Health Survey results of BMWED workers focusing on diseases, injuries, and death among members

A Report to the Brotherhood of Maintenance of Way Employes Division
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Background

The Brotherhood of Maintenance of Way Employes Division (BMWED) is a national union, affiliated with the International Brotherhood of Teamsters, representing the workers who build, inspect, and maintain the tracks, bridges, buildings and other structures on railroads throughout the United States. Railroad track workers (maintenance-of-way (MOW) workers) are employed in road gang crews on approximately 300,000 miles of railroad track across the United States. When there is any sort of railroad emergency or where the track bed, bridges or related infrastructure are damaged or require regular maintenance, BMWED members provide the skilled workforce to restore the rail infrastructure to federal standards. Simply put, the BMWED provides a mobile construction and maintenance team on behalf of the nation's railroads.

Workplace health hazards

For the mortality and morbidity analysis we reviewed the published literature seeking to understand what railroad exposures might be linked to increased risks. MOW workers are exposed to diesel exhaust, creosote, asbestos, silica (ballast) and cement dusts, solvents, electromagnetic fields, welding fumes, high levels of vibration, PCBs, and herbicides. In our report we listed the MOW exposures and possible health effects or causes of death linked to them. BMWED members work in close proximity to rolling equipment and thus at risk for higher rates of traumatic injury deaths and transportation injuries. We conducted standardized mortality ratio (SMR) analysis of deceased BMWED members who were aged age 65 years or less at the time of death, and we also examined mortality rates in a proportional mortality ratio (PMR) analysis that permitted us to examine all workers, regardless of age. We also used a survey of approximately 4,800 union (BMWED) members in order to assess the associations between job history and injury and disease risk. As far as we know, this is the first mortality and morbidity analysis of national MOW workers in the U.S.

All Causes of death and non-cancer findings

We found that BMWED members between 18 and 64 years old (active workers) have a 1.6 times greater likelihood of dying from all causes of death compared to the U.S. male population. In general, this means that there are 60% more deaths from all causes among this non-retired group than we expect. Since there are so many causes of death that significantly exceed a SMR of 1.00, we will focus on those near or exceeding a doubling of risk (an SMR greater than 2.00). Our results demonstrate that septicemia shows a SMR of 2.19; Parkinson's and Alzheimer's diseases both show elevated SMRs of 3.09 and 7.15, respectively; hypertensive and atherosclerotic heart disease both show elevated SMRs of 2.11; chronic lower respiratory disease (including chronic obstructive pulmonary disease--COPD) has a SMR of 1.89; kidney disease or nephritis produced a SMR of 2.57; and transportation accidental deaths have a SMR of 3.27 (95% CI: 3.08, 3.46). Non-transportation accidents, such as fatal falls or deaths at home, produced a SMR of 1.96.

Cancer mortality findings

Our research examined the cancer causes of death among male BMWED members aged 18 to 64. When combined, all cancers showed an SMR of 1.79. This means that there is nearly 80% more cancer deaths than we expect from this group of men who have not yet reached age 65, normal retirement age in the U.S. Stomach cancer and colo-rectal cancers produced risk levels close to or exceeding 2.0, with SMRs of 2.06 and 1.99, respectively. Liver cancer had an SMR of 2.36; pancreatic cancer produced an SMR of 2.17; lung cancer had a SMR of 1.82; prostate cancer had an SMR of 1.93; bladder cancer produced an SMR of 1.95; among the blood/lymph cancers only leukemia had a SMR of 1.96; *in situ* cancers had a SMR of 2.1. We examined the silica and asbestos related deaths such as silicosis (SMR 1.42), mesothelioma (SMR 1.62), and asbestosis (SMR 2.05), but there were too few deaths for reliable findings (Tan and Goldsmith, 2018).

