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Suicide, overdose, and worker exit in a cohort of Michigan autoworkers

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Over the past 20 years, mortality rates for drug overdose and suicide have increased in the United States across all ages, but most dramatically for working aged adults.[1,2] Case and Deaton were the first to note rising midlife mortality rates among White, non-Hispanic Americans ages 35 to 54 with a high school education or less.[3] They identified drug overdose, suicide, and alcohol-related liver disease mortality as the causes of the increase and attributed these "deaths of despair" to reduced economic opportunity among less educated adults.[4]

Increases in these "deaths of despair" have now been identified across multiple race and ethnic groups and geographic contexts.[5,6] Rising mortality rates have been reported for U.S. Blacks, Hispanics, Asians and Pacific Islanders, 25-64 years of age, with as drug overdoses the leading cause of the recent increases in all these sub-populations.[5,6] Reversing decades of steady decline, these disturbing shifts are particularly pronounced for midlife individuals with a high school education or less.[6] Suicide rates have also increased by 33% since 2000, with the steepest increase for White males.[7] Though the rise has been less dramatic for suicide than for overdose, it emerged in 2016 as the fourth leading cause of death among adults, aged 35-54.[8] Rural counties had consistently higher suicide rates than metropolitan counties.[9]

Coincident with the increases in midlife mortality rates, the long-term decline in US manufacturing has limited good employment options for many less educated adults. In the 1970s, 36% of all employed U.S. males worked in manufacturing--in 2018, only 15% did.[10] The most dramatic decreases have occurred since 2000, with a loss of over 5 million jobs.[11] As these well-paying jobs with standard employer-employee relationships and job security have declined, precarious work has been on the rise.[12]

Prior to the Great Recession, China's entry into the World Trade Organization in 2001 accelerated its export surge in manufacturing, and contributed to U.S. contraction.[13] Impacts of the China Shock are most visible in the local labor markets with a concentration of industries exposed to foreign competition where workers who lose jobs may end up out of the job market entirely.[14]

The US automobile industry offers a striking case study of an impacted industry in decline. From the 1950s until the China Shock of the early 2000s, the "Big Three" Detroit companies Ford, Chrysler and General Motors dominated the automobile market. By the late 1960s, foreign automakers began to capture a share of the domestic market. The oil embargo in 1979 further fueled the rise of imported smaller cars. Detroit automakers responded by shifting to light trucks, minivans, sports utility vehicles and pick-up trucks. Between 1980 and 1996, stronger vehicle safety regulations, increasing oil prices and the emergence of hybridized vehicles further challenged the domestic industry. By 2008, Toyota had become the largest producer worldwide--a title General Motors had held for 77 years.[15] After the US financial crisis in 2008, the US government bailed out the automobile industry at a cost of $80 billion, and restructured GM and Chrysler after they entered bankruptcy in 2009.

This study focuses on the implications of the erosion of the US automobile industry for the mental health and safety of Michigan autoworkers who faced potential job loss. Involuntary worker exit has been found to have substantial effects on depressive symptoms, even after adjusting for baseline health.[16] Taking advantage of individual-level data from an existing study of a United Autoworkers-General Motors (UAW-GM) cohort, we examine associations between worker exit and risk of suicide

and fatal overdose. The cohort includes workers at three GM manufacturing facilities in Michigan--one located in an urban center, one in a more rural area, and one in a small city. We focus on the period since the late 1970s that captures acceleration in the decline of the industry. By the end of follow-up all three study plants had closed.

METHODS

The UAW-GM cohort mortality study was originally designed to assess the health effects of occupational exposures. Details regarding the study have been described in previous publications.[17,18] Here, we describe the more recently employed subset of the cohort included in this analysis.

Study population: The UAW-GM cohort includes all hourly workers identified through company records at three automobile manufacturing plants in Michigan who were hired between January 1, 1938 and December 31, 1982 and worked for at least three years. The study population for this analysis includes the more recent subgroup employed in 1970 or later. Plant 1, located in the urban center of Detroit, employed almost all the Black subjects in the cohort. Plant 2 was located 50 miles west in a small town best known as the site of the Willow Run manufacturing complex during World War II.[19] Plant 3 was further upstate in a once thriving lumber and manufacturing center that suffered high unemployment and population loss in the late 1900s. Mortality follow-up starts in 1970 or three years after date of hire, whichever comes later, and ends in 2015. Less than 0.6% of the subjects were lost to follow-up.

