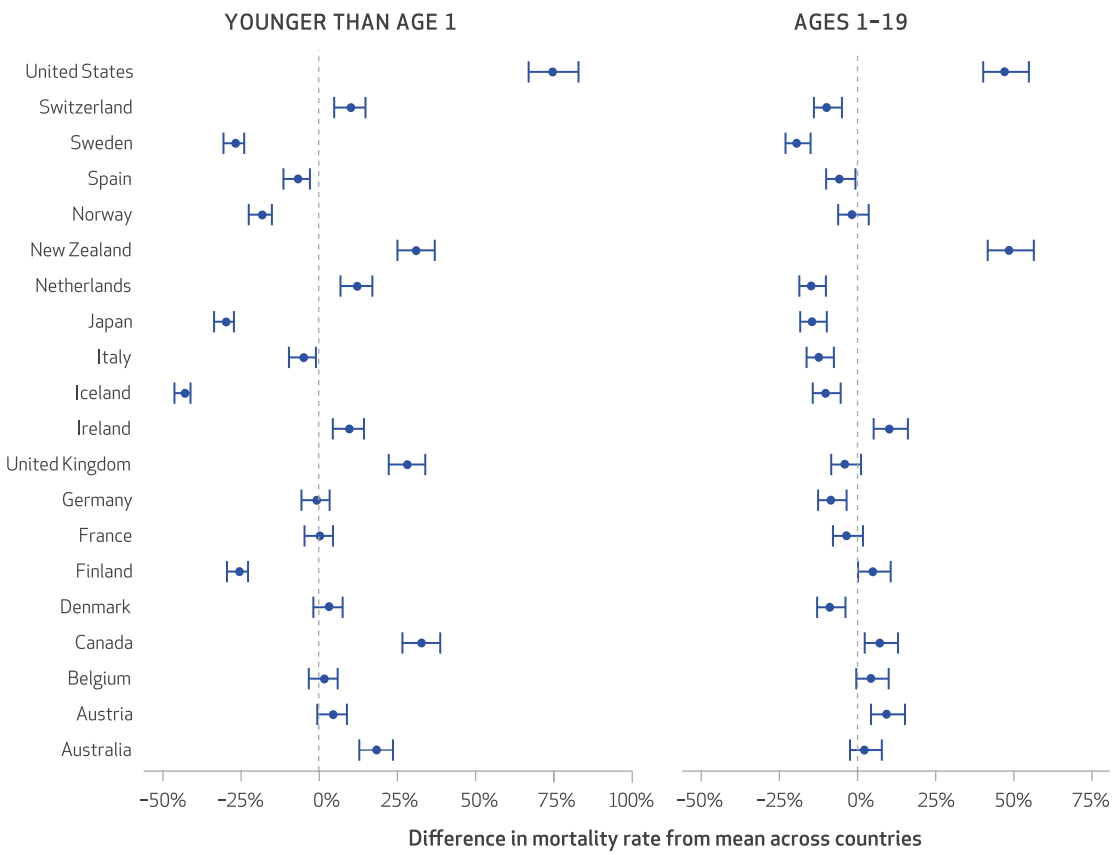
250,000 were among those ages 15–19. Thus, 90 percent of excess deaths occurred in infants or adolescents ages 15–19.

COUNTRY-SPECIFIC RANKINGS To describe childhood mortality rates for each nation independently, we plotted mortality rates by year for each age group on a logarithmic scale (appendix A2).[18] For infant mortality, the countries with the fastest rates of improvement were Spain (5.7 percent decline per year), followed by Italy (5.6 percent) and Austria (5.0 percent). For mortality in children ages 1–19, the fastest declines were seen in Japan (3.5 percent decline per year), Italy (3.4 percent), and Germany (3.3 percent). The slowest declines for infant mortality were in the Netherlands (2.9 percent per year), the US (3.1 percent), and New Zealand (3.3 percent). For age-adjusted rates for children ages 1–19, the countries with the slowest rates of improvement were the US (2.0 percent), New Zealand (2.0 percent), and Ireland (2.2 percent).