Previously published studies of diesel exposed railroad workers have found excess risk for lung cancer (Benbrahim-Tallala et al., 2012, consistent with IARC labeling diesel exhaust as a known human carcinogen) and for chronic obstructive pulmonary disease (COPD) [Hart et al., 2009; ATS, 2016]. Our study of BMWED members confirms both of these risks, with an SMR for lung cancer of 1.82 and an SMR of 1.89 for COPD.

We examined the SMRs over time in four groups, 1979 - 1987, 1988 - 1996, 1997 - 2005, and 2006 – 2014 to assess if there are trends for health risks. All-cause mortality shows no clear trends over the four time periods, with an SMR of 1.45 in the period 1979 to 1987 and an SMR of 1.64 in 2006 to 2014. Similar findings are seen for all heart disease. By contrast, the SMR risk for chronic lung disease or COPD has risen from 0.52 in 1979 - 1987 to 2.91 in 2006 - 2014. A similar trend was observed for all malignant neoplasms, although not as striking. The trend for kidney disease/nephritis suggests an increasing SMR, although in the 2006 - 2014 period the SMR is barely greater than 1.00. The SMR for transport accidents demonstrates a very clear decline among BMWED members, with an SMR of 1.44 in 1979 - 1987 decreasing to an SMR of 0.32 in 2006 - 2014.

In order to examine the mortality risks for workers in the active and retired ages, we also calculated the proportionate mortality ratio (PMR). The PMR asks if the observed mortality has a greater fraction of cause of death than the general U.S. male population. Furthermore, we undertook the calculate PMRs in order to determine if death patterns for all ages are consistent with those in the active years, ages 18 to 64. It does appear for certain diseases and cancers the SMR and PMR findings have parallel mortality excesses. Examples include septicemia (SMR=2.19; PMR=1.21); anemias (SMR=1.60; PMR=1.22); diabetes (SMR=1.57; PMR=1.36); chronic lower respiratory disease or COPD (SMR=1.89; PMR=1.04 [borderline]); nephritis (SMR=2.50; PMR=1.18); transport accidents (SMR=3.27; PMR=1.70). Among cancers, we found all malignant neoplasms (SMR=1.79; PMR=1.03 [borderline]); esophageal cancer (SMR=1.82; PMR=1.10); stomach cancer (SMR=2.06; PMR=1.26); colorectal cancers (SMR=1.99; PMR=1.06); lung cancer (SMR=1.82; PMR =1.05); prostate cancer (SMR=1.93: PMR=1.06 [borderline]); kidney cancer (SMR=1.75; PMR=1.14) and in situ cancers (SMR=2.11; PMR=1.05 [borderline]). Two very interesting excess SMRs were not seen in the PMR assessment—Alzheimer's and Parkinson's disease.

Case-control findings from survey of membership

We conducted a survey assessment that offered the opportunity to analyze the associations between self-determined cases of disease and MOW work area exposures. In order to examine patterns of workplace illness and injury, we have calculated case-control estimates (see Checkoway et al., 2004; Breslow and Day, 1987) linking specific jobs and positive responses to the question about whether a physician or health provider indicated the BMWED member had a selected group of conditions, including some common cancers. (Goldsmith and Frasketi, 2018). We asked if these conditions were diagnosed by a physician or health care provider in order that union members would not self-diagnose their conditions, though we have no medical records to validate their responses. The measure we are calculating is called the odds ratio (OR); OR is a very good approximation of the relative risk (RR). The RR is the risk of illness among the exposed compared to the same risk among the unexposed. However when calculating the OR, we are asking if the cases of disease have more exposure to a work area than that of controls (the non-cases). And for this analysis, controls are all BMWED members who do not have the disease or condition we are analyzing.

We have calculated two types of ORs, one is called 'crude' because we are simply asking if the cases have spent more time in the job/work area than controls; the second is adjusted for known/assumed confounding factors. Those include current age of BMWED member, ethnicity, and smoking. There are some conditions such as prostate cancer, melanoma, and Parkinson's disease where smoking plays no role and smoking has not been adjusted. We also decided not to calculate the OR when there were fewer than 7 cases because that would lead to very small numbers of study subjects producing unreliable findings. We included only statistically significant findings, but the text will focus only on results producing an elevated risk with 95% CIs excluding a value of 1.0.