Exposure: The primary exposure is worker exit, defined as employment termination at the three plants, and measured in two ways. First, we used time-varying

employment status (active or inactive) as an indicator of leaving work. The binary variable equals 0 until the year of termination and 1 thereafter.

In the second analysis, we defined exposure as the age at worker exit in order to distinguish retirement from early worker exit. During the follow-up period, unionized jobs at GM offered generous benefits and wages. Retirement benefits depended on a combination of age and tenure and were specified in contract negotiations between GM and the UAW. In 1950, a worker could retire with full benefits after 10 years of employment at age 65. In 1964, the age of eligibility for early retirement with partial benefits decreased from 62 to 55.[20]

All of this informed our decision to categorize age at worker exit, with the reference group defined as leaving work at age 55 or older, when the decision to retire was likely to be voluntary. We assume that workers who left GM earlier, when they were younger than 55 and ineligible for benefits, were less likely to have left voluntarily.[21]

Outcome: Data on vital status and cause of death were obtained through the Social Security Administration, the National Death Index, company records, death certificates, and state mortality files.[22] We used diagnostic codes for suicide from the International Classification of Diseases (ICD) 9th and 10th revisions. In the present study, the ICD codes for suicide are: E950-E959 (ICD-9) and U03, X60-X84, and Y87 (ICD-10). Those for unintentional overdose are: E850-E858 and E980 (ICD-9) and X40-X44 and Y10-Y14 (ICD-10).

Covariates: Individual characteristics, including year of birth, sex (male or female), race (White, Black, or unknown), and work-site (Plant 1, 2, or 3) were obtained from company records. Prior to 1970, race was not systematically recorded on GM

employment records at hire. Subjects with unknown race (7.7%) were assumed to be White in this analysis based on the observed racial composition by plant over calendar time.[23] The analyses were restricted to men because the outcome was too infrequent among women workers (10 suicides and 3 fatal overdoses).

Analytic method: A directed acyclic graph illustrates the anticipated relationships between the exposure, outcome, and hypothesized confounding variables (eFigure 1 in the online supplement). We used Cox proportional hazards regression to estimate the associations linking job loss with suicide alone and with suicide combined with overdose. We controlled for *a priori* specified confounders including age, race, plant, year of hire, and calendar year of follow-up. Depression, depicted as a time-varying confounder affected by prior exposure, was not measured, limiting interpretation of our results.

The primary model estimates adjusted hazard ratios for suicide and overdose in relation to worker exit in a Cox proportional hazards model. Although mortality follow up extends to 2015, employment records end on December 31, 1994, and we censor subjects still employed at that time. The time metric for these Cox models was age, and the model includes race, plant, and year of hire, as well as a time-dependent penalized spline function of calendar year of follow-up.

The secondary model uses decade of age at worker exit as the exposure of interest, to contrast workers retiring at retirement age (≥ 55) versus workers exiting before retirement age. The time metric in these models was years since worker exit; mortality follow-up starts at the date of exit. Individuals still employed when work

records end on December 31, 1994 were necessarily excluded from these models because date of exit (and thus start of follow-up) was unknown.

We also analyzed the combined outcome, including both fatal overdose and suicide, to account for outcome misclassification. Suicides using opioids and other drugs are substantially under-reported by medical examiners and coroners.[24]

Sensitivity analyses: The sensitivity analyses we conducted are described in the online supplement. To account for the possibility that the recorded work termination dates might be artificially back-dated when an employee dies suddenly, we reclassified cases that occurred within a week of leaving work as having occurred while still employed. To limit the analysis to the most proximal outcomes (those hypothesized to be most likely related to job exit), we restricted follow-up to five years after leaving work.

The study was approved by the Office for the Protection of Human Subjects at University of California, Berkeley. Analyses were performed in R version 3.6.1. Cox proportional hazards models were estimated using the "survival" package.[25,26]

RESULTS

Table 1 presents summary statistics for the study population of all male workers employed in or after 1970 and for the subset with complete work records who had left work by December 31, 1994 when employment records were truncated. In the entire cohort of 26,890 men, there were 258 deaths due to suicide (n = 203) or overdose (n = 55). Plant 2 accounted for 38% of the workers, 46% of the suicides, and 62% of the overdose fatalities. Histograms for the age at death by suicide or overdose (eFigure 2) are presented in the on-line Supplement.

