356 (350) words

**Importance**: Implications of the decline in the US automobile industry for the mental health and safety of Michigan autoworkers.

**Objective**: We examined associations between worker exit and risk of suicide and fatal overdose among male Michigan autoworkers.

**Design**: We exploited individual-level data from the United Autoworkers-General Motors (UAW-GM) cohort study. Mortality follow-up extended from 1970 to 2015, covering the period of industry decline from 1970 to the present.

**Setting**: Three General Motors manufacturing facilities in Michigan – Plant 1 in an urban center, Plant 2 in a small town, and Plant 3 in a small city. By the end of follow-up all three study plants had closed.

**Participants**: The study cohort included autoworkers hired before 1983 who worked at least one day after 1970 at one of the three plants and worked for at least three years.

**Exposure**: We first examined time-varying employment status (active or inactive) as the exposure. We then examined age at leaving work and compared those who left at retirement age (55 or older) with those who left work younger.

**Main outcome**: The primary outcomes suicide and overdose mortality.

**Results**: Among the 26,890 male autoworkers there were 258 deaths due to suicide (n=203) or overdose (n = 55). All but 15 cases had left work prior to death. The hazard of suicide was 17.7 times higher among those who had left their job than among active employees (95% CI:10.8, 29.1). Hazard ratios were elevated for all ages at exit relative to retirees; those who exited at 30-39 had the highest risk of suicide. The HR increased for the two youngest groups after including fatal overdose; those who left work between 19 and 39 had a significantly elevated 2-fold risk. Restricting follow-up to five years after exit, HRs were 2.3 (95% CI: 1.6, 3.4) and 2.1 (95% CI: 1.3, 3.3) for those who left work in their 30s and 20s, respectively.

**Conclusions and Relevance**: Michigan autoworkers who left work had higher risk of suicide or fatal overdose than active employees. 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.

**Suicide and worker exit in a cohort of Michigan autoworkers**

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 collectively considered drug overdose, suicide, and alcohol-related liver disease and initially noted rising midlife (age 35-54) mortality rates among white, non-Hispanic Americans with a high school education or less.3 They coined the term “deaths of despair” and attributed the rise to reduced economic opportunity among less educated adults.4

Over the last few years, these alarming increases in so-called “deaths of despair” have been identified across multiple race and ethnic groups and geographic contexts.5 Following the initial observation, rising rates have been reported for U.S. Blacks, Hispanics, Asians and Pacific Islanders, of age 25-64 years, with drug overdoses as the leading cause of the recent increases in all these sub-populations.5 Reversing decades of steady decline, these disturbing shifts are particularly pronounced for midlife individuals with a high school education or less.5 Suicide rates have also increased by 33% since 2000, with the steepest increase for White males.6 Though the rise in suicide rates has been less dramatic than for overdose, in 2016, suicide emerged as the fourth leading cause of death among adults, aged 35-54.7 Rural counties had consistently higher suicide rates than metropolitan counties.8

Coincident with the increases in midlife mortality rates, the long term decline in US manufacturing has limited good employment options for many noncollege adults. Although manufacturing has been in decline for more than 50 years, the most dramatic decreases occurred since 2000, resulting in a loss of over 5 million jobs.9 In the 1970s, 36% of all employed U.S. males worked in manufacturing – in 2018, only 15% did.10 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.11 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.12

The US automobile industry offers a striking case study of an 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 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 hybrids further challenged the domestic industry. By 2008 Toyota had become the largest producer worldwide - a title General Motors held for 77 years.13 The situation was so dire after the US financial crisis in 2007-2008 that the US government bailed out the industry at a cost of $80 billion, and restructured GM and Chrysler after they declared bankruptcy in 2009.

This study focuses on 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 substantial effects on depressive symptoms, even after adjusting for baseline health.14 Exploiting individual-level data from an existing study of the United Autoworkers-General Motors (UAW-GM) cohort, we examine associations between worker exit from active employment and risk of suicide and fatal overdose. The cohort included 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 focused on the period since the late1970s that captured a period of acceleration in industry decline. By the end of follow-up all three study plants had been closed.

**Methods**:

The UAW-GM cohort mortality study was designed to assess the health effects of occupational exposures. Details regarding the study have been described extensively in previous publications.15,16 Here, we describe the cohort in brief.

**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 1981, and worked for at least three years. 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.17 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 began in 1941 and ended in 2015. Less than 0.6% of the subjects were lost to follow-up. This analysis included the recent subset employed in or after 1970.

**Exposure**: The primary exposure was worker exit, defined as employment termination at the three plants, and measured in two ways. In the first analysis, time-varying employment status (active or inactive) was used as an indicator of leaving work.

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. Though benefits and wages eroded over the past 50 years, these jobs remained attractive relative to other employment options available for noncollege workers. Particularly in the smaller industrial towns where Plants 2 and 3 were located, there were few attractive employment options during this period. 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 to 55.18

All of this informed our decision to categorize age at worker exit, with the reference group defined as leaving work after age 55, 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.

**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.19 The ICD codes for suicide are E950 - E959 (ICD-9) and U03, X60 - X84, and Y87 (ICD-10). The ICD codes for 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. 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.20 The analyses were restricted to men because there were too few cases among women (10 suicides and 3 fatal overdoses).

**Analytic Method**: A directed acyclic graph illustrates the hypothesized relationships between the exposure, outcome, and Confounding variables (eFigure 1 in the online supplement). We fitted Cox Proportional Hazard models to model the relationship between suicide and overdose and job exit, and to control for hypothesized 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 estimated adjusted hazard ratios for suicide and overdose in relation to worker exit in a Cox proportional hazards model. Mortality follow-up started in 1970 or three years after date of hire, whichever came later. Worker exit was coded as a binary variable that equals 0 until the day of termination and 1 thereafter. Although mortality follow up extended through 2015, employment records ended on December 31,1994; we censored subjects still employed at that time. The time metric for these Cox models was age, and the model included race, plant, and year of hire, as well as a time-dependent penalized spline function of calendar year of follow-up.

The secondary model used age at worker exit as the exposure of interest, to contrast risk among workers retiring at retirement age (>=55) versus workers exiting before retirement age (<55). The time metric in these models was years since worker exit; mortality follow-up started at the date of exit. Individuals still employed when work records end on December 31, 1994 were not eligible for follow-up.

We also conducted an analysis of 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.21

**Sensitivity Analyses**: The sensitivity analyses we conducted are described in detail in the eAppendix. To account for the possibility that the recorded work termination dates might have been 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 worker exit. The presence of competing risks from other causes of death (e.g., cardiovascular disease and cancer) was most likely to have affected estimates among the workers who were oldest at time of leaving work. To address the possibility that lower suicide risk among retirees might be due to competing risk rather than the benefits of attaining retirement, we compared standard estimates to estimates accounting for competing risks using multiple methods (described in the eAppendix).22

The study was approved by the Office for the Protection of Human Subjects at University of California, Berkeley.

**Results**:

The study population of male employees who worked at least 1 day in or after 1970 are presented in Table 1. Among the 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% 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 for outcome follow-up, the risk of suicide did not decline. These workers may have potentially been still 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, all but 21 occurred after worker exit. 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). The adjusted HR was dramatically elevated for those who had left work (Table 2). 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 (eTable 1). When follow-up was restricted to five years after exit, the HR increased to 25.4.

Table 3 presents adjusted HRs for suicide and for the combined outcome by age at worker exit. Hazard ratios were elevated for all groups who exited younger than retirement age. Those who were 30-39 at worker exit had the highest risk of suicide. When overdose was added to the outcome, the HR for that group increased to 2.3 and the HR for the youngest group increased to 2.1; both elevated HRs were statistically significant. Restricting follow-up to the five years after worker exit, HRs for the combined outcome remained elevated: 2.3 (95%CI: 1.4, 3.9) and 1.8 (95%CI: 1.0, 3.5) for those who left work in their 30s and 20s, respectively (eTable2).

Age at worker exit by calendar year of job loss and by employment status are presented separately for suicide and overdose cases in the subset with complete employment records (eFigures 4a and 4b).

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 (eFig 5). 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 at older ages of worker exit but remained slightly elevated relative to the risk at retirement age.

Figure 2 presents mortality rates for suicide and fatal 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 1995. When workers still active in 1994 were included, the risk of the combined outcome increases to a maximum of more than 3 per 10,000 (Figure 2b). Among the 7227 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 (eFigure2) indicates that most cases occurred within a few years after worker exit. Although we do not know when after 1995, these additional cases had left work, almost all the overdoses occurred in Plant 2 during the years leading up to the closing of that plant in 2010.

Results of the sensitivity analysis suggest that competing risks made less of a difference to the outcomes in the years shortly after worker exit (See eAppendix). Thus, limiting follow-up to five years reduces bias due to competing risks.

**Discussion**:

Using data from an existing cohort study initially designed to assess the health effects of occupational exposures, we examined a broader question about suicide and overdose in relation to leaving work. Our results suggest that leaving prior to retirement was associated with increased risk – and that the risk remained significantly elevated even when follow-up was restricted to five years after worker exit. Few events occurred while employed and most occurred among those who left before age 55. These results are consistent with sociological studies of the health consequences of worker exit.23–25 Although we have no data on subsequent employment, the literature suggests that rehire may mitigate the adverse impacts, but does not eliminate the distress.24

These findings are in line with recent ecologic studies. 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 suggested that increasing both by 10% would have prevented 1230 suicides annually, but had no impact on drug overdoses.26 Another study found that higher state-wide union density was associated with lower mortality rates for suicide and overdose.27 A third study applied a difference-in-differences approach and reported an association between county-level automobile assembly closures, 1999 to 2016, and opioid mortality.28

Suicide rates in the U.S. are higher for men than women and have increased substantially for both middle-aged men and women since 1999. Suicide risk among 45 to 64 year old men was higher than for those aged 25 to 44: 29.7 and 24.3 per 100,000, respectively, in 2014.6 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 towards the null, since retirees are the reference in this study.

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.18 The largest plant in the world at the time, employing more than 100,000 workers, it was constructed by Ford Motor Company in 1941 to produce the B-24 Liberator heavy bomber. Willow Run was sold to GM after a fire in 1953 and by 1970, 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 DAG (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.

Our findings are most robust 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

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