There are several work classifications showing elevated risk for high blood pressure, high cholesterol, and high risks for arthritis: Surfacing Gang workers, Foreman, Track Inspectors, Roadway equipment operators, and Bridge and Building workers for hypertension and arthritis only. These results will be discussed in detail by Doctors Landsbergis and Johanning in their report. We found that the Surfacing Gang workers and Track Inspectors had an elevated OR for tingling in hands and legs; Welders and Bridge and Building had higher risks for memory issues and forgetfulness. Track Inspectors and Foremen had elevated risks for melanoma, and Track Inspectors had increased risk for bladder cancer. Prostate cancer showed elevated ORs for Bridge and Building and Roadway equipment mechanics. There were a variety of acutely elevated injury ORs among MOW workers for foot/ankle, back, shoulder, knee, head, and neck. The most striking was an adjusted OR of 14.88 for injuries to the trunk among Electric Traction workers (see Frasketi and Goldsmith, 2018).

Comparisons with Prior Health Studies with Findings from Railroad Workers

We are not aware of prior health studies of U.S. MOW workers, though there have been studies of other railroad craft workers with some similar exposures. Previously published studies of diesel exposed railroad workers have found excess risk for lung cancer (Benbrahim-Tallala et al., 2012, consistent with IARC labeling diesel exhaust as a known human carcinogen) and for chronic obstructive pulmonary disease (COPD) [Hart et al., 2009; ATS, 2016]. Our study of BMWED members confirm both of these risks, with an SMR for lung cancer of 1.82 and an SMR of 1.89 for COPD. MOW workers are also exposed to asbestos and to silica dusts (both known as IARC known human carcinogens), and they produced excess risks for lung cancer and COPD. Furthermore, diesel exposure in combination with silica and/or asbestos dusts may be the causal explanation. We know from our survey that 48.3% of responders were current or past smokers, and smoking can play a role in many excess tumor findings. Other tumor sites such as bladder cancer may be related to workplace exposure to creosote or other polycyclic aromatic hydrocarbons (PAH) [Rota et al., 2014], which are common among MOW workers. Exposure to pesticides and herbicides may be linked with prostate cancer excesses (Alavanja et al., 2003; Krstev et al. 1988) and soft tissue sarcomas in Scandinavian rail workers (Hardell, 1993). A prior study of Swiss railroad workers exposed to electromagnetic radiation (Roosli M et al. (2007) suggested a link with neurological diseases—a finding we duplicated among active workers with Parkinson's and Alzheimer's diseases both showing elevated SMRs of 3.09 and 7.15, respectively. We should assess the possible role of welding fumes related to Parkinson's disease. An elevated SMR of 2.57 for kidney disease/nephritis in this cohort may be a reflection of high exposure to silica dust from ballast. Several SMR excesses for oral, esophageal, stomach, kidney and colorectal cancers may be related to high exposures to asbestos and to silica dusts.

Working Conditions and Other Health Risks

There are excess SMRs for septicemia, diabetes, hepatitis, liver disease, and suicide among deceased MOW workers (ages 18-64) that seem to lack any clear connection to work exposures among BMWED members. We are continuing to seek evidence from other studies of railroad workers to explain these health outcomes. Some increased cancer risks for pancreatic, liver, brain, Hodgkin's disease, and lymphatic cancers may be associated with paint fumes and possibly high solvent (including benzene and cleaning solvent) exposures.

Introduction

The text below describes the research we undertook to describe the health and mortality of BMWED members. Our study included a review of the known and presumed right of way exposures and their health effects; the mortality studies examining non-cancer and cancer findings; the results of our membership survey and allied health problems; and recommendations for future work.