Figure 1 presents time trends for suicide rates from 1970 to 2015 for the subset of 19,663 with complete work records (Figure 1a) and for the entire cohort (Figure 1b). For those who had left work by 1995 (complete work records), the suicide rate declined after 1995. When workers still active in 1994 were included in outcome follow-up, the rate of suicide did not decline. Some of these workers may have still been employed in the early 2000s when the plants were downsizing prior to closing down; Plant 1 closed in 2012, Plant 2 in 2010 and Plant 3 in 2014.

Among the 179 suicides with complete work records, all but 21 occurred after worker exit. The adjusted HR was dramatically elevated for those who had left work (Table 2). There was a spike in suicides in the year just after exit, and most of the remaining cases occurred within five years of leaving work (eFigure 3). When cases that occurred within a week of leaving work were reclassified as having occurred while still employed, the HR decreased from 17.7 to 12.5 (Table 2).

Table 3 presents results from the secondary model that contrasted individuals who left work at retirement versus earlier ages. Hazard ratios were elevated by 40-70% for groups who exited before age 40. Those who were 30-39 at worker exit had the highest risk of suicide (HR = 1.7, 95% CI: 1.1-2.6). When overdose was included in the outcome, the HR for that group increased to 2.1, and the HR for the youngest group increased from 1.4 (0.8-2.3) to 2.0 (1.2-3.1). Restricting follow-up to the five years after worker exit, HRs for the combined outcome remained elevated: 2.0 (95% CI: 1.2-3.4) and 1.7 (95% CI: 0.80-3.4) for those who left work in their 30s and 20s, respectively (eTable1).

When a penalized spline function of age at worker exit was substituted for the categorical variable in the Cox models, the HRs for both suicide and the combined outcome were highest for those who left work in their mid-30s (eFigure 4). The maximum HR was almost 2-fold for suicide and 2.5-fold for overdose combined with suicide, relative to those who left work after age 55. The HRs decline as age at worker exit increases from mid-30s to 55 but remain slightly elevated relative to the risk at retirement age.

Figure 2 presents cause-specific mortality rates for suicide and overdose combined, for the subset with complete work records and for the entire cohort. For those who had left work by 1995 (complete work records), the rate declined after 2000. When workers still active in 1994 were included, the rate of the combined outcome increased to a maximum of more than 3 per 10,000 (Figure 2b). Among the 7,227 men still at work on December 31 1994, there were 45 additional cases, 24 suicides and 21 fatal overdoses. The distribution of the date of death relative to date of worker exit (eFigure 3) indicates that most cases occurred within a few years after worker exit. Although we do not know when the additional cases left work after 1995, almost all the overdoses occurred in Plant 2 during the years leading up to the closing of that plant in 2010.

DISCUSSION

This study used data from an existing cohort study initially designed to assess the health effects of occupational exposures to examine the implications of leaving work for risk of death by suicide and overdose. Our results suggest that leaving work prior to retirement age was associated with increased risk even when follow-up was restricted

to five years after worker exit. Few deaths by suicide or overdose occurred while workers were still employed, and most occurred among those who left work before age 55. These results are consistent with sociological studies of the health consequences of worker exit.[27–29] Although we have no data on subsequent employment, the literature suggests that rehire may mitigate the adverse impacts, but does not eliminate the distress.[28]

These findings are also consistent with findings from recent studies linking conditions of employment with mental health, suicide, and overdose mortality. We reported effects of layoffs on mental healthcare utilization and injury risk among workers at 30 US plants using a difference-in-differences approach.[30] In that study, the increase in the probability of mental health-related prescriptions appeared attributable primarily to opioid use. In an ecologic study leveraging variation in state economic policies over time, a quasi-experimental design was used to examine the impact of minimum wage and earned income tax credit policies on deaths of despair. Causal models suggest that increasing both by 10% would have prevented 1230 suicides annually, but had no impact on drug overdoses.[31] Another study found that higher state-wide union density was associated with lower mortality rates for suicide and overdose.[32] In a study directly relevant to this one, a difference-in-differences approach resulted in an association between county-level automobile assembly closures, 1999 to 2016, and opioid mortality.[33]

Of the three study plants, Plant 2 had the highest incidence rate of suicide in this study. This plant was located at the site of Willow Run, a factory in southeastern Michigan renowned for the mass production of fighter planes during WWII.[19]

Constructed by Ford Motor Company in 1941 to produce the B-24 Liberator heavy bomber, the plant was the largest in the world at the time, employing more than 100,000 workers. Willow Run was sold to GM after a fire in 1953. By 1970, it employed 10,000 workers making automatic transmissions. Plant 2 closed in 2010 as part of GM's bankruptcy proceedings. In 1970, the population of the surrounding township was 30,000; today it is 20,000. This scenario dramatizes the challenges smaller towns face in coping with the decline in manufacturing.

