Disparities in Fatal Occupational Injury Rates in North Carolina, 1978–2017: Comparing Nonmanagerial Employees to Managers

David B. Richardson,[a] *Stephen R. Cole,*[b] *Amelia T. Martin,*[b] *Elizabeth S. McClure,*[b,c] *Maryalice Nocera,*[c] *John Cantrell,*[c] *Shabbar I. Ranapurwala,*[b,c] *and Stephen W. Marshall*[b,c]

Background: We examined fatal occupational injuries among private-sector workers in North Carolina during the 40-year period 1978–2017, comparing the occurrence of fatal injuries among nonmanagerial employees to that experienced by managers.

Methods: We estimated a standardized fatal occupational injury ratio by inverse probability of exposure weighting, taking nonmanagerial workers as the target population. When this ratio measure takes a value greater than unity it signals settings in which nonmanagerial employees are not provided as safe a work environment as that provided for managers.

Results: Across all industries, nonmanagerial workers in North Carolina experienced fatal occupational injury rates 8.2 (95% CI = 7.0, 10.0) times the rate experienced by managers. Disparities in fatal injury rates between managers and the employees they supervise were greatest in forestry, rubber and metal manufacturing, wholesale trade, fishing and extractive industries, and construction.

Conclusions: The results may help focus discussion about workplace safety between labor and management upon equity, with a goal of providing a work environment for nonmanagerial employees as safe as the one provided for managers.

Keywords: Cohort studies; Injury; Mortality; Standardized mortality ratios; Statistical

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From the [a]Department of Environmental and Occupational Health, Program in Public Health, University of California, Irvine, CA; [b]Department of Epidemiology, School of Public Health, University of North Carolina at Chapel Hill, Chapel Hill, NC; and [c]Injury Prevention Research Center, University of North Carolina at Chapel Hill, Chapel Hill, NC.

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Correspondence: David B. Richardson, Department of Environmental and Occupational Health, Program in Public Health, University of California, Irvine, CA 92697. E-mail: david.richardson@uci.edu

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INTRODUCTION

Programs that promote occupational health equity aim to reduce disparities in injury and disease among workers that occur even among workers who are employed in the same industry.[1] These programs focus on avoidable differences in work-related injury and disease, particularly for workers who are at higher risk for occupational injury and illness because of historical social and economic structures.[2] Contemporary injury prevention theory emphasizes that the occurrence of occupational injury is influenced not only by the physical environment but also by the social environment, including norms, policies, and organizational factors.[3–5] Studies that focus on occupational health equity aim to inform understanding of these factors and improve institutional infrastructures to address these disparities.

In this article, we examine fatal occupational injuries among private-sector workers in North Carolina during the 40-year period 1978–2017. The project draws upon North Carolina's statewide medical examiner system, operated by the North Carolina Division of Public Health, which provides records of forensic investigations of fatal occupational injuries.[6–8] We compare the occurrence of fatal injuries among nonmanagerial employees to that experienced by managers by means of a standardized fatal occupational injury ratio. When this ratio measure takes a value greater than unity it signals settings in which nonmanagerial employees are not provided as safe a work environment as that provided for managers. We quantify the success of occupational fatality control strategies for nonmanagerial workers relative to the protections afforded to managerial workers; and, within each major industry group, we assess whether nonmanagerial workers experience fatal injury rates comparable to those of their managers. In this way, the results may help focus discussion about workplace safety between labor and management upon equity, with the goal of achieving a work environment for nonmanagerial employees as safe as the one provided for managers.