Background literature of hazardous exposures among Railroad workers

The BMWED is a national union, affiliated with the International Brotherhood of Teamsters, representing the workers who build, inspect, and maintain the tracks, bridges, buildings and other structures on railroads throughout the United States. Railroad track workers (i.e., maintenance-of-way (MOW) workers) are employed in road gang crews on approximately 300,000 miles of railroad track across the United States. When there is any sort of railroad emergency or where the track bed, bridges or related infrastructure are damaged or require regular maintenance, BMWED members provide the skilled workforce to restore the rail infrastructure to federal standards. Simply put, the BMWED provides a mobile construction and maintenance team on behalf of the nation's railroads.

The BMWE was chartered in 1887. In 2004, the BMWE merged with the International Brotherhood of Teamsters to become a Division of the Teamster Rail Conference. Employment of railroad maintenance-of-way workers in the U.S. peaked in 1927 at over 416,000. By the mid 1950's membership had fallen to approximately 225,000. BMWED currently has approximately 35,000 members. Automation, MOW worker productivity, the rise of trucking and airline transportation, and the split of Canadian workers has reduced both potential and enrolled membership.

Over the past two years Dr. David Goldsmith has led a team of research investigators to examine the health of BMWED members. This effort has been divided into two projects, one that has studied the causes of death among deceased BMWED members from 1979 to 2014 and a second that has assessed the links between health effects and MOW work via a union-wide survey. The survey has provided information on the frequency of injuries and illnesses among the current membership. We have used replies to the survey to analyze the association between certain injuries and illnesses and past railroad exposure, consistent with job exposures of BMWED members.

For the mortality analysis we reviewed the published literature seeking to understand which railroad exposures might be linked to increased risks. MOW workers are exposed to diesel exhaust, asbestos, silica (ballast) and cement dusts, solvents, electromagnetic fields, creosote, welding fumes, high levels of vibration, and herbicides. BMWED members work in close proximity to moving trains and MOW equipment and thus have higher rates of traumatic injury and death from transportation accidents.

Workplace health hazards

Table 1 provides a broad assessment of common MOW and railroad exposures and some possible health problems or excess causes of death.

Table 1: MOW Exposures and Known Health Effects	
Railroad Exposures	**Health Effects**
Diesel Fumes and Exhaust	Lung cancer, COPD
Welding fumes	Parkinson's & other neurological conditions
Silica ballast dust	Lung diseases (COPD), silicosis, lung cancer, auto-immune diseases, kidney disease
Creosote, Organic solvents & polycyclic aromatic hydrocarbons (PAHs)	Dermatitis, lymphatic cancers & neurological conditions, bladder cancer & melanoma
Polychlorinated Biphenyls (PCBs)	Lymphatic cancers & melanoma
Electromagnetic Fields	Lymphatic & brain cancers & melanoma & neurological conditions; electrocutions
Heavy rolling equipment	Traumatic injury & death
Asbestos	Asbestosis, lung & esophageal cancers, & mesothelioma
Herbicides	Prostate & lymphatic cancers, soft tissue sarcomas
Vibration	Musculoskeletal disorders including Carpal Tunnel Syndrome, Tendinitis, Back ailments, deafness

The sections below describe both the lengthy list of health problems possibly linked with railroad employment as well as the disease risks associated with some of the most common hazards MOW workers are exposed to. It is important to keep in mind that studies of common MOW hazards come from studies of workers from other industries such as silica and asbestos exposed employees.

General railroad employment and chronic diseases

Krstev et al. (1988) conducted a study of prostate cancer risk among residents of Atlanta, Detroit, and 10 counties in New Jersey with cancer registries. They reported an odds ratio (OR) of 5.85 (95% CI 1.25, 27.4) for the occupation of long term railroad line haulers. There were no studies of a general category of railroad workers for emphysema, nasopharyngeal or kidney cancers.

Silica dust exposure

Silica exposure and kidney cancer

Karami and colleagues (2011) undertook a large hospital based case-control study of kidney cancer among nephrology clinics in Central and Eastern Europe. There were 1097 renal cell cancers and 1476 controls. They found a risk of 1.0 for sand and crystalline silica exposure. However, they reported an OR for brick dust exposure (with high silica content) of 1.5 (95%CI 1.0, 2.4), and the risk rose as duration of exposure and cumulative exposure was measured (p for trend <0.05).

Attfield and Costello (2004) examined the mortality risks of 5,414 Vermont granite workers with health records on file in the Vermont Department of Health having well documented exposure to silica dust from 1950 to 1994. They found a standardized mortality ratio (SMR) of 1.37 for kidney cancer that produced a dose-response gradient among the eight cumulative exposure groups.

Pukkala and co-workers (2009) conducted an exhaustive study of occupational cancer incidence among 15 million residents of five Nordic countries from 1960 to 2004. The authors calculated standardized incidence ratios (SIR) for four occupational groups of interest—miners and quarry workers and smelting workers (having silica exposures in common), and transport workers and drivers (having diesel exhaust in common). For miners and quarry workers there was a SIR for kidney cancer of 1.07 (95% CI 0.95, 1.21), and a SIR for smelter workers of 1.07 (95% CI 1.00, 1.15).

Silica exposure and nasopharyngeal cancer

Pukkala et al. (2009) provides the only assessment of this association. For cancer of the pharynx, miners and quarry workers had a SIR of 0.71 (95% CI 0.50, 0.99), while smelting workers had an SIR of 0.99 (95% CI 0.85, 1.15). For nasal cancer the SIR for miners and quarry workers was 0.72 (95% CI 0.37, 1.25) and for smelter workers the SIR was 1.20 (95% CI 0.93, 1.53).

Silica dust exposure and prostate cancer

Pukkala and colleagues (2009) examined these links in their study. Miners and quarry workers had an SIR of 0.89 (95% CI 0.85, 0.94), and smelter workers had an SIR of 0.95 (95% CI 0.92, 0.98).

Silica dust and lung cancer risk

It is important to recognize that the evidence for silica's carcinogenicity has been reviewed three times by the International Agency for Research on Cancer (IARC) in 1987, 1997 and 2012 (IARC, 1987; 1997; 2012), California's Proposition 65 in 1988 (Proposition 65, 1988), by the National Toxicology Program in 2000 and reaffirmed in 2011 (NTP, 2000; 2011), by the National Institute for Occupational Safety and Health (NIOSH, 2002), and by the Occupational Safety and Health Administration (OSHA, 2016). Even though there are associations between silica dust exposure and other cancer sites, lung cancer has been examined in almost every assessment. All of these authoritative agencies have found that silica dust exposure is clearly linked with an increased risk of lung cancer. Seen in this context, silica dust is considered a known human carcinogen like well-known hazards such as asbestos, smoking, and arsenic. Ballast dust and cement dust exposure are the routes by which MOW workers are exposed to quartz.

Critics of the ties between silica exposure and lung cancer want to argue that silicosis is a required precursor to any finding of lung cancer, and that any lung cancer finding is the result of fibrotic processes and <u>not</u> a function of silica dust exposure. That concept was rebutted by a very large Chinese study by Liu (2013) of a cohort of 34,000 tungsten and iron miners and ceramic workers. The authors excluded 427 known lung cancer cases among workers with silicosis, and analyzed the remaining 119 employees with lung cancer but who did <u>not</u> have silicosis. They found a dose-response relative risk for workers based on cumulative quartiles of silica exposure that ranged from 1.12, to 1.41, to 1.58 to 1.70. These authors also studied a group of nonsmokers, comparing those with high and low cumulative silica exposure. This led to a significant relative risk of 1.60 (95% CI 1.01, 2.55) in the high exposure group compared to the low exposure group. And for highly exposed smokers the relative risