Case-Control Study of Lung Cancer and Truck Driving in the Teamsters Union

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Abstract: We conducted a case-control study of lung cancer deaths in the Teamsters Union to compare the risk of different occupations within the teamsters, after controlling for smoking and other confounders. Occupations with no presumed exposure to diesel fumes were used as the nonexposed group. The study population consisted of 996 cases and 1,085 controls who had died in 1982-83 after applying for pensions. Next of kin provided information on smoking, work history, and other potential confounders. Work history data were also obtained from the Teamsters Union. While no single job category had a significant excess risk compared to the non-exposed group, certain sub-groups were elevated. The odds ratio for those with long-term employment as long-haul truckers after 1959 (an approximate date for the introduction of diesel engines) was 1.55 (95% CI: 0.97, 2.47). Long-term drivers of primarily diesel trucks had an odds ratio of 1.89 (95% CI: 1.04, 3.42). Overall, our results suggest that diesel truck drivers have an excess risk of lung cancer compared to other teamsters in jobs outside the trucking industry. However, our findings were not uniformly consistent and our data have many limitations, the most important of which is the lack of data on exposure to diesel fumes. (*Am J Public Health* 1990; 80:670–674.)

Introduction

Inhaled diesel exhaust causes lung tumors in rodents,[1] and there is limited industrial hygiene data showing that truck drivers are exposed to diesel exhaust.[2] Recent human studies[3,4] also have indicated an excess lung cancer risk for diesel-exposed workers, after controlling for smoking. To test the hypothesis that truck drivers have an excess risk of lung cancer, we conducted a case-control study of lung cancer in the Teamsters Union. The risk for men in different occupations within the trucking industry was compared to that of men outside the trucking industry in jobs with no presumed diesel exposure. We had no direct data on level of exposure to diesel exhaust. A separate National Institute for Occupational Safety and Health/National Cancer Institute (NIOSH/NCI) project is now in progress to measure current exposure to diesel exhaust in the trucking industry, and to estimate historical exposures.

Methods

Study Population and Data Sources

Cases and controls were selected from the 10,699 male decedents from the Central States Teamsters files who had filed claims for pension benefits (requiring 20 years tenure in the union) and who had died in 1982 and 1983. We obtained death certificates for 10,485 (98 percent) of these men. Cases were all deaths from lung cancer, coded as ICD 162 or 163 for underlying or contributory cause on the death certificate (n = 1,288). Controls (n = 1,452) were every sixth death from the entire file (sorted by Social Security number), excluding deaths from lung cancer, bladder cancer, and motor vehicle accident.

Next of kin were questioned in detail on work history and potential confounders such as smoking, diet, and asbestos exposure. The response rate was 81 percent (see Figure 1). Most non-response was the result of our inability to locate the next of kin. Of the responses, 80 percent of the interviews were obtained by mail and 20% via follow-up phone calls; 76 percent were completed by spouses, and 24 percent were completed by some other next of kin. On the average, the next of kin had known the decedents for 39 years (38 for cases, 40 for controls).

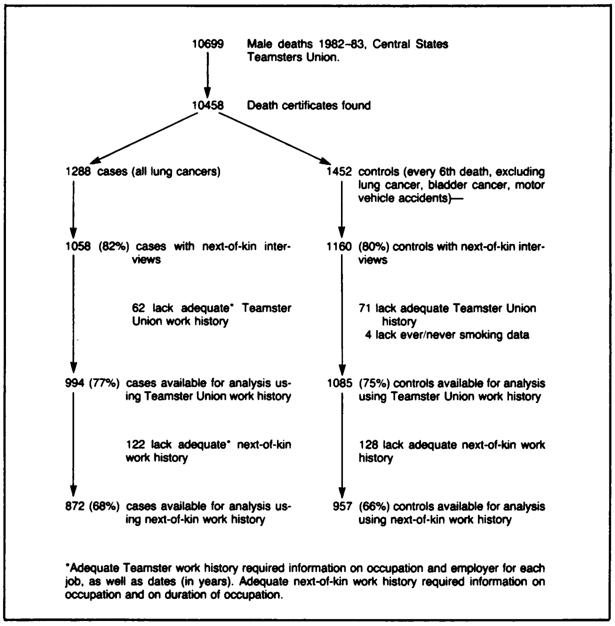

FIGURE 1—Cases and Controls Use in Study of Lung Cancer and Truck Driving in the Teamsters Union

