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Original Contribution

Trends in Socioeconomic Inequalities in Motor Vehicle Accident Deaths in the United States, 1995–2010

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Motor vehicle accident (MVA) mortality has been declining overall, but little is known about trends by socioeconomic position. We examined trends in education-related inequalities in US MVA death rates from 1995 to 2010. We used mortality data from the National Center for Health Statistics and population estimates from the Current Population Survey, and we calculated vehicle- and person-miles traveled using data from the National Household Travel Survey. We used negative binomial regression to estimate crude and age-, sex-, and race-adjusted mortality rates among adults aged 25 years or more. We found larger mortality decreases among the more highly educated and some evidence of mortality increases among the least educated. Adjusted death rates were 15.3 per 100,000 population (95% confidence interval (CI): 10.7, 19.9) higher at the bottom of the education distribution than at the top of the education distribution in 1995, increasing to 17.9 per 100,000 population (95% CI: 14.8, 21.0) by 2010. In relative terms, adjusted death rates were 2.4 (95% CI: 1.7, 3.0) times higher at the bottom of the education distribution than at the top in 1995, increasing to 4.3 times higher (95% CI: 3.4, 5.3) by 2010. Inequality increases were larger in terms of vehicle-miles traveled. Although overall MVA death rates declined during this period, socioeconomic differences in MVA mortality have persisted or worsened over time.

health inequalities; mortality; motor vehicle accidents; socioeconomic position; trends

Abbreviations: CI, confidence interval; MVA, motor vehicle accident; NHTS, National Household Travel Survey; NPTS, Nationwide Personal Transportation Survey; PMT, person-miles traveled; RII, Relative Index of Inequality; SEP, socioeconomic position; SII, Slope Index of Inequality; VMT, vehicle-miles traveled.

Motor vehicle accident (MVA)–associated injuries are among the leading causes of death in the United States, and they are the leading cause of death for persons aged 10–24 years (1). In 2010, MVA injuries led to 35,332 US deaths, with the highest death rates being seen in persons aged 15–24 years and persons aged ≥75 years (1). From 1958 to 2008, the US road traffic fatality rate per population declined by 40% and the fatality rate per distance driven declined by 76%, with the greatest declines being observed in the youngest and oldest age groups (2). These declines can be attributed to improvements in vehicle engineering, road design, emergency room care, and road safety legislation (3). Legislation against alcohol-involved driving, such as 0.08-g/dL blood alcohol concentration laws, sobriety checkpoints, and minimum legal drinking age laws, have reduced fatal and nonfatal crash injuries since they first were enacted in the 1970s (4). Mandatory seat-belt laws, particularly when robustly enforced, increase seat-belt use and have reduced mortality since their introduction in 1984 (5, 6). There have also been improvements in alcohol-impaired driving fatalities and the use of safety restraints (7, 8).

Although overall MVA mortality has declined substantially, persistent social inequalities remain. Rates among men are 2.5 times those among women, and rates in American Indians/Alaska Natives are 2–5 times those in other racial/ethnic groups (9). Inequalities by socioeconomic position (SEP) have been less well documented (10, 11). Some studies have found socioeconomic gradients at the neighborhood or state level, with MVA injuries and fatalities being more common in poorer regions, as defined by aggregate measures of income, poverty, and low education (12–15). There have also been a few studies of socioeconomic inequalities in MVA-related mortality at the individual level. Lower educational status (10, 14, 16), blue-collar (14) or lower-status occupations (17), and lower incomes (14) have been associated with increased risk of traffic accident–related mortality. Educational inequalities have also been observed when risk status is examined by annual number of vehicle trips (10). Outside of the United States, there is evidence of similar socioeconomic gradients in MVA-related injuries and deaths among adults in developed countries (18–23).