METHODS

We draw upon data from a study of fatal occupational injuries (i.e., deaths adjudicated to be on the job) among North Carolina workers. The current analysis is restricted to people who were at least 18 years of age and who were employed in the private sector in North Carolina over the period 1978–2017. We obtained information on fatal occupational injuries from the North Carolina State Center for Health Statistics death certificate data system and from the North Carolina Office of the Chief Medical Examiner. The Chief Medical Examiner obtains fatal injury data from local medical examiners. Each medical examiner determines the causes of and circumstances surrounding deaths in their jurisdiction, including whether the injuries that led to death occurred at work. An occupational fatality was defined as any injury leading to death within 30 days that was sustained by an individual in North Carolina engaged in legal work carried out for pay. Deaths during the study period that were flagged as "at work" in the State Center for Health Statistics data system or "on the job" in the Office of the Chief Medical Examiner data system were eligible for study inclusion. A review of the circumstances surrounding each death was then conducted, and complex cases were adjudicated by trained investigators to make a final determination of "at work status" for purposes of inclusion.[9] The current analysis is restricted to unintentional deaths (i.e., deaths for which the manner was determined to be "accidental"); we did not include homicides, suicides, and deaths of undetermined intent. Information on the age and sex of the decedents was abstracted from the death certificate and the medical examiner's report. We determined the class of worker (i.e., whether the worker was employed in the private sector) upon review of the medical examiner's report. We extracted information on the occupation and industry at the time of fatal injury from the medical examiner report and coded to the 1990 US census occupation and industry classification; we defined managerial workers as those classified to census occupational codes (003-199) (https://usa.ipums.org/usa/volii/occ1990.shtml). These analyses combine historical study data for NC deaths 1978–1991[9] with recently collected study data for NC deaths 1992–2017; we coded the historical data in the major categories of occupation and industry that are used in the current study to allow for comparability in coding across the entire study period. We assembled estimates of the annual North Carolina labor force from the US decennial censuses of 1970, 1980, 1990, 2000, and 2010 with intercensal interpolation and extrapolation based on linear models within strata of age, sex, occupation, industry, and class of worker. The study was reviewed by the Office of Human Research Ethics of the University of North Carolina at Chapel Hill with the determination that this research does not constitute human subjects research as defined under federal regulations.

Statistical Methods

We tabulated study cohort data in a discrete-time (i.e., person–period) data structure.[10,11] We tabulated the distribution of worker–years, and fatal occupational injury, by sex and age group; in addition, we calculated the crude fatal injury rate among managerial and nonmanagerial workers.

We compare the occurrence of fatal injury among nonmanagerial employees to that experienced by managers. This comparison is quantified in terms of a standardized mortality ratio estimated by inverse probability of exposure weighting, taking the nonmanagerial workers as the target population, and standardizing to account for potential demographic differences between nonmanagerial and managerial workers.[12,13] Our choice of nonmanagers as the target population follows other work on disparities in which questions have been framed in terms of what would be the impact of interventions on a target population that may be socially disadvantaged had they experienced the illness or injury rate of the more advantaged.[14,15]

Briefly, let X denote an indicator variable that takes a value of 1 if the worker is a nonmanagerial employee, else 0 for manager. Let Y index the outcome of interest, fatal occupational injury, and S indexes covariates. We defined a weight that took a value of 1 for all study members for whom $X = 1$ (i.e., nonmanagerial workers), and a value of $\frac{P(X|S)}{1-P(X|S)}$ for all study members for whom $X = 0$ (i.e., managers), where $P[X=1|S]$ denotes the probability of being a nonmanagerial employee conditional on covariates.[12] The probability of being a nonmanagerial employee conditional on covariates was estimated via a logistic regression model fitted to the person–period data predicting X as a function of a set of covariates that included indicators for attained age (categorized as: 18–34, 35–44, 45–54, 55–64, and 65+ years), sex, and the product terms between age group and sex. Categorization of age was necessary given the census-based population counts used in this analysis. We estimated a ratio measure comparing the occurrence of the outcome among nonmanagerial employees to the weighted occurrence of the outcome among managers, defined as $\mathrm{SMRX} = \frac{[Y|X=1]}{[Y|X=0]\frac{P(X|S)}{1-P(X|S)}}$, via a weighted log-linear Poisson regression model fitted for the outcome, Y, with X as the only explanatory variable, applying the weight described above, and including the log of person-time as an offset. The antilog of the parameter estimate associated with the explanatory variable yields the estimate of the standardized ratio of mortality across managerial categories, X (SMRX).

We calculated *SMRX* to compare fatal occupational injury rates between managers and their nonmanagerial counterparts. We examined variation in this mortality ratio by age group, sex, industry group, and calendar period. Weights for each of the subgroup analyses were estimated separately for each subgroup. We derived a 95% confidence interval (CI) for this ratio measure by normal bootstrap with 500 samples. In the eAppendix; http://links.lww.com/EDE/C38 we provide illustrative SAS code to implement our proposed approach for the estimation of *SMRX* and associated 95% CI derived using a bootstrap method.

RESULTS

Table 1 reports the distribution of workers by sex and age group in the observed data. The crude fatal injury rate among managerial workers was 0.4 per 100,000 worker–years (95% CI = 0.4, 0.5); the crude fatal injury rate among nonmanagerial workers was 3.8 per 100,000 worker–years (95% CI = 3.7, 4.0). Managers were more likely to be male than nonmanagers, and managers tended to be older than nonmanagers. Table 1 also reports the distribution of workers, and deaths, in the weighted data. The mean weight applied to managers was 4.0 (range 2.8–6.3), whereas nonmanagerial workers were always assigned a weight of unity. In the weighted data, managers and nonmanagers had covariate distributions that were comparable (and corresponded to the target population of nonmanagerial workers).