Men were then classified into the job category in which they had worked the longest (diesel truck driver, gasoline truck driver, driver of both types of trucks, truck mechanic, and dock worker), according to 1980 US Census occupation and industry codes.[5] Those who had never worked in any of these job categories were classified either as non-exposed, or as men who had held other jobs with potential diesel exposure (see Appendix A). Approximately 12 percent of the study subjects could not be classified into a principal job category because of missing data (e.g., the number of years worked in specific jobs was unknown to next of kin).

A second work history file was created based on the Teamster Union pension application which listed all teamster

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jobs, as reported by the subject. Each job listed occupation, employer, and dates of employment. Both applicants and Teamster Union staff spent considerable effort to ensure the accuracy of these pension applications.

For the Teamster Union data, each job for each individual was assigned a three-digit US Census code (see Appendix A) for occupation and industry[5] (the latter obtained from commercial listings of employers which included type of industry). The four principal job occupations based on Teamster Union records were long-haul drivers, short-haul or city drivers, truck mechanics, and dock workers (see Appendix A). The Teamster Union work history did not provide information on whether men drove diesel or gasoline trucks. Men were again categorized according to the job category in which they had worked the longest. Most men had worked in only one exposed job category.

Diesel trucks were gradually introduced into the trucking fleet in the 1950s and 1960s in most of the country (before 1950s in Western states). Diesel trucks formed the majority of heavy duty truck sales for the first time in 1961.[6] However, many trucking companies (where most study subjects worked) had completed most of the dieselization of their fleets by 1960, while independent drivers and nontrucking firms may have obtained diesel trucks later (personal communication from companies in NIOSH/NCI industrial hygiene survey). We have chosen 1960 as the date used in our analysis, but we also report results using 1965 as the date for presumed dieselization.

Case-Control Analyses

The number of cases and controls available for analysis is shown in Figure 1. The method of analysis was unconditional logistic regression.[7] A series of dummy (0/1) variables was used to estimate the risk of a number of different job categories in relation to the same nonexposed group (see Appendix B).

All data on covariates, such as smoking and diet, were taken from the next-of-kin interview, while work history data were taken either from the Teamster Union pension applications or from next-of-kin interviews. Separate analyses were conducted for each type of work history data. Analyses considered employment (usual versus never) in a principal job category, as well as the number of years worked in that job. In some analyses using the Teamster Union work histories, only employment after 1959 (or 1964) was considered.

Details on covariate selection for inclusion in the model can be found in Appendix B. In summary, the only covariates that were included in the final model were age (five categories), smoking (six categories), asbestos (dichotomous), and a dichotomous variable for having held other jobs with potential diesel exposure. The fit of this basic model and four continuous exposure variables from the Teamster Union work history was evaluated via the method described by Lemeshow and Hosmer.[8] The chi square resulting from this test was 18.0, with 18 degrees of freedom ($p = .46$), indicating a good fit of the model.

Results

Table 1 shows the number of men and the average duration of employment in the different job categories. Table 2 shows the results of analyses when exposure was considered as a dichotomous variable (i.e., main job versus non-exposed), based on Teamster Union and on next-of-kin work history. No single job category had a highly elevated risk compared to non-exposed men, although most were somewhat elevated.

We further analyzed the Teamster Union work history data by estimating risk by duration of employment as a categorical variable (Table 3). When no cutoff date for employment was used, there was little indication of any trend of increasing risk with increasing duration of employment for any of the job categories. When only employment after 1959 was considered, both long-haul (test for trend, $p = .04$) and short-haul drivers (test for trend, $p = .22$) showed an increase in risk with increased years of exposure; truck mechanics showed no increase in risk with increased years of exposure; truck mechanics showed no increase in risk with time. If 1964 was used for a cutoff date instead of 1959, long-haul drivers continued to show a significant positive trend ($p = .04$), and the highest duration category (13+ years) had an odds ratio of 1.64 (95% CI: 1.05, 2.57). Short-haul drivers, however, no longer showed a positive trend. If duration of employment was used as a continuous variable, significant positive trends

TABLE 1—Number of Men and Average Years Worked in Different Job Categories by Case-Control Status, from Teamster Union Work History and Next-of-Kin Data

Teamster Union Data	Number Cases	Number Controls	Average Years in Job Cases	Average Years in Job Controls
Overall	994	1085	na	na
Long-haul truck driving	609	604	24.2	24.0
City truck driving	121	134	23.4	24.5
Truck mechanic	50	37	22.3	23.3
Dock worker	70	92	23.1	23.3
Other potentially exposed jobs	99	143	na	na
No potential for diesel exposure	45	75	na	na
Next-of-kin data				
Overall	994	1085	na	na
Primarily diesel truck driver	176	155	29.6	27.6
Primarily gasoline truck driver	245	309	29.0	29.7
Drove both types of truck	248	246	31.2	31.2
Diesel truck mechanic	43	41	32.4	32.3
Dock worker	28	40	25.4	25.1
Other potentially exposed jobs	87	128	na	na
No potential for diesel exposure	45	75	na	na
Missing required data	122		na	na

TABLE 2—Odds Ratios for Exposure Considered as Main Job (ever vs never)

Job category	Odds ratio* (95% CI)
Teamster Data	
Long haul driver	1.27 (.83–1.93)
Short haul driver	1.31 (.81–2.11)
Truck mechanic	1.69 (.92–3.09)
Dock worker	0.92 (.55–1.55)
Other potentially diesel exposed	1.44 (.88–2.39)
Next-of-kin data	
Truck driver, primarily diesel truck	1.42 (.89–2.26)
Truck driver, primarily gasoline truck	1.22 (.79–1.88)
Truck driver, both types of truck	1.25 (.81–1.95)
Truck mechanic (diesel)	1.35 (.74–2.47)
Dock worker	0.93 (.49–1.78)
Other potentially diesel exposed	1.54 (.93–2.15)

*Adjusted for age, smoking, and asbestos, the reference group is the non-exposed.

were observed both for long-haul drivers and mechanics, but only after 1959.

Similar trend analyses, based on next-of-kin data, are shown in Table 4. None of the job categories showed a significant increasing trend, although men whose main job was driving diesel trucks did show a marginal increase in risk with increasing duration of employment as a truck driver ($p = .12$). For truck drivers who drove 35 years or longer and drove primarily diesel trucks, the odds ratio for lung cancer was 1.89 (95% CI: 1.04, 3.42). If duration was considered as a continuous variable, only the trend for diesel truck drivers approached significance ($p = .09$).

Using either the Teamster Union work history or that supplied by next of kin, there were no significant interactions between age and exposure, or smoking and exposure. It did not appear that excess risks were confined to any specific category of smokers or non-smokers. The results for lagged analyses (discounting any exposure in the five years preceding death) were similar to the analyses with no lag.

Concordance between Teamster and next-of-kin job categories could not be easily evaluated because job categories were defined differently in each data set (e.g., diesel truck drivers based on next of kin, long-haul drivers based on Teamster Union data). Discrepancies between next-of-kin and Teamster Union work history could occur because next of kin were reporting lifetime work history, while the Teamster records only covered Teamster years. However, 90 percent of men identified by next of kin as primarily diesel truck drivers were long-haul drivers by Teamster Union data, and the corresponding proportions were 82 percent for mechanics and 81 percent for dock workers.

Discussion

The Teamsters Union keeps very thorough records regarding their members, which have not yet been fully utilized by epidemiologists. We were able to study Teamster pensioners using data on their vital status and work history which had been collected by the Union's Pension Fund. It is worth noting that the Union, jointly with employers, has created a Health and Welfare Fund which might be used for studying morbidity.