During the decade 2001–10, the age-sex-year adjusted childhood mortality rate in the US was 75 percent higher for infants and 50 percent higher for children ages 1–19 than the average rate across all twenty countries in our analysis (exhibit 3). For this decade, the US ranked lowest of all twenty nations. Although New Zealand had lower mortality rates than the US for the younger age group, there was no significant differences between the two countries for the older age group. During this decade, other low performers in infant mortality were the Anglo countries Canada, New Zealand, the United Kingdom, and Australia; for ages 1–19, the other low performers were New Zealand, Ireland, Austria, and Canada. The highest performers for infants were Iceland, Japan, Sweden, Finland, and Norway; for the older age group, the highest performers were Sweden, the Netherlands, and Japan. When we completed the same analysis for other decades for children of all ages, we found that the US ranked fourteenth in the 1960s and 1970s, nineteenth in the 1980s, and twentieth in the 1990s (data not shown). Overall, for children of all ages during 1961–2010, the

EXHIBIT 3

Country-specific effects on all-cause childhood mortality rates, 2001–10



SOURCE Authors' analysis of data on twenty countries from the Human Mortality Database (University of California, Berkeley, and Max Planck Institute for Demographic Research). **NOTE** The bars represent 95% confidence intervals.

country with the lowest childhood mortality rate was Sweden (data not shown).

CAUSE-SPECIFIC MORTALITY Cause-of-death data by category demonstrated several trends. Mortality due to infections dropped precipitously in both the US and the OECD19, leading to nearly identical mortality rates from the 1980s on (appendix A3).[18] Higher perinatal mortality rates in the US stemmed from lagging improvement from 1975 to 1989 and, in particular, from stagnating rates between 1983 and 1989. The mortality gap between the US and OECD19 in intentional injuries rose dramatically from 1960 to a peak in 1993 (appendix A3).[18] This trend was driven almost exclusively by a rise in mortality among males (exhibit 4). During these thirty-three years, US male mortality from intentional injuries rose fivefold, from 10 to 50 deaths per 100,000 population, while US female rates rose from 3 to 10, and OECD19 rates remained roughly stable at 10 and 3 per 100,000 for males and females, respectively.

Childhood mortality from unintentional injuries was also consistently higher in the US than in the OECD19 over the fifty years of our analysis (exhibit 5). As with intentional injuries, males had higher mortality rates than females. Overall trends were encouraging for both the US and the OECD19: From 1973 to 2010, mortality from unintentional injuries per 10,000 population fell from 110 to 30 for American males and from 80 to 15 for American females, while they fell from 20 to 15 among OECD19 males and were stable at 10 for OECD19 females.