The prior work on socioeconomic inequalities in MVA-related mortality has limitations. To our knowledge, no prior studies of individual SEP and MVA mortality have examined changes over time, which makes it difficult to know whether the national improvements have been shared equally. Moreover, no studies have assessed inequality trends using "exposure-based" denominators that account for socioeconomic differences in the use of different modes of transport. Lower SEP is associated with some modes of travel that have higher mortality risks (e.g., motorcycle, bicycle, walking) (24) but also some with lower mortality risks (e.g., bus travel) (25). We addressed this gap by examining crude and demographic factor–adjusted trends in MVA-associated mortality in the United States from 1995 to 2010 by level of educational attainment. We estimated mortality rates both by population and by travel exposure and examined inequalities over time in absolute and relative terms (26, 27).

METHODS

Data

Numbers of MVA-related fatalities were obtained through the National Vital Statistics System for the years 1995–2010 (28). We included deaths of motor vehicle occupants, pedal cyclists, pedestrians, and other persons involving collisions between motor vehicles and fixed or moving objects, or motor vehicle noncollision accidents (e.g., fires, breakages, falls) occurring on public roadways or elsewhere. We used the Ninth and Tenth revisions of the *International Classification of Diseases* to classify the underlying causes of deaths from MVAs for the periods 1995–1998 and 1999–2010, respectively (specific *International Classification of Diseases*, Tenth Revision, codes are listed in footnote "c" of Table 1). We aggregated deaths into strata based on age (25–34, 35–44, 45–54, 55–64, or ≥65 years), sex, race (black, white, or other/multiracial), educational attainment (less than high school, high school graduate/General Educational Development diploma, some college/associate's degree, or college graduate or higher), and year of death. Age stratification was restricted to persons aged 25 years or older to increase the likelihood that educational attainment would accurately reflect years of completed education.

We used 2 types of denominators for rate calculations: persons and miles traveled. The Current Population Survey contains population counts by age, sex, race, and education, from which we estimated annual populations by averaging the monthly demographic totals over each year (29). We also updated the sample with amended Current Population Survey extracts for the years 2000–2002, which used corrected Census 2000 weights (30). Consistent with previous studies (31), we restricted our analysis to 45 states plus the District of Columbia, which were the areas with at least 80% completeness of education reporting on death certificates in all years during 1995–2010 (see Web Figure 1, available at http://aje.oxford journals.org/). We estimated average miles traveled for demographic groups using data from the Nationwide Personal Transportation Survey (NPTS) in 1995 and the National Household Travel Survey (NHTS) in 2001 and 2009 (32–34). The NHTS/NPTS is a national telephone survey collecting data on trips made in a 24-hour period, which allows quantification of travel behavior and identification of traveler characteristics (35). Because the NHTS/NPTS censored the identities of states with populations of less than 2 million persons in 1995 and 2001, we restricted the analyses using exposure-based denominators to 30 uncensored states (shown in Web Figure 1) that also had ≥80% complete information on deaths by educational level.

We derived annual demographic totals of vehicle-miles traveled (VMT) and a measure of person-miles traveled (PMT) to estimate death rates as a function of travel exposure. VMT quantifies distance traveled in privately owned vehicles and only records mileage for persons who report driving vehicles. PMT quantifies travel distances for all forms of vehicular and nonvehicular transport for all occupants (35), which is arguably more relevant for persons of lower SEP, who are generally less likely to own cars. We modified the PMT measure by restricting it to forms of transport relevant to MVA fatalities, including privately owned vehicles, buses, streetcars, taxis, and vehicles for the disabled, in addition to nonmotorized forms of road transport such as cycling or walking.

The NHTS and NPTS were designed to be nationally representative of the civilian noninstitutionalized population, but we found that respondents with low educational attainment were systematically underrepresented in 2009. For example, persons aged ≥25 years with less than a high school education comprised 13.2% of the US population but 9.4% of the weighted NHTS population. To account for possible undercoverage by education, we adjusted (10) the NHTS/NPTS person-weights by sex, race, age, and education category using the Current Population Survey as the reference and regenerated adjusted travel day-weights used to estimate the VMT and PMT denominators. We used linear interpolation to generate annual estimates of VMT and modified PMT by demographic category from the benchmark years of 1995, 2001, and 2009, with extrapolation to 2010.