We observed positive trends in lung cancer risk with duration of employment for long-haul truck drivers after either 1959 or 1964 (Teamster work history), and for truck drivers who drove primarily diesel trucks (next-of-kin work

TABLE 3—Odds Ratios According to Length of Employment for Long-haul Truck Drivers, Short-haul Truck Drivers, and Truck Mechanics

Job Category	Length of Employment (years)	Odds Ratio (95% CI)*	Cases	Controls
No Cutoff Date				
Long-haul driver	1–21	1.25 (.78, 1.97)	205	218
	22–27	1.12 (.72, 1.77)	199	195
	28 or more	1.47 (.94, 2.31)	199	195
Short-haul driver	1–21	1.52 (.86, 2.71)	52	52
	22–27	1.73 (.92, 3.25)	40	34
	28 or more	0.83 (.45, 1.56)	29	57
Truck mechanic	1–21	2.23 (.97, 5.17)	22	13
	22–27	1.20 (.53, 2.72)	17	17
	28 or more	1.88 (.66, 5.35)	11	8
*Exposure after 1959***				
Long-haul driver	1–11	1.08 (.68, 1.70)	162	230
	12–17	1.41 (.90, 2.21)	228	203
	18 or more	***1.55 (.97, 2.47)	213	171
Short-haul driver	1–11	1.11 (.61, 2.03)	36	58
	12–17	1.15 (.63, 2.43)	37	45
	18 or more	1.79 (.94, 3.42)	40	31
Truck mechanic	1–11	1.83 (.80, 4.19)	19	16
	12–17	2.08 (.78, 5.52)	15	8
	18 or more	1.50 (.59,3.40)	16	13

*These data reflect two analyses, with employment restricted to after 1959 or without such a restriction. Each analysis included all the above exposure variables. Odds ratios were also adusted for age, smoking, and asbestos. Variables for work as a dock worker or in other potentially diesel-exposed jobs were also included in the model. For all comparisons, the non-exposed were those who had never worked in principal jobs categories nor in any other job potentially exposed to diesel exhaust.

**For the 1959 cutoff, we have used different cutpoints, because the maximum possible length of employment in a given job category is 23 years (1960–83). Cutpoints were chosen a priori by dividing long-haul drivers into three groups of approximately equal size. See text for results using 1964 cutoff.

***The linear trend in odds ratios for long-haul drivers was significant ($p = .04$). The coefficient was 0.027, which increased to .037 when exposure was defined after 1964.

SOURCE: Teamster Union Work History.

TABLE 4—Odds Ratios According to Length of Employment for Men as a Truck Driver or Mechanic for Men Whose Main Job Was Diesel Truck Driver, Gasoline Truck Driver, Driver of both Gasoline and Diesel Trucks, or Truck Mechanic

Main Job Category	Years of Employment* (years)	Odds Ratio (95% CI)**	Cases	Controls
Diesel truck driver	1–24	1.27 (.70, 2.27)	48	52
	25–34	1.26 (.74, 2.16)	72	67
	35 or more	1.89 (1.04, 3.42)	56	36
Gasoline truck driver	1–24	1.24 (.74, 2.16)	72	87
	25–34	1.10 (.67, 1.80)	87	112
	35 or more	1.34 (.81, 2.22)	86	111
Drove both truck types	1–24	1.27 (.71, 2.26)	50	51
	25–34	1.15 (.70, 1.90)	95	100
	35 or more	1.34 (.81, 2.20)	102	95
Truck mechanic	1–24	1.69 (.61, 4.67)	11	9
	25–34	1.39 (.63, 3.07)	20	16
	35 or more	1.09 (.44, 2.66)	12	16

*Years of employment as a truck driver does not necessarily signify years of employment driving a particular type of truck.
**All the above exposure variables were included in the model together. In addition, odds ratios were adjusted for age, smoking, and asbestos. Dock workers and men in other potentially exposed jobs were also included in model. For all comparisons, the non-exposed were those who had never worked in principal job categories nor in any other jobs potentially exposed to diesel exhaust.
SOURCE: Next-of-Kin Data

history). These findings suggest that there may be a real increase in risk with increased employment driving a long-haul or diesel truck.