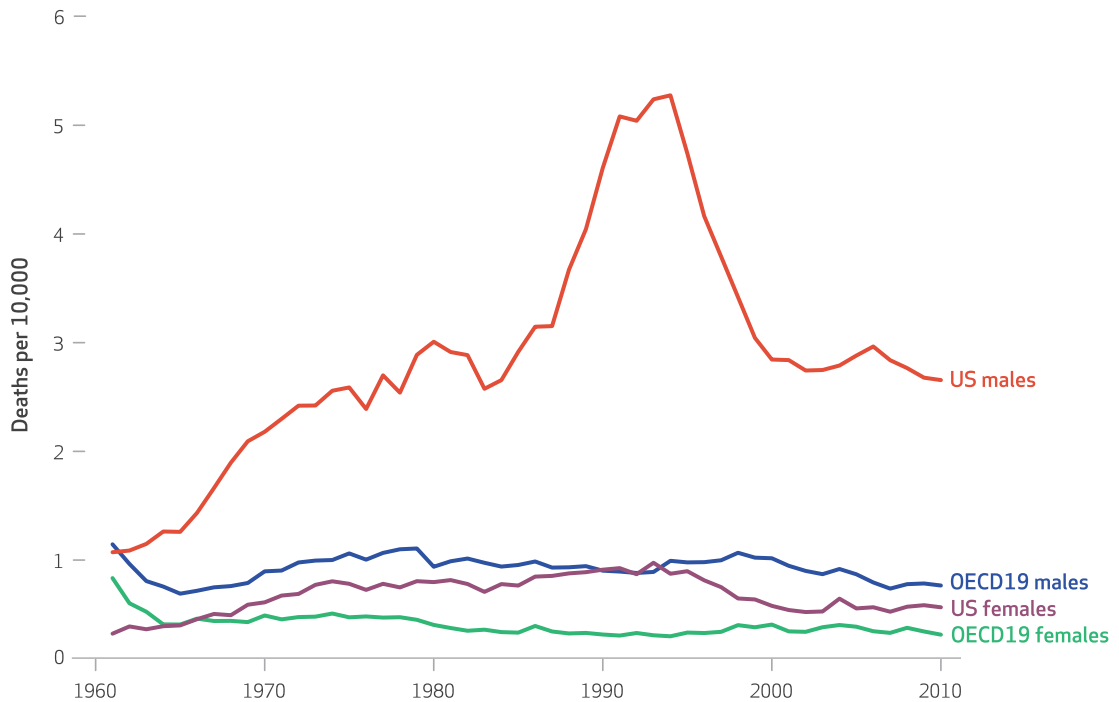
We identified the leading specific causes of death by ICD-10 codes from 2001 to 2010 for the US and the sixteen OECD19 countries that used ICD-10 during this decade (data not shown). For infants, the two leading causes of death in the US during the period were extreme immaturity and sudden infant death syndrome, with US-to-OECD19 rate ratios of 3.0 and 2.3, respectively. The two leading causes of death for children ages 15–19 were motor vehicle accidents and assaults by firearm, with US-to-OECD19 rate ratios of 2.1 and 82.2, respectively. The latter statistic indicates that from 2001 to 2010, a person in the 15–19 age group was eighty-two times more likely to die from gun homicide in the US than in other wealthy nations.

Discussion

Over the fifty-year period from 1961 to 2010, childhood mortality progressively declined in the US and OECD member nations. This is a

EXHIBIT 4

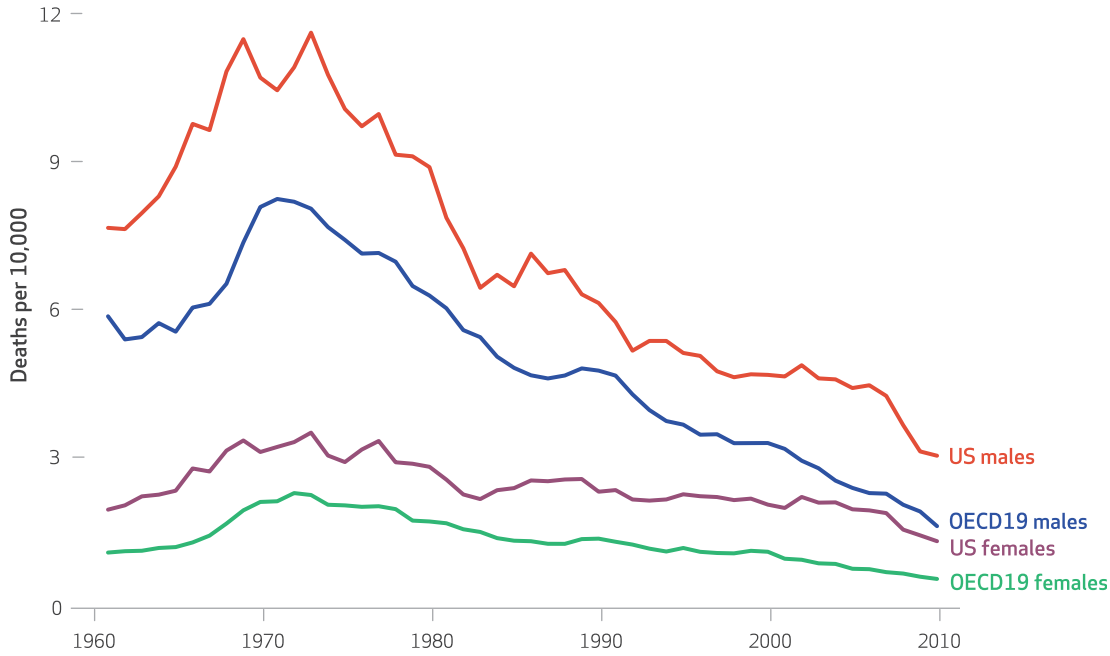
Mortality rates for intentional injuries in the US and the OECD19, by sex for all ages, 1960–2010