Statistical analysis

To examine trends in MVA mortality rates per population and per miles of travel, we fitted a series of negative binomial regression models (Poisson models were overdispersed) with robust variance estimation and either persons or miles traveled as the offset (36). Models included fixed effects for each education group and each year, as well as product terms for interactions between the fixed effects for education and year. We used the *margins* command in Stata software, version 12 (StataCorp LP, College Station, Texas), to estimate marginal predicted incidence rates and standard errors by means of the delta method. We estimated overall and education-specific

Table 1. Crude Death Counts and Death Rates for Motor Vehicle Accident–Associated Deaths Among US Adults Aged 25 Years or More, According to Population, Vehicle-Miles Traveled, and Person-Miles Traveled, 1995 and 2010

Demographic Group	1995					2010				
	Population-Based Denominators[a]		Exposure-Based Denominators[b]			Population-Based Denominators[a]		Exposure-Based Denominators[b]		
	No. of Deaths[c]	Rate per 100,000 Population	No. of Deaths[c]	Rate per 100 Million VMT	Rate per 100 Million PMT	No. of Deaths[c]	Rate per 100,000 Population	No. of Deaths[c]	Rate per 100 Million VMT	Rate per 100 Million PMT
Sex										
Male	17,491	23.57	16,107	1.69	1.43	16,772	18.61	15,381	1.54	1.29
Female	8,801	10.75	8,167	1.46	0.90	7,125	7.33	6,492	1.01	0.66
Race										
White	22,204	16.71	20,455	1.53	1.15	20,076	13.10	18,309	1.33	1.01
Black	3,124	18.59	3,031	2.37	1.65	2,894	13.90	2,820	1.68	1.26
Other	964	14.99	788	1.60	1.22	927	7.00	744	0.78	0.55
Education										
Less than high school	7,197	25.71	6,722	3.81	2.58	4,921	20.57	4,590	4.14	2.70
High school/GED	11,424	21.62	10,551	2.15	1.57	10,565	18.25	9,650	2.10	1.53
Some college/ associate's degree	4,252	10.94	3,879	0.93	0.71	5,025	10.26	4,551	0.97	0.76
College graduate	3,419	9.40	3,122	0.72	0.56	3,386	6.00	3,082	0.51	0.40
Age group, years										
25–34	7,206	18.79	6,665	1.58	1.19	5,211	13.60	4,775	1.47	1.10
35–44	5,854	14.78	5,374	1.19	0.94	4,249	11.34	3,890	0.99	0.76
45–54	3,815	13.11	3,518	1.10	0.84	4,792	11.58	4,394	1.03	0.81
55–64	2,696	13.87	2,487	1.41	1.01	3,885	11.55	3,558	1.17	0.89
≥65	6,721	22.70	6,230	4.19	2.66	5,760	15.79	5,256	2.72	1.85
Total	26,292	16.84	24,274	1.60	1.19	23,897	12.76	21,873	1.33	1.01

Abbreviations: GED, General Educational Development; PMT, person-miles traveled; VMT, vehicle-miles traveled.

[a] Based on the aggregate of 45 states plus the District of Columbia (excluding Georgia, Kentucky, Oklahoma, Rhode Island, and South Dakota).

[b] Based on the aggregate of 30 states (excluding Alaska, Delaware, the District of Columbia, Georgia, Hawaii, Idaho, Kentucky, Maine, Montana, Nebraska, Nevada, New Hampshire, New Mexico, North Dakota, Oklahoma, Rhode Island, South Dakota, Utah, Vermont, West Virginia, and Wyoming).

[c] *International Classification of Diseases*, Tenth Revision, codes V02–V04, V09.0, V09.2, V12–V14, V19.0–V19.2, V19.4–V19.6, V20–V79, V80.3–V80.5, V81.0–V81.1, V82.0–V82.1, V83–V86, V87.0–V87.8, V88.0–V88.8, V89.0, and V89.2.

rates of MVA mortality, and we calculated both crude rates and rates adjusted for age, sex, and race. To examine how inequalities in MVA deaths by educational attainment changed over time, we estimated mortality rate changes by education group between 1995 and 2010 and differences between education categories in each year. To see whether education-specific mortality trends were consistent across all races and sexes, we included 3-way product terms for interactions between education, year, and race or sex and tested whether racial or sex differences in the education-specific rate trends were jointly equal to zero.

In addition to estimating differences in mortality for each education group, we also calculated the Slope Index of Inequality (SII) (37) and the Relative Index of Inequality (RII) (26) for each year. The SII and RII take account of all education groups and account for changes over time in the distribution of education. This is particularly relevant because there was a shift towards higher education between 1995 and 2010 (the proportion of persons aged 25 years or older with a college degree or graduate-level education increased from 23% in 1995 to 30% in 2010). For these measures, we ranked the population by category of education (from highest to lowest) in each year and calculated for each group the midpoint of its position in the cumulative distribution of the population (ridit score). We then used negative binomial models to regress deaths on the ridit score and covariates, and we obtained marginal predictions of death rates. The SII represents the estimated absolute difference in mortality from the top of the cumulative education distribution to the bottom—that is, from 0 to 1 (37). We calculated the RII as the ratio of predicted mortality rates at the bottom of the education distribution versus the top (26, 38).

Sensitivity analyses

There were differences in the coding of educational attainment by states over time, as some states revised the coding of education on death certificates after 1989. To test whether

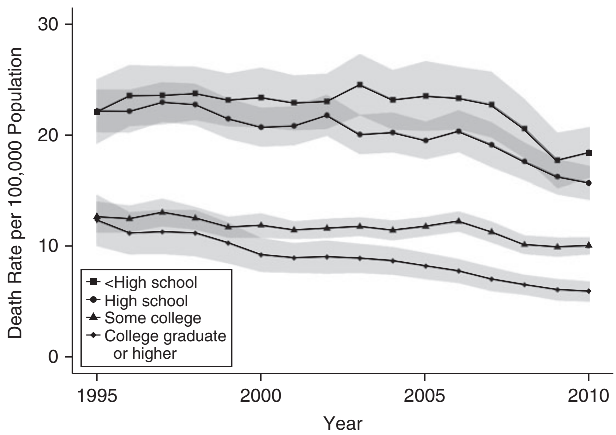

Figure 1. Age-, sex-, and race-adjusted trends in motor vehicle accident deaths per 100,000 population (marginal predicted rates obtained after conducting negative binomial regression) among persons aged 25 years or more in 45 US states and the District of Columbia, by category of education, 1995–2010. Excludes Georgia, Kentucky, Oklahoma, Rhode Island, and South Dakota. Shading indicates 95% confidence intervals.

this had any impact on the trends, we restricted our analysis to a sample of 16 states that used the original 1989 form of education coding consistently throughout the sample period. We also assessed the robustness of our restriction to 80% completeness of education reporting by examining mortality rates in all states, irrespective of missing educational information. Additionally, given some evidence of misclassification of education on death certificates (largely biased toward higher years/degree status), we implemented correction ratios based on a prior linkage study (39). We multiplied observed death counts by the published correction ratio in each education group, separately for men and women, to obtain misclassification-corrected numbers of deaths. With respect to exposure-based denominators, we also performed sensitivity analysis to estimate the potential impact of misclassification of VMT/PMT. More highly educated individuals were more likely to have used travel diaries, which capture 0.5 more daily trips, on average, than recall alone (40). We revised the age-, sex-, race-, and education-specific VMT/PMT for persons who reported not using a travel diary by adding the VMT/PMT implied by an additional half trip per day multiplied by their average travel distance for this form of travel (errands, recreational travel, shopping, etc.). We also reran our analyses without adjusting the travel surveys for underrepresentation by education.

RESULTS

Between 1995 and 2010, overall MVA mortality rates fell by 15%–25%, depending on whether they were measured as a function of population, VMT, or PMT (Table 1). Crude mortality rates were higher in men, blacks, and persons aged 65 years or older. Crude mortality rates were highest in persons with less than a high school education and decreased with ascending category of educational attainment.