Mechanics showed marginal elevated risks of lung cancer, especially based on Teamster work history. Preliminary sampling results from NIOSH/NCI surveys indicate that mechanics are likely to have been exposed to relatively high levels of diesel exhaust, especially in winter. However, the risk for mechanics did not appear to increase consistently with duration of employment. Also, there is evidence in the literature that mechanics have been exposed to low levels of asbestos in the course of working on brakes.[9] While we included data from next of kin on asbestos exposure in the model, the data on asbestos may have been inadequate to control for confounding.

Dock workers showed a slight deficit in risk. It is possible that dock workers have had less diesel exposure than truck drivers and mechanics. Dock workers frequently unloaded trailers disconnected from the cabs with engines in open air terminals. Short-haul drivers in the Teamster data, but not gasoline drivers (next of kin data), showed some evidence of increased risk.

The principal limitation in this study is the lack of exposure data indicating level of diesel exhaust for the different job categories studied. Such data would enable us to draw firmer conclusions with respect to the role of diesel exhaust, rather than employment in presumably diesel-exposed jobs. Unfortunately, little data exist on historical levels of diesel exhaust in the trucking industry.

Other limitations include: 1) possible misclassification of smoking habits by next of kin, 2) misclassification of exposure by next of kin, 3) a relatively small non-exposed group (n = 120) which by chance might have had a low lung cancer risk, and 4) lack of sufficient latency (time since first exposure) to observe a lung cancer excess. On the other hand, next-of-kin data on smoking have been shown to be reasonably accurate[10], non-differential misclassification of exposure (between cases and controls) would only bias our findings toward the null hypothesis of no association, and the trends of increased risk with increased duration of employment in certain jobs would persist even if the non-exposed group had had a higher lung cancer risk. Finally, the lack of potential latency would also make any positive results more striking.

In view of the above limitations, the results of this study should be considered cautiously. However, other recent findings support our results. The study of Boffetta, *et al*,[3] based on data from the American Cancer Society, indicates that truck drivers show an increased risk of lung cancer after correction for smoking (RR = 1.24, 95% CI: 0.93, 1.66), and that this increase is primarily associated with truck drivers with long duration of diesel exposure (self-reported). Other recent data support an increased lung cancer risk due to diesel exposure in general. The Boffetta study cited above showed an increased in lung cancer risk for those with diesel exposure in any occupation (RR = 1.18, 0.97–1.44), and this risk increased with duration. Garshick, *et al*,[4] conducted a case-control study of 1,256 lung cancer cases and matched controls who had died in 1982–83 after railroad work. Industrial hygiene assessments were done to determine which job categories had significant exposure to diesel exhaust. Those men with 20 years or more duration of employment in diesel-exposed jobs after 1959 (date when locomotives were all presumed to be diesel) showed a significant excess risk (odds ratio = 1.41) compared to the non-exposed, after controlling for smoking and asbestos. These positive findings for truck drivers and other diesel-exposed workers lend plausibility to our own results.

ACKNOWLEDGMENTS

The NIOSH clerical staff, led in this study by Pauline Bishak, and the Central States Teamsters Pension Fund staff (particularly Alan Levy, Mary Balint, Viola Baba, and Mark Felke) performed invaluable service in collecting the raw data for this study. A preliminary version of this paper was presented at the American Public Health Association conference in Chicago, October 25, 1989.

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APPENDIX A

1980 Census[5] Occupation and Industry Codes Used in Defining Job Categories in Teamster Union Work Histories

Job category	Occupation Codes	Industry Codes
Long-haul driver	804 (truck driver, heavy)	any
City driver	805 (truck driver, light)	any
	806 (driver/sales for bakeries dairies, cleaners, or beverage company	111, 101, 771, 120, any if occupation is sales or route driver
Truck mechanic	507 (truck mechanic)	410 (trucking)
Dock worker	343 (checker)	410
	359, 363 (dispatcher)	410
	364 (shipping clerk)	410
	365 (stock clerk)	410
	368 (checker)	410
	843 (dock foreman)	410
	883 (dockman)	410
	856 (forklift operator)	410
	889 (warehouseman)	410
	859 (moving man)	410
Other jobs with potential diesel exposure	all except above jobs in 410 (trucking)	410
	503–517 (other mechanics)	any
	803–859 (other vehicle drivers)	any
	343 (checker)	any except 410
	359, 363 (dispatcher)	any except 410
	364 (shipping clerk)	any except 410
	365 (stock clerk)	any except 410
	368 (checker)	any except 410
	843 (dock foreman)	any except 410
	883 (dockman)	any except 410
	856 (forklift operator)	any except 410
	889 (warehouseman)	any except 410
	859 (moving man)	any except 410
	885 (service station work)	any
	019 (Teamster official)	410

APPENDIX B

Definition of Non-exposed and Selection of Covariates for Inclusion in the Model

The same non-exposed group was used for the analyses based on Teamster Union work history and the analyses based on next-of-kin work history. The non-exposed group was chosen from those who, based on Teamster work history, had never worked as either a long-haul driver, a short-haul driver, a mechanic, a dock worker, or any other potentially diesel-exposed job (Appendix A). Many of these men worked in dairies. Those with no potential diesel exposure via Teamster work history (n = 156) were then further reviewed to exclude anyone with any jobs reported by next of kin which might have had potential diesel exposure (e.g., men who drove trucks prior to joining the Teamsters Union and working in a non-exposed job). The classification of men into the non-exposed group, like all classifications into job categories, was done without any knowledge of case-control status.

Exposure variables and covariates were tested by adding them to a basic model, which included variables for smoking (six categories) and age (five categories). The odds ratios for lung cancer did not increase monotonically with age (using the youngest group as referent), prompting our use of categorical rather than continuous age variables (odds ratios, in reference to age less than 45 years, were 2.86 for ages 45–54, 3.42 for ages 55–64, 3.71 for ages 65–74, and 2.12 for ages greater than 75). Cigarette smoking was categorized into never smoker, current smoker (current at time of death) with unknown amount, current moderate smoker (one pack or less), current heavy smoker (more than one pack), former smoker who quit before 1963, and former smoker who quit 1963–79. The odds ratios for smokers, in reference to never smokers, were 5.64 for current light smokers, 8.85 for current heavy smokers, 4.48 for former smokers who quit in the 20 years before death, and 2.41 for former smokers who quit prior to 20 years before death.

Variables other than exposures, smoking, or age were not included in the model if they did not act as confounders (did not change the estimates of exposure effect), and if they did not interact significantly with the exposure variables. Trends with duration of employment were tested either via inclusion of continuous variables, or via categorization of duration and a test for trend described by Rothman.[11] Cutoff points for categories of duration were chosen a priori, based on dividing long-haul (or diesel when using next-of-kin data) truck drivers into three categories of duration with approximately equal numbers in each. These same cutpoints were then used for the other job categories.

The following variables were neither significant predictors of lung cancer nor acted as confounders: smoking a pipe or cigar, race, state of residence at death, coffee drinking, work in construction, work in shipyards, and driving a truck with a partner who smoked. The frequency of consumption of certain types of vegetables and fruits was of interest because of a possible protective effect of Vitamin A.[12,13] The only significant diet variable was consumption of deep yellow vegetables. The odds ratio for infrequent consumers (one or two times a month or less) of yellow vegetables was 1.38 (1.10–1.76), and for average consumers (one or two times per week) was 1.26 (.98–1.62), both compared to frequent consumers (three or more times per week). However, these variables did not confound the associations under study and were not included in the final model. Asbestos exposure was a significant predictor (odds ratio = 2.80), had some confounding effect on the exposure variables for mechanics, and was retained in the final model.

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