Limitations

Interpretation of our results is constrained by lack of information on diagnosis or treatment for depression. As illustrated in the causal diagram (e Figure 1), it is plausible that depression contributes to the risk of both worker exit and suicide, and is therefore a time-varying confounder. Without information on mental health status over time, we cannot adjust for confounding or parse out the direct effect of worker exit from a pathway through ongoing depression.

Suicide rates in the U.S. are higher for men than for women and have increased substantially in middle age for both sexes since 1999. Suicide risk among 45 to 64 year old men was higher than for those aged 25 to 44, with rates of 29.7 and 24.3 per 100,000, respectively, in 2014.[7] To the extent that suicide risk increases for older age groups, there will be less potential for confounding by age when follow-up is restricted to five years after exit. The bias, however, would be toward the null, since retirees are the reference in this study.

Although suicide rates are slightly higher for older ages, competing risks from other causes of death, e.g., cardiovascular disease and cancer, are far more likely for

workers who are oldest at the time of leaving work. The direction of this bias depends on the relative risk of suicide among the observed and unobserved older workers; arguments could be made to support either direction.

Our findings are most precise for suicide. Mortality follow-up ends in 2015, and we observed a rise in the number of overdose fatalities in the last 5-10 years of follow-up. Together the trends suggest that since the 1990s, suicide rates have fallen as the rate of drug overdose has increased, consistent with the steeply rising rate of opioid mortality in the U.S. since 1999. In total, however, there were too few overdose cases to examine separately.

Conclusions

Michigan autoworkers who left work after 1970 had a higher risk of death from suicide or overdose than those who remained actively employed. Most events occurred within five years of leaving work among those who left before retirement age, suggesting that leaving work early may increase the risk.

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TABLES

Table 1. Summary of the UAW-GM Cohort restricted to men employed in or after 1970.

	Full cohort		Subset with complete records [b]	
N (person-years)	26 890	(933 187)	19 663	(650 685)
Race, n (%)				
White	19 388	(72%)	13 293	(68%)
Black	5 262	(20%)	4 142	(21%)
Unknown	2 240	(8%)	2 228	(11%)
Plant [a], n (%)				
Plant 1	6 935	(26%)	6 627	(34%)
Plant 2	10 351	(38%)	6 412	(33%)
Plant 3	9 604	(36%)	6 624	(34%)
Complete work records	19 663	(73%)	19 663	(100%)
Year of hire	1967	(1956, 1975)	1965	(1953, 1971)
Age at hire	24	(20, 31)	25	(20, 33)
Year of birth	1942	(1927, 1950)	1936	(1923, 1947)
Year of worker exit	1991	(1982, 1995)	1987	(1979, 1993)
Age at worker exit	49	(40, 58)	52	(39, 61)
Age at death among deceased	70	(60, 79)	71	(61, 80)
Year of death among deceased	1999	(1989, 2008)	1997	(1988, 2007)
Suicide cases	203		179	
Fatal overdose cases	55		34	

Notes: Statistics shown are median (first quartile, third quartile), unless otherwise indicated.

[a] Some subjects worked at several sites; plant indicates the site of longest work record time.

[b] Left work by December31, 1994 when employment records were truncated.

Table 2. Adjusted hazard ratio estimates for suicide by employment status in the UAW-GM Cohort restricted to men employed in or after 1970.

	Recorded worker exit date			Fuzzy worker exit date [a]		
Job exit status	n	HR	95% CI	n	HR	95% CI
At work	21	1.0	–	27	1.0	–
Not at work	158	17.7	10.8, 29.1	152	12.5	7.9, 19.7

Abbreviations: CI, confidence interval; HR, hazard ratio

Notes: Estimates were adjusted for plant, race, year of hire, and calendar year. Risk sets were indexed by age. Women were excluded from this analysis.

[a] Cases that occurred within a week after the recorded worker exit date were assumed to have occurred while still employed.

Table 3. Adjusted hazard ratio estimates for suicide and the combined outcome of suicide and fatal overdose in the UAW-GM Cohort restricted to men employed in or after 1970.