Education-specific trends in rates adjusted for age, sex, and race showed gradual declines in mortality in all groups when measured by population (Figure 1), but we found larger declines in mortality rates between 1995 and 2010 among college graduates (a change of −6.4 deaths per 100,000 population, 95% confidence interval (CI): −8.9, −4.0) and high school graduates (−6.5 deaths per 100,000 population, 95% CI: −8.6, −4.3; Table 2). While the mortality gap between high school graduates and college graduates was relatively constant over time, the gap between college graduates and persons with some college increased by 3.8 deaths per 100,000 population (95% CI: 1.0, 6.7), from 0.30 in 1995 to 4.11 in 2010. Notably, all groups experienced a sharp decline in death rates around 2008, the approximate time of the Great Recession (which began in December 2007 (41)).

The 2 summary measures of inequality were also consistent with a pattern of increasing inequality. In 1995, the SII suggested that moving from the top of the education distribution to the bottom increased estimated mortality rates by 15.3 deaths per 100,000 population (95% CI: 10.7, 19.9). In relative terms, this is more than a doubling of rates (RII = 2.4, 95% CI: 1.8, 3.0). Between 1995 and 2010, both relative and absolute inequalities increased, but only the change in the RII was statistically distinguishable from zero.

Table 2. Age-, Sex-, and Race-Adjusted Rates of Motor Vehicle Accident–Associated Death per 100,000 Population Among Adults Aged 25 Years or More, by Educational Attainment, in 45 US States and the District of Columbia,[a] 1995–2010

Education	1995			2010			Change From 1995 to 2010			
	Rate[a]	RD	95% CI	Rate	RD	95% CI	Rate	95% CI	RD	95% CI
Less than high school	22.09	9.74	6.18, 13.30	18.43	12.49	10.17, 14.81	−3.66	−7.12, −0.21	2.75	−1.48, 6.98
High school graduate/GED	22.15	9.80	6.96, 12.64	15.68	9.74	8.12, 11.36	−6.47	−8.64, −4.31	−0.06	−3.32, 3.19
Some college/associate's degree	12.64	0.30	−2.34, 2.94	10.05	4.11	3.00, 5.22	−2.59	−4.10, −1.08	3.82	0.95, 6.68
College graduate	12.35	0	Referent	5.94	0	Referent	−6.41	−8.86, −3.96	0	Referent
Slope index of inequality		15.30	10.67, 19.92		17.87	14.80, 20.95			2.58	−2.94, 8.09
Relative index of inequality		2.36	1.77, 2.96		4.33	3.39, 5.27			1.97	0.85, 3.08

Abbreviations: CI, confidence interval; GED, General Educational Development; RD, rate difference.
[a] Marginal predicted rates obtained after conducting negative binomial regression. Excludes Georgia, Kentucky, Oklahoma, Rhode Island, and South Dakota.

Table 3. Age-, Sex-, and Race-Adjusted Rates of Motor Vehicle Accident–Associated Death per Specified Population Among Adults Aged 25 Years or More, by Measure of Travel Exposure and Educational Attainment, in 30 US States,[a] 1995–2010

Denominator and Education	1995			2010			Change From 1995 to 2010			
	Rate	RD	95% CI	Rate	RD	95% CI	Rate	95% CI	RD	95% CI
Per 100,000 population										
Less than high school	21.85	9.51	5.78, 13.24	18.06	12.22	9.90, 14.53	−3.79	−7.32, −0.26	2.71	−1.67, 7.08
High school graduate/GED	22.05	9.72	6.63, 12.80	15.42	9.58	7.94, 11.21	−6.64	−8.99, −4.28	−0.14	−3.62, 3.34
Some college/associate's degree	12.02	−0.32	−3.00, 2.37	9.74	3.90	2.83, 4.96	−2.28	−3.60, −0.97	4.22	1.33, 7.11
College graduate	12.34	0	Referent	5.84	0	Referent	−6.50	−9.08, −3.91	0	Referent
SII		15.21	10.37, 20.05		17.56	14.51, 20.61			2.35	−3.33, 8.04
RII		2.38	1.74, 3.02		4.35	3.41, 5.29			1.97	0.84, 3.11
Per 100 million vehicle-miles traveled										
Less than high school	4.75	3.42	2.62, 4.21	7.50	6.86	4.50, 9.22	2.75	0.29, 5.21	3.44	0.95, 5.93
High school graduate/GED	3.30	1.96	1.40, 2.53	2.36	1.72	1.34, 2.10	−0.93	−1.53, −0.34	−0.24	−0.92, 0.44
Some college/associate's degree	1.49	0.15	−0.25, 0.56	1.11	0.47	0.29, 0.65	−0.38	−0.67, −0.09	0.31	−0.13, 0.76
College graduate	1.33	0	Referent	0.64	0	Referent	−0.69	−1.03, −0.35	0	Referent
SII		4.92	3.80, 6.05		7.93	5.49, 10.37			3.01	0.33, 5.68
RII		5.61	3.76, 7.46		21.37	12.05, 30.69			15.76	6.24, 25.28
Per 100 million person-miles traveled										
Less than high school	2.69	1.77	1.35, 2.19	3.64	3.20	2.22, 4.17	0.95	−0.09, 1.99	1.43	0.36, 2.49
High school graduate/GED	2.17	1.25	0.88, 1.62	1.51	1.07	0.84, 1.29	−0.66	−1.04, −0.28	−0.18	−0.62, 0.25
Some college/associate's degree	0.96	0.04	−0.20, 0.28	0.80	0.36	0.25, 0.46	−0.16	−0.31, −0.01	0.32	0.05, 0.58
College graduate	0.92	0	Referent	0.45	0	Referent	−0.48	−0.69, −0.26	0	Referent
SII		2.66	2.06, 3.27		3.86	2.85, 4.87			1.19	0.02, 2.37
RII		4.53	3.17, 5.89		13.61	8.68, 18.53			9.08	3.95, 14.21

Abbreviations: CI, confidence interval; GED, General Educational Development; RD, rate difference; RII, relative index of inequality; SII, slope index of inequality.

[a] Marginal predicted rates obtained after conducting negative binomial regression. Excludes Alaska, Delaware, the District of Columbia, Georgia, Hawaii, Idaho, Kentucky, Maine, Montana, Nebraska, Nevada, New Hampshire, New Mexico, North Dakota, Oklahoma, Rhode Island, South Dakota, Utah, Vermont, West Virginia, and Wyoming.

Table 3 shows estimates for 30 states that permitted calculation of both population-based and exposure-based denominators. The population-based estimates and trends for this subset of states were nearly identical to those for the 45 states plus the District of Columbia. Figure 2 shows trends in death rates per 100 million VMT (trends per 100 million PMT were similar) and demonstrates a widening gap between persons with less than a high school diploma and all other education groups. In fact, adjusted rates among those with less than a high school education actually increased by 2.75 deaths per 100 million VMT (95% CI: 0.29, 5.21) and 0.95 deaths per 100 million PMT (95% CI: −0.09, 1.99) (Table 3). For exposure-based denominators, death rates for groups with at least a high school education generally decreased by a similar magnitude. We found no evidence that the relationship between education and mortality over time was modified on the additive scale by either race or sex (all P values > 0.97).

Summary measures of inequalities in exposure-based rates increased regardless of whether they were measured on the absolute scale or the relative scale, though the increases were much larger on the relative scale (Table 3). The SII increased by 3 deaths per 100 million VMT (95% CI: 0.3, 5.7) or 1.2 deaths per 100 million PMT (95% CI: 0.0, 2.4) between 1995 and 2010. The ratio of death rates per 100 million VMT at the bottom of the education distribution versus the top increased from 5.6 to 21.4, an increase of 15.8 (95% CI: 6.2, 25.3). Mortality inequalities were generally smaller when estimated using deaths per 100 million PMT.

Sensitivity analyses restricted to the 16 US states using the original 1989 educational attainment coding on death certificates suggested slightly larger inequalities (Web Table 1), but trends were quantitatively similar to the main results. National trends estimated using all states irrespective of completeness of education reporting on death certificates were nearly identical to the estimates for our restricted sample of 30 states in Table 3 (Web Table 2). Death rates adjusted for misclassification of education reporting on death certificates (39) (Web Table 3), estimated in the entire sample, led to

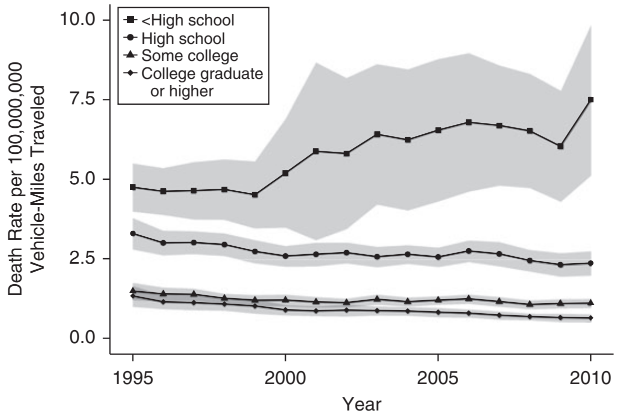

Figure 2. Age-, sex-, and race-adjusted trends in motor vehicle accident deaths per 100 million vehicle miles traveled (marginal predicted rates obtained after conducting negative binomial regression) among persons aged 25 years or more in 30 US states, by category of education, 1995–2010. Excludes Alaska, Delaware, the District of Columbia, Georgia, Hawaii, Idaho, Kentucky, Maine, Montana, Nebraska, Nevada, New Hampshire, New Mexico, North Dakota, Oklahoma, Rhode Island, South Dakota, Utah, Vermont, West Virginia, and Wyoming. Shading indicates 95% confidence intervals.

slightly larger education gradients in death rates, but changes over time were similar to our main results in Table 3. Adjustment for potential misreporting of VMT/PMT also produced similar changes over time (Web Table 4). Finally, Web Table 5 shows larger increases in inequalities over time without our adjustments to increase the representativeness of travel weights.

DISCUSSION

In this study, we documented strong socioeconomic patterning of MVA mortality. We have presented some evidence that educational inequalities increased between 1995 and 2010. More highly educated groups generally showed stronger declines in death rates over time, leading to increases in summary measures of inequality. The increases in inequality were particularly evident when we used travel exposure-based denominators to calculate death rates and were driven largely by increases in mortality rates among persons with less than a high school education. The increase in exposure-based death rates we observed among those with less than a high school diploma is especially striking given that overall MVA mortality rates are generally declining, though this finding must be viewed in the light of several study limitations described below.

Consistent with prior evidence on recessions and traffic accident deaths (42, 43), we found that death rates decreased in 2008 after the Great Recession began (Figures 1 and 2), with some indication that the absolute decrease was larger among the less educated. This may have kept educational inequalities from increasing more than they would have in the absence of the recession. Cotti and Tefft (44) provided evidence that most of the mortality decrease came from reductions in alcohol-related fatal crashes and fewer crashes per mile traveled, which also suggests that less educated groups may have derived some relative benefits from the recession in terms of fatal crashes avoided.

In comparing population-based denominators with exposure-based denominators, we found that relative educational inequalities in death rates were approximately twice as large after taking travel exposure into account. Since the late 1990s, deaths per miles traveled have increased among persons with the least education, widening inequalities to a larger extent than was observed on a per-population basis. This suggests that characteristics of low-SEP travelers and their vehicles and the accidents they are involved in are important components of rising inequality. We additionally found that measured inequalities were larger when measured using PMT, probably by accounting for transport by bus, taxi, or walking—forms of transport that are more common among lower-SEP individuals (24) but are generally associated with lower exposure-based risk.

The excess risk among persons with a low level of education is probably due to several factors, including behavioral, contextual, and vehicle-related factors. Lower SEP has been associated with ownership of vehicles with lower crash-test ratings and absence of advanced vehicle safety features (45). Taking account of miles traveled may also relate to features such as rurality, which has been associated with greater overall risk of mortality (46) and mortality in the less educated (10). Changing area characteristics may also have relevance, as rural and higher-poverty areas have seen declines in the presence of hospital trauma centers over time (47), which may have increased MVA mortality in low-SEP groups given limited access to trauma specialists (48).

Despite the success of drunk-driving laws (4), lower educational level has also been associated with higher blood alcohol concentration among crash victims in the United States (10), although studies relying on self-reports of drunk driving do not show socioeconomic gradients (49, 50). Less ambiguous is seat-belt use (5), for which several studies show lower adherence in less educated individuals (10, 49, 51–54). However, because seat-belt use has increased faster among the less educated (53), educational inequalities in seat-belt use have been declining, most likely due to greater responsiveness to mandatory seat-belt laws (55). Trends in seat-belt use are thus somewhat inconsistent with our evidence that educational inequalities in death rates have increased, which suggests that mechanisms other than seat-belt use may play an important role in explaining differences in MVA risk. Farmer and Lund (56) found that improvements in vehicle safety have played an important role in reducing MVA death rates, particularly since the mid-1990s. To the extent that the rate of diffusion of safer vehicles lags among lower-SEP groups because of higher costs or other mechanisms (57), this may also serve as a contributing cause of increasing inequalities in MVAs.

There are some limitations to our analyses. First, we interpolated miles traveled between 2001 and 2009 based on surveys that allowed estimation by socioeconomic group. There is evidence that the Great Recession reduced the number of vehicle miles traveled (44), so we may have underestimated miles traveled in the years prior to the recession. To the extent that less educated groups reduced their miles traveled more than more educated groups, this could have led to some overestimation of the education-related gradient in death rates between 2001 and 2009. Second, we used education as a measure of SEP, but alternative indicators (such as income) could show different trends were such data available on death certificates. One recent linkage study using data from the National Health Interview Survey (58) showed that both higher income and higher education demonstrated inverse associations with MVA death, but data on MVA trends by income are scarce. More importantly, educational attainment on death certificates was based not on years of education completed from 1989 to 2002 but on type of degree conferred from 2003 onward, which was gradually adopted by 31 states and the District of Columbia in 2010. The 2003 revision identifies 2% more persons with less than a high school education, 13% fewer persons with a high school or General Educational Development diploma, and 8% more persons with some college education (1, 59). Our sensitivity analysis carried out in a subset of states that predominately used the original education coding (Web Table 1) largely validated the robustness of our findings, although it showed weaker evidence of increases in mortality in the lowest educational group by PMT over time.

Third, creating subnational samples of the NHTS/NPTS or the Current Population Survey could have led to measurement error in exposure-based denominators, since these surveys are primarily designed to be nationally representative. The adjustments to travel survey weights we made to account for underrepresentation of less educated groups may have been conservative, as estimates without any adjustments showed larger increases in socioeconomic gradients. Fourth, the NHTS/NPTS is based on self-reporting, and this may lead to travel estimates measured with error, particularly for measures in which respondents are asked to recall miles of travel. In all survey cycles, respondents were sent a travel diary to aid recall (32–34); the diaries were used by 75%–80% of those reporting travel. Our sensitivity analyses adjusting for education-specific differences in the use of diaries were consistent with unadjusted results.

Our findings suggest that additional work should investigate underlying risk factors for MVA death at the individual or community level, with particular focus on how the distributions of these risk factors by education have changed over time. One potential strategy for evaluating risk factors by education would be linkage between the Fatal Accident Reporting System and death certificate data, an approach which has been previously explored cross-sectionally (10) but not longitudinally. Examining the sensitivity of different socioeconomic groups to road safety legislation or the relative benefit in different groups would also seem worthwhile. Although we found declines in overall MVA mortality, it is apparent that these declines have not affected all education groups equally, and MVAs continue to contribute to the excess mortality observed in socioeconomically disadvantaged populations.

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All of the publicly available data and statistical code for reproducing the results of this study are available with unrestricted open access from the corresponding author's Dataverse (https://dataverse.harvard.edu/dataverse/samharper).

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