350 words

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

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

**Design**: We exploit individual-level data from the United Autoworkers General Motors (UAW-GM) cohort study. Mortality follow-up extends from 1941 to 2015, covering the period of decline from 1970 to the present.

**Setting**: Three General Motors manufacturing facilities in Michigan – Plant 1 located 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 includes all autoworkers hired between 1938 and 1982 at one of the three General Motors plants who worked for at least three years. We focus on the subset employed since 1970.

**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 were mortality rates for suicide and overdose.

**Results**: Among the 26,890 male autoworkers employed since 1970, there were 213 deaths due to suicide (n=179) or overdose (n=34). All but 14 of the cases had left work prior to death. The risk of suicide was 26.56 times higher among those who had left their job than among active employees (95% CI:14.91, 47.31). In the second analysis, the hazard ratios were elevated for all age groups relative to retirees; those who were youngest (age 20 to 35) when they left work were at highest risk, HR = 2.16 (95% CI: 1.26, 3.72). When suicide and overdose were combined, the HR = 2.56 (95%CI: 1.54, 4.25) within five years of leaving work.

**Conclusions and Relevance**: Michigan autoworkers who left work between 1970 and 2015 had a dramatically higher risk of death from suicide or overdose than active employees. Most events occurred within five years of leaving work among those who left before retirement age.

**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. 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.1 They coined the term “deaths of despair” and attributed the rise to reduced economic opportunity among less educated adults.2

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. Following the initial observation, rising rates have been reported for U.S. Blacks, Hispanics, Asians and Pacific Islanders, 25-64 years of age, with drug overdoses the leading cause of the recent increases in all these sub-populations.3 Reversing decades of steady decline, these disturbing shifts are particularly pronounced for midlife individuals with a high school education or less. Suicide rates have also increased by 33% since 2000, with the steepest increase for white males.4 Though the rise has been less dramatic than that for overdose, suicide emerged in 2016 as the fourth leading cause of death among adults aged 35-54.5 Rural counties had consistently higher suicide rates than metropolitan counties.6

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 have occurred since 2000, with a loss of over 5 million jobs.7 In the 1970s, 36% of all employed U.S. males worked in manufacturing – in 2018, only 15% did.8 Prior to the Great Recession, China’s entry into the World Trade Organization in 2001 accelerated its export surge in manufacturing, contributing to U.S. contraction.9 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.10

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 had held for 77 years.11 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 entered 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 been found to have substantial effects on depressive symptoms, even after adjusting for baseline health.12 Exploiting individual-level data from an existing study of the 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 and the other two in more rural areas. 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 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.13,14 Here, we describe the methods in brief.

**Study Population**: The full 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. Mortality follow-up begins in 1941 and was most recently extended to 2015. Less than 0.6% of the subjects have been lost to follow-up.

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

For the second, we defined exposure as the age at exit in order to distinguish retirement from other reasons for leaving. During the follow-up period, positions at GM were union jobs with generous benefits and wages. Though benefits and wages eroded over time, 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 fewer and fewer good 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 from 62 to 55.15 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 when they were younger than 55 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.16 The ICD codes for suicide are ICD-9: E950 through E959 and ICD-10: U03, X60 through X84, and Y87: The ICD codes for overdose are: ICD-9: E850 through E858 (accidental) and E980 (intent unknown) and ICD-10: X40 through X44 (accidental) and Y10 through Y14 (intent unknown).

**Covariates**: Subject 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. Subjects with unknown race were assumed to be White in this analysis based on the observed racial composition by plant over calendar time.17 The analyses were restricted to males because there were too few cases among women (n=??).

**Analytic Method**: Our hypothesis, assumptions, confounders, and target parameter are illustrated in the directed acyclic graph (DAG) (eFigure 1 in the on-line supplement). Our primary exposure is worker exit, or age at worker exit, and our target parameter is the direct effect of worker exit on suicide and overdose. Baseline covariates, sex, race, plant and decade of hire, as well as calendar year, are potential confounders that need to be controlled. Depression, depicted as a time-varying confounder affected by prior exposure, was not measured, limiting interpretation of our results.

Initially we estimated adjusted hazard ratios for suicide and overdose in relation to employment status (active vs inactive) in a Cox proportional hazards model. Follow-up starts three years after date of hire. Employment status is binary, set equal to 0 until the year of termination and is equal to 1 thereafter. Although mortality follow up extends to 2015, employment records end on December 31, 1994, and subjects still employed at that time are censored. The time metric for these Cox models was age, and the model includes race, plant, and decade of hire, as well as a time-dependent penalized spline function of calendar year of follow-up.

We then focused on age at worker exit as the exposure of interest. We estimated associations between worker exit in decades prior to retirement age (55) and suicide, as adjusted hazard ratios in Cox proportional hazards models. The time metric in these models was years since worker exit; follow-up starts at the date of exit. Subjects still employed when work records end on December 31, 1994, were not eligible for follow-up. Once again, race, plant, decade of hire and calendar year all affect the probability of lay-off as well as the outcomes, and so were included in all models to adjust for confounding.