Table 2 reports the crude fatal injury rate for nonmanagerial workers, the weighted fatal injury rate for managerial workers, and the *SMRX*, for major industrial categories. After standardization for age and sex, across all industries, the fatal occupational injury rate among nonmanagerial workers was 8.2 times that of managerial workers (*SMRX* = 8.2; 95% CI = 7.0, 10.0). Among workers aged 35–44 and 45–54 years, the mortality ratio was somewhat larger in magnitude than the overall summary mortality ratio; and, among workers aged <35 years and ≥55 years, the mortality ratio was somewhat smaller in magnitude than the overall summary mortality ratio (eTable 1; http://links.lww.com/EDE/C38). There was evidence of variation in the *SMRX* by sex (eTable 1; http://links.lww.com/EDE/C38), noting that most fatal occupational injuries occurred among men; among men the summary *SMRX* was 9.0 (95% CI = 7.1, 11.4), whereas among women the summary ratio was 2.7 (95% CI = 1.5, 5.4).

There was no major industry group in which the fatal injury rate among managers was equal to or greater than that observed among the employees they supervise. Those industries with the smallest disparities in fatal injuries between managers and the employees they supervise were the retail, entertainment, food, tobacco, and textile manufacturing industries, where nonmanagerial employees experienced fatal injury rates approximately three times that of their managers (Table 2). Those industries with the largest disparities in fatal injuries between managers and the employees they supervise were forestry, rubber and metal manufacturing, wholesale trade, fishing and extractive industries, and construction (Table 2). We observed the largest number of fatal occupational injuries among nonmanagerial workers in the construction industry, where the *SMRX* was 7.3 (95% CI = 4.3, 15.9). The highest fatal occupational injury rates for nonmanagerial workers were in the fishing and extractive industries, agriculture, transport, and construction industries; in addition, in those industries, employees experienced fatal injury rates at least five times that of their managers.

eTable 2; http://links.lww.com/EDE/C38 reports fatal injuries among private-sector workers in North Carolina during the periods 1978–1987, 1988–1997, 1998–2007, and 2008–2017. Despite the fact that crude fatal injury rates among managerial and nonmanagerial workers declined to 0.3 and 2.2 per 100,000 worker–years, respectively, in the most recent decade of study, the overall disparity between the fatal injury rates of managers and nonmanagers (*SMRX* = 6.4; 95%

TABLE 1. Distribution of Deaths and Worker–years by Manager Versus Nonmanager Status, Observed, and Weighted Data

	Original data			Weighted data		
	Nonmanager ($X = 1$)	Manager ($X = 0$)	Total	Nonmanager ($X = 1$)	Manager ($X = 0$)	Total
	(n = 88124041)	(n = 23680042)	(n = 111804083)	(Σ_w = 88124041)	(Σ_w = 88124039)	(Σ_w = 176248080)
Males						
Age category (years)						
<35	44.7%	33.2%	42.4%	44.7%	44.7%	44.7%
35–44	24.6%	29.5%	25.6%	24.6%	24.6%	24.6%
45–54	18.5%	23.9%	19.6%	18.5%	18.5%	18.5%
55–64	9.0%	10.7%	9.4%	9.0%	9.0%	9.0%
65+	3.1%	2.8%	3.1%	3.1%	3.1%	3.1%
Females						
Age category (years)						
<35	41.8%	38.7%	41.1%	41.8%	41.8%	41.8%
35–44	24.9%	30.2%	26.1%	24.9%	24.9%	24.9%
45–54	19.6%	21.5%	19.6%	19.6%	19.6%	19.6%
55–64	10.3%	7.8%	9.4%	10.3%	10.3%	10.3%
65+	3.5%	1.9%	3.1%	3.5%	3.5%	3.5%
Deaths						
Number	3378	100	3478	3378	409.7	3787.7
Rate (per 100,000 worker–years)	3.8	0.4	3.1	3.8	0.5	2.1

Σ_w = sum of weight.