	Suicide			Suicide and fatal overdose		
Age at worker exit	n	HR	95% CI	n	HR	95% CI
55 or older	42	1.0	–	45	1.0	–
40 to 54	48	1.2	0.8, 1.8	51	1.2	0.8, 1.8
30 to 39	41	1.7	1.1, 2.6	56	2.1	1.4, 3.1
19 to 29	27	1.4	0.8, 2.3	38	2.0	1.2, 3.1

Abbreviations: CI, confidence interval; HR, hazard ratio

Notes: Estimates were adjusted for race, plant, and calendar year of worker exit. Risk sets were indexed by time since worker exit. Women and those with unknown date of worker exit were excluded from this analysis.

FIGURES

Figure 1. Crude rate (per 10,000 person-years) of suicide by calendar year in the UAW-GM Cohort restricted to men employed in or after 1970.

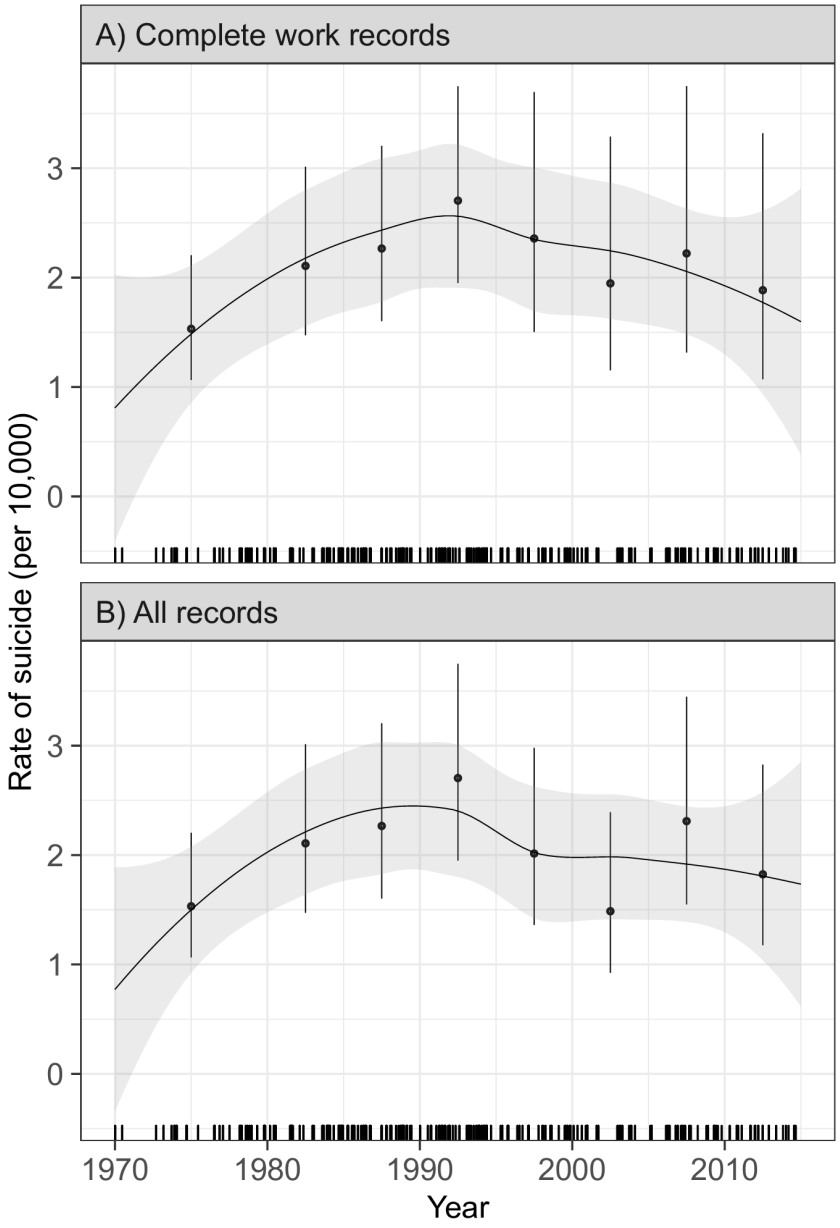
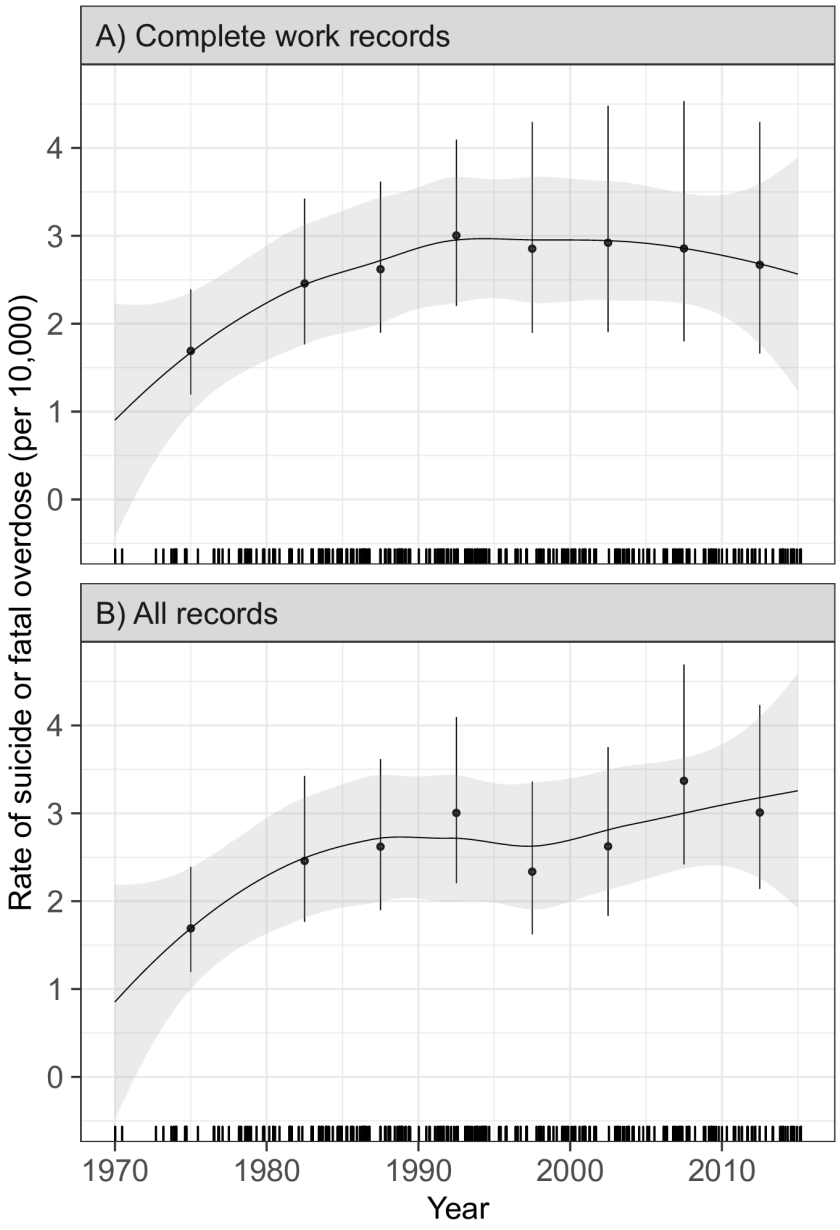