Sensitivity Analyses: The several sensitivity analyses we conducted are described in more detail in the eAppendix. To examine the associations between worker exit and suicide over a longer period of time, we repeated our main analyses for the full cohort, followed from 1941 to 2015. To increase proximity of the outcome to the date of worker exit, we restricted follow-up to five years after leaving work. Although there were too few overdose deaths to assess alone, we combined overdose with suicide as the outcome of interest. To account for the possibility that the recorded work termination dates might be artificially back-dated when an employee dies suddenly, we conducted a sensitivity analysis after reclassifying cases that occurred within a week of leaving work as having occurred while still employed.

Competing risks are more substantial among the group that was oldest at time of leaving work. In that group, higher mortality rates for cardiovascular disease and cancer, for example, reduce the opportunity for suicide. To address the possibility that lower suicide risk among retirees might be due to competing risk rather than the benefits of retirement, we compared standard estimates to estimates accounting for competing risks based on sub-distribution hazards18 and cause-specific hazards.19

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

**Results**:

The sub-cohort of male employees who worked at least one day during the period 1970-1994 is presented in Table 1. Summary statistics are also presented separately for the suicide and fatal overdose cases within this subcohort. Among the 26,890 male subjects, there were 213 deaths due to suicide (n=179) or overdose (n=34). Plant 2 accounted for 38% of the subjects but for more of the suicides and of the overdose fatalities. Demographics for the full cohort of 39,799 and are presented in eTable 1 in the Supplement.

Figures 1ab present crude risks by calendar year from 1970 to 2015, treated as a continuous variable and as a discrete variable with 5-yr bins, for suicide (Figure 1a) and for the two outcomes combined (Figure 1b). The risk of suicide by calendar year increased up to 1990 and fell off in the more recent decades. By contrast the risk for the combined outcomes continues to rise throughout the follow-up period. Crude incidence rates are presented for the full cohort from 1941 to 2015 (e Figures 2ab).

Of the 179 suicides, all but 15 cases occurred after leaving work. This disparity is reflected in the adjusted hazard ratio (HR) for suicide and inactive employment status of 4.47 (95% CI: 2.99, 6.68). Most suicides happened within months of leaving work (eFigure 7). When we reclassified cases that occurred within a week of leaving work as having occurred while still employed, the HR dropped to 3.52 (95% CI: 2.37, 5.25) (Table 2). The rural plants both had higher rates of suicide than the urban plant; the HR for Plant 2 compared to plant 1 was 1.75 (95%CI:1.13, 2.71).

Table 3 presents adjusted HRs for suicide and age at worker exit in the full cohort and more recent sub-cohort, with follow-up restricted to the 5 years after leaving work to capture the more proximate cases. Hazard ratios were elevated for all age groups in both the full and recent cohorts relative to those who left work after age 55, although the patterns was not monotonic. Those who were in the second to youngest age group (30 to 39) when they left work were at highest risk and at slightly higher risk in the more recent subset, HR = 1.95 (95% CI: 1.13, 3.38). Combining suicide and overdose (Table 4), the HR increased most for those who left between 19 and 29 years of age. When follow-up continued to 2015, the HR rose to 2.15 (95%CI: 1.36, 3.39) for that youngest age group. Restricting follow-up to the five years after worker exit, HRs were 2.30 (95%CI: 1.38, 3.84) and 1.98 (95%CI: 1.04,3.76) for those who left work in their 30s and 20s, respectively.

Results of our sensitivity analysis suggest that competing risks made less of a difference to the outcomes in the years shortly after worker exit (See eAppendix in the Supplement). Thus our 5-year truncation of follow-up also 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 was highest within five years of worker exit. Few events occurred while still employed and most occurred among those who left before age 55. These results are consistent with sociological studies of the mental health consequences of worker exit.[citations? At least Catalano maybe?] Although we have no data on subsequent employment, the literature suggests that although rehire may mitigate the adverse impacts, it does not eliminate the distress.21 Furthermore, few opportunities for comparable re-employment existed in this area during the period from 1970 to 2015.[citation?]

These findings are also 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 suggest that increasing both by 10% would have prevented 1230 suicides annually, but had no impact on drug overdoses.22 Another study found that higher state-wide union density was associated with lower mortality rates for suicide and overdose.23 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.24

Suicide rates are higher for men than women and have increased substantially for both middle-aged men and women since 1999. In the United States, suicide risk among 45 to 64-year-old men was higher than for those age 25 to 44: 29.7 and 24.3 per 100,000, respectively, in 2014.4 When we restrict follow-up to 5 years after worker exit, age at death will be constrained. To the extent that risk is slightly higher for older age groups, there will be more potential bias when follow-up continues to 2015. 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

Michigan autoworkers who left work between 1970 and 2015 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.

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