TABLE 2. Fatal Occupational Injuries Among Private-sector Workers in North Carolina by Industry Category, 1978–2017

		Deaths (Weighted Data)		Rate per 100,000 Worker–years (Weighted Data)			
Industry Category	Census Codes	Nonmanager	Manager	Nonmanager	Manager	SMRX	95% CI[a]
Agriculture and related services	015–025	372	79.8	21.0	4.5	4.7	1.7, 14.6
Fishing and extractive industries	035–045	74	7.7	35.8	3.8	9.5	2.5, 20.1
Construction	065	951	124.9	12.7	1.7	7.6	4.3, 15.9
Food/tobacco/textile manuf.	100–199	260	74.6	2.0	0.6	3.5	1.8, 7.1
Forestry/rubber/metal manuf.	200–299	464	24.6	5.9	0.3	18.9	6.4, 59.5
Machinery/computers manuf.	300–399	95	21.5	1.4	0.3	4.4	1.9, 6.9
Transport	400–415	550	94.9	14.3	2.5	5.8	2.3, 17.1
Utility (radio, electric, gas, water)	445–475	148	21.8	6.1	0.9	6.8	3.7, 17.6
Wholesale trade	505	138	13.1	3.3	0.3	10.5	3.7, 29.8
Retail	585–645	176	54.1	0.9	0.3	3.3	2.1, 10.9
Service (financial, repair, lodging)	705–775	93	25.8	0.9	0.2	3.6	2.0, 11.5
Entertainment and related	805–815	57	23.2	0.5	0.2	2.5	1.7, 4.1
All industries	015–815	3378	409.7	3.8	0.5	8.2	7.0, 10.0

[a]Bootstrap-based 95% confidence interval.
SMRX indicates standardized mortality ratio across management categories.

CI = 4.8, 10.1) was only modestly lower in magnitude than that observed over the full study period.

DISCUSSION

Overall, in North Carolina over the 40 years of study, the fatal occupational injury rate among nonmanagerial workers was 8.2 (95% CI = 7.0, 10.0) times the fatal occupational injury rate among managers. We observed mortality differentials between private sector nonmanagerial and managerial NC workers among young, middle age, and older adult workers, and the standardized mortality ratio was larger in analyses of male workers than female workers (eTable 1; http://links.lww.com/EDE/C38).

Increases over time in employment in some industries, and declines in others, may influence the magnitude of the overall mortality ratio, emphasizing the importance of industry-specific examinations of disparities. There were notable differences in the mortality ratio across industries. In retail, entertainment and related services, food, tobacco and textile manufacturing industries, mortality rates among nonmanagerial workers were moderately higher than among managers (Table 2); and, in forestry, rubber and metal manufacturing, fishing and extraction, wholesale trades, and construction, mortality rates among nonmanagerial workers were substantially higher than among managers (Table 2).

Fatal occupational injury rates declined substantially over the study period (eTable 2; http://links.lww.com/EDE/C38). Although some industries may be viewed as inherently more hazardous than others, all industrial hazards are amenable to control. The marked decline in fatal occupational injury rates in North Carolina demonstrates that injury prevention is possible, and has successfully led to improving safety on the job for managers and nonmanagers. However, the reductions in rates led to quite modest improvements in equity between managers and nonmanagerial employees in fatal occupational rates; in the most recent decade of study, nonmanagerial workers experienced mortality rates 6.4 times the rate of their managers, despite a substantial overall reduction in fatal injury rates over the study period (eTable 2; http://links.lww.com/EDE/C38).

One reason for differences in fatal injury risk between managerial and nonmanagerial workers may be that these groups of workers often perform different tasks, such that protections may be afforded to managers via task assignment. This may reflect decisions on the distribution of dangerous tasks (and interventions to reduce injury); consequently, an elevated mortality ratio value reflects not just the inherent risk of these working environments but also the allocation of job tasks between managers and nonmanagers that allows for excess injury deaths among nonmanagers relative to managers. Although in some industries, such as retail, managers and the employees they supervise may do similar tasks in similar work locations, other industries have not created, or have not been required to create an equitably safe work environment. Of course, the mortality ratio is a population-based metric, and not all of the excess hazard was fully under the control of on-site managers at the time of the employee death. Attention to relative equity in workplace safety, such that employers provide a work environment for nonmanagers that is as safe as the one for managers, may stimulate new ideas for injury prevention and help to reduce the magnitude of disparity.

The coarse groupings of occupation and industry used in the current analysis reflect the fact that our study draws upon historical data (as well as bridge coding across censuses) that limited our ability to redefine occupation and industry coding. Moreover, estimation of the inverse probability of exposure weights as a function of age and sex can be difficult in narrow categories of industry, or in highly sex- or age-segregated industries (e.g., settings in which managers are almost entirely of one sex while nonmanagers include both sexes). This problem, sometimes referred to as a positivity violation, may be signaled by extreme values of the weight used in our proposed method. The category of managers, for example, includes census occupation codes for other professionals such as architects, teachers, lawyers, and health professionals (although those occupation codes are uncommon among the industries where fatal occupational injury primarily occurred).

In the current analysis, we chose not to standardize for race noting that if there is employment segregation (e.g., disproportionately white workers in managerial positions), a mortality ratio that exceeds one signals that disproportionately nonwhite nonmanagerial employees experience higher fatal injury rates than their disproportionately white managers. Contrasts that jointly consider race and managerial status could be handled in extensions of this approach (e.g., a ratio contrast of the observed number of fatal injuries among nonwhite nonmanagerial employees in an industry to the number expected based on the fatal injury rates of white managers in that industry).

Our standardized mortality ratio does not rely upon an external reference population (i.e., comparisons are drawn between workers employed within similar industries). However, to interpret a mortality ratio value greater than unity as indicative of the effect of workplace hazards that differ between nonmanagerial and managerial workers, one must assume that, conditional on the measured covariates, in the absence of the nonmanagerial occupational exposure conditions, managers and nonmanagers would have similar fatal occupational injury risks. While this is an important limitation of the proposed estimator, most reasonable estimators using observational data will be subject to strong conditional exchangeability assumptions.[16] Although the assumption of conditional exchangeability is unverifiable, we posit that many of the important factors associated with differences in fatal occupational injury rates between nonmanagerial and managerial employees are related to the organization and conduct of work-related activities. Covariate adjustment, of course, is a way to address concerns about the confounding of comparisons between managers and nonmanagerial employees. Similar to classical SMR standardization approaches,[17,18] and consistent with many occupational injury studies that draw upon administratively collected data,[9,19,20] in the current analysis the adjustment set of covariates is limited to a small number of demographic factors (i.e., age and sex).

A standardized mortality ratio may be appealing given its relative ease of calculation, its potential utility as a summary measure of occupational equity in injury rates across industry sectors, and its intuitive interpretation. A ratio measure describes relative equity in fatal occupational injury rates; however, we also report the absolute numbers of events and fatal injury rates, permitting consideration of+ absolute disparities as well. eTable 2; http://links.lww.com/EDE/C38 reports standardized rate differences as well as rate ratios; the rate difference declined monotonically over the study period whereas the ratio measure exhibited no obvious trend with calendar time. Prior authors have noted that, in many applied settings, ratio measures exhibit stability over time or across levels of covariates whereas difference measures exhibit variation.[21,22] Absolute and ratio measures are both of interest, although ratio measures have historically played an important role in the summarization of epidemiologic findings as well as informing public health interventions.[23] Similar to the interpretation of the classical standardized mortality ratio,[24] this simple calculation does not involve the estimation of the counterfactual failure times for nonmanagerial workers had they experienced the fatality rates of managers.[18] Rather, we assume that a difference in the occupational fatal injury rates between managers and nonmanagerial employees does not meaningfully affect the distribution of person-time among nonmanagerial workers; such an assumption is reasonable given the rarity of fatal occupational injury in this period. The g-formula can also provide a standardized marginal estimator[18,25] and future work will explore the construction of a g-computation analog to the SMR across management categories. Also, similar to the classical SMR, these ratios are standardized to a particular target population; consequently, the comparison of *SMRX* should be viewed with caution, particularly if the populations under comparison have very different covariate structures.

We undertook these analyses to emphasize equity in discussions regarding workplace safety between labor and management, with the goal of providing a work environment for nonmanagerial employees as safe as the one that managers themselves experience. Injury deaths at work are serious and preventable, and employers under Occupational Safety and Health Administration jurisdiction are obliged to report every fatality on the job, take action to prevent its recurrence, and provide a safe workplace free of known safety hazards.[26] These analyses of standardized mortality ratios, in which we observe persistent, sizable mortality differentials between private sector nonmanagerial and managerial workers in North Carolina provide another set of quantitative analyses to support equity-focused workplace organizing and safety interventions.

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The datasets generated during and/or analyzed during the current study are not available. Requests for the mortality data provided by the Office of the Chief Medical Examiner, North Carolina Department of Health and Human Services, and should be directed to that office. The code used for statistical analysis is provided as an eAppendix.