Figure 2. Crude rate (per 10,000 person-years) of the combined outcome of suicide and fatal overdose by calendar year in the UAW-GM Cohort restricted to men employed in or after 1970.



Online-only Content

EAPPENDIX

A directed acyclic graph (DAG) showing our working hypothetical causal structure is presented in eFigure 1. Under our working assumptions, reducing the risk of worker exit prior to retirement would reduce the risk of suicide and fatal overdose. Note that underlying depression was unmeasured. By conditioning on calendar time and plant, the causal parents of plant closure, we partially reduced the magnitude of confounding bias through that path.

Histograms of age at death among those who died of suicide and fatal overdose are presented in eFigure 2.

Employment status was determined using worker exit dates from company job records. If a death occurred after worker exit, their exit date should precede their date of death. If a death occurred while employed, their exit date should equal their death date. However, we expected the exit dates to be imperfectly recorded, given the administrative nature of the data. We attempted to characterize the extent of possible misclassification by examining the distribution of the difference between the dates of death and exit.

The left-side panel of eFigure 3 presents a histogram of the difference between death and exit dates for suicide deaths. The distribution had a strong right-skew and a striking mode in the third bin, representing deaths whose death date was later than their exit date and less than or equal to one year after exit. Among deaths that occurred within a year of job exit, the distribution still showed a strong right skew, but with two

local modes centered approximately around 0 and 33 days. The observed times centered around 0 were roughly bounded by a radius of 14 days (see eFigure 3b).