SOURCE Authors' analysis of data from the World Health Organization Mortality Database. **NOTE** The OECD19 is a group of nineteen developed nations other than the US in the Organization for Economic Cooperation and Development.

EXHIBIT 5

Mortality rates for unintentional injuries in the US and the OECD19, by sex for all ages, 1960–2010



SOURCE Authors' analysis of data from the World Health Organization Mortality Database. **NOTE** The OECD19 is a group of nineteen developed nations other than the US in the Organization for Economic Cooperation and Development.

tremendous public health success. Despite this achievement, reductions in mortality rates were not evenly distributed across the twenty nations in this study. By the 1990s and into the 2000s, the US ranked lowest of all twenty nations in terms of child mortality rates. Compared to the OECD19 in the first decade of the 2000s, infants in the US had a 76 percent increased risk of death, and children ages 1–19 a 57 percent increased risk of death. If the US had achieved just the average childhood mortality rate of the OECD19 over the fifty-year study period, over 600,000 deaths could have been avoided—a rate of about 20,000 excess deaths per year by the turn of the century.

These results corroborate other research demonstrating a mortality disadvantage for US children compared to children in other wealthy nations.[2,29–31] Our findings extend this work by identifying when this disadvantage developed over a fifty-year time span and by describing which age subpopulations were most affected. Furthermore, our cause-of-death analysis gives a unique perspective on the sources of these fifty-year trends, reflecting the successes and failures of past public health efforts and pointing to health policy interventions that could reverse the poor US performance.

Our analysis by cause of death showed that there is not a single category for which the OECD19 had higher mortality rates than the US over the last three decades of our analysis. Nevertheless, the US has had success in reducing mortality from infectious diseases, cardiovascular disease, malignant neoplasms, and neuropsychiatric conditions. For each of these categories, we found no statistically meaningful differences in US rates compared to OECD19 rates over the last twenty years of our analysis. For all twenty countries, the consistent success at reducing mortality from infectious diseases is particularly impressive. Meanwhile, the most striking disparities between the US and OECD19 arose from perinatal conditions (consisting of immaturity, birth injuries, postnatal asphyxia/atelectasis, hemolytic diseases of the newborn, maternal conditions affecting the fetus or newborn, and fetal malnutrition) and from injuries.

GENERALIZED MORTALITY TRENDS An Institute of Medicine report on US health from an international perspective determined that the nation's poor health outcomes stem from adverse socioeconomic conditions, risky health behaviors, and a fragmented health system, all in the context of a weak social safety net that fails to buffer vulnerable populations from the impacts of these circumstances on health.[4] Our findings on the child mortality disadvantage support this verdict. The disadvantage developed between the late 1960s and the mid-1980s, at

The US mortality rate from firearm homicide was eighty-two times the rate of the OECD19 during 2001–10.

precisely the time when relative socioeconomic status for children fell in the US compared to other wealthy countries. The US has had one of the highest rates of child poverty among wealthy nations since at least the early 1980s,[4] and in the mid-1980s child poverty increased by almost one-third in the US.[32] US children also have performed among the lowest of wealthy nations in educational outcomes since at least the mid-1960s, when international comparisons were first conducted.[33] Both poverty and education have repeatedly been shown to track along a gradient of health in children, with lower incomes and lower education correlated with worse health outcomes.[34–36]

These two phenomena—increased relative poverty and stagnating educational attainment—occurred in the context of a relatively weak social safety net for children. During the period we analyzed, the US spent significantly less of its gross domestic product per capita on child health and welfare programs, compared to other wealthy nations.[37] More equitable social policies have been shown to mitigate the accumulating disadvantages that can lead to poor health outcomes in children.[38] In fact, two studies found strong associations between the style of welfare regime in a country and health outcomes. Anglo-Saxon/Liberal nations (with means-tested and residual welfare regimes) performed worse than both Conservative (with wage-earner social insurance models) and Social Democratic (with universalist models) regimes. One study found that governing style accounted for 47 percent of the variation in life expectancy,[39] and another found that it accounted for 20 percent of the variation in infant mortality and 10 percent of the variation in low birthweight.[40]

INFANT MORTALITY FROM PERINATAL CAUSES The relatively poor US performance in infant mortality has been fully described, and existing research points to a particularly heavy burden of mortality from premature birth in the US.[2,29,41–43] Our findings support this conclusion, as two of the four most common causes of infant deaths in the US from 2001 to 2010 related to prematurity: extreme immaturity of the newborn, for which the US rate was three times that of the OECD19, and "prematurity (other)," for which the US rate was five times that of the OECD19.

The physiological mechanisms of preterm labor remain unclear, making it difficult to model medical interventions.[43] Nevertheless, social determinants have been established and validated in association with preterm labor and resulting preterm delivery. Both preterm delivery and low birthweight, a proxy for preterm delivery, have been strongly and consistently associated with poverty. Furthermore, striking racial disparities persist in the US, with African Americans demonstrating higher rates of preterm delivery than any other major racial/ethnic group.[44,45]

ADOLESCENT MORTALITY FROM INJURIES The five decades in our analysis witnessed a steep rise and slower fall in mortality rates from injuries in the US. For children ages 15–19, the two most common causes of death during 2000–10 were motor vehicle accidents and assaults by firearm. Recent evidence shows that youth mortality in the US from motor vehicle accidents has improved since the 1990s, as the result of a multipronged public health effort that addressed drivers (for example, drunk-driving legislation), motor vehicles (such as enhanced safety features in automobiles), and the environment (for example, divided highways).[46,47] Still, countries in the OECD19 are improving at faster rates: a 2013 report on traffic safety and accidents found that the US reduced road fatalities by 23 percent from 2000 to 2011, while the countries in the OECD19 reduced rates by 26–64 percent over the same period.[48]

Trends for youth homicide by firearm tell a different story. Although mortality rates from all intentional injuries improved greatly over the 1990s, our analysis found that the US mortality rate from firearm homicide was still eighty-two times the rate of the OECD19 during 2001–10. This disturbing disparity is consistent with previous research that found the gun homicide rate for Americans ages 15–24 to be forty-nine times higher than that in twenty-three OECD countries in 2012.[49] As with preterm births, these trends reveal stark racial disparities. US adolescent victims are disproportionately non-Hispanic black males; for boys in this demographic category, homicide by firearm is the leading cause of death in the US.[48]

Conclusion

From 1961 to 2010 the world's wealthy democratic nations made consistent improvements in survival rates for children of all ages. There has never been a better time to be born in any of these twenty nations. Despite this generalized trend, children are less likely to survive and transition into adulthood in the US than in other OECD nations. Persistently high poverty rates, poor educational outcomes, and a relatively weak social safety net have made the US the most dangerous of wealthy nations for a child to be born into. All US policy makers, pediatric health professionals, child health advocates, and families should be troubled by these findings. The findings should motivate Americans to do everything possible to improve the medical and social conditions of children that are responsible for these preventable deaths. ■

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18 To access the appendix, click on the Details tab of the article online.

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