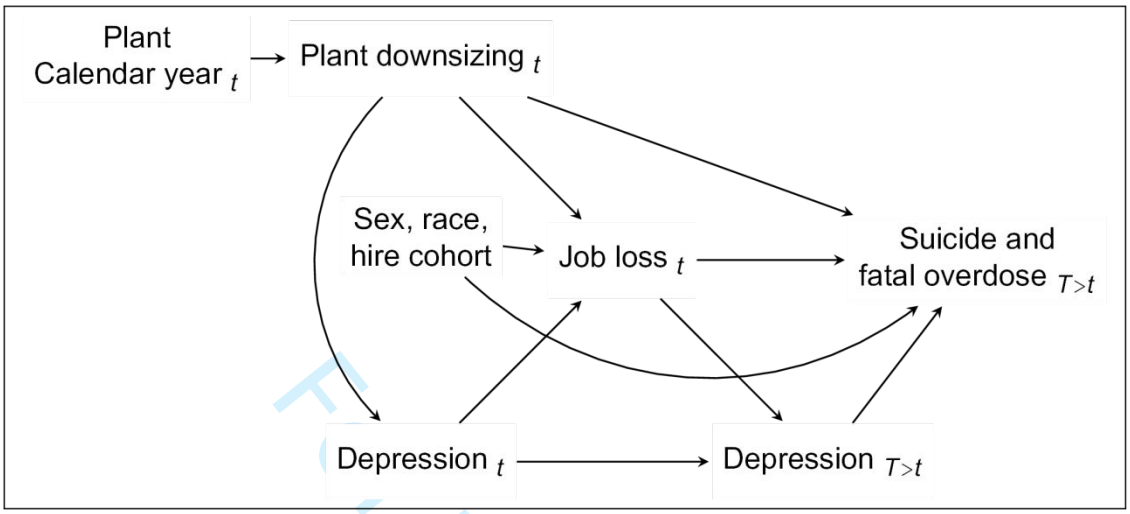
In the main analysis, we assumed that deaths occurred while employed if the death date preceded or equaled the recorded exit date. In the sensitivity analysis we assumed that a death occurred while employed if the death date was within a week of the exit date. That is, we assumed that all the deaths whose exit dates preceded their death dates by no more than one week were misclassified as not employed at death when they were in fact employed (see right-side of Table 2).

To estimate the hazard ratio for a more temporally-proximate outcome, we restricted follow-up to more than five years after worker exit. eTable 1 presents hazard ratio estimates for suicide and the combined outcome within 5 years after worker exit.

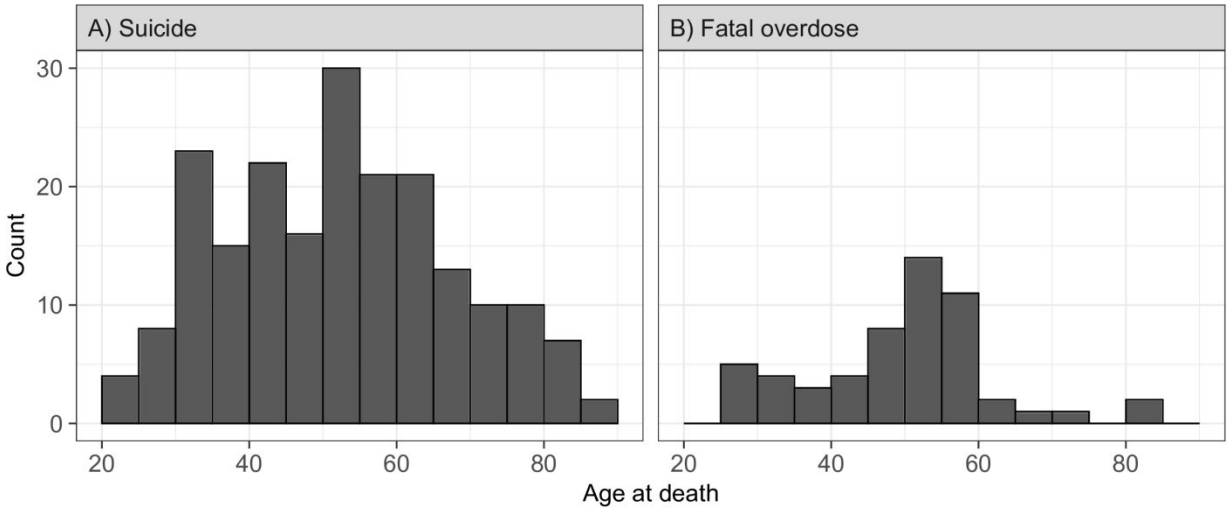
To better understand the shape of the exposure-outcome relationship, we fitted models which included a restricted penalized spline function (df = 4) of continuous age at exit. To fit these splines and compute hazard ratio estimates, we assumed that the hazard associated with age at exit was constant for those who left work at 55 or older, conditioning on all other covariates. To complement the analyses for categorical age at exit presented in the main body, we fitted these models for suicide and for the combined outcome (eFigure 5).

ONLINE-ONLY TABLES AND FIGURES

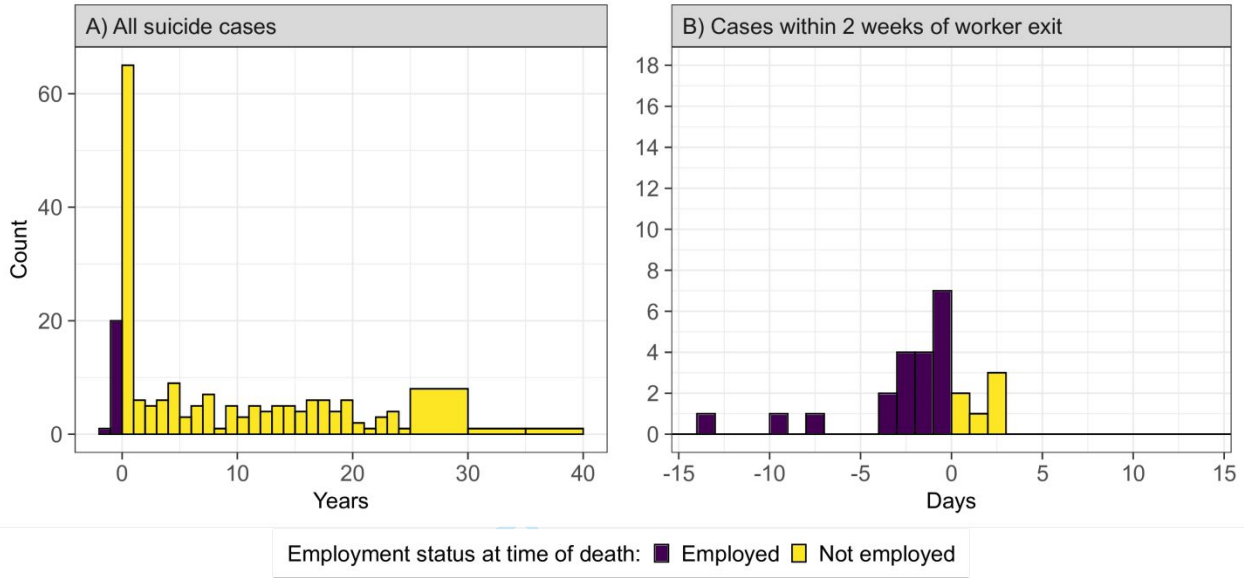
eFigure 1. Directed acyclic graph representing our working causal assumptions.



eFigure 2. Histograms of age at death due to suicide and fatal overdose in the UAW-GM Cohort restricted to men employed in or after 1970.



eFigure 3. Histograms of time between worker exit date and date of suicide in the UAW-GM Cohort restricted to men employed in or after 1970. Bins corresponding to deaths that occurred while employed are indicated in purple.



eTable 1. Adjusted hazard ratio estimates for suicide and the combined outcome of suicide and fatal overdose in the UAW-GM Cohort, within five years of worker exit, restricted to men employed in or after 1970 who left work by December 31, 1994.

	Suicide			Suicide and fatal overdose		
Age at worker exit	n	HR	(95% CI)	n	HR	(95% CI)
55 or older	28	1.0	–	30	1.0	–
40 to 54	28	1.3	(0.8, 2.3)	29	1.3	(0.8, 2.3)
30 to 39	21	1.7	(1.0, 3.0)	26	2.0	(1.2, 3.4)
19 to 29	9	1.2	(0.5, 2.6)	13	1.7	(0.8, 3.4)

Abbreviations: CI, confidence interval; HR, hazard ratio

Notes: Estimates were adjusted for race, plant, and worker exit date. Risk sets were indexed by time since worker exit. Women and those with unknown date of worker exit were excluded from this analysis.

eFigure 4. Continuous adjusted hazard ratio estimates for suicide and the combined outcome of suicide and fatal overdose in the UAW-GM Cohort restricted to men employed in or after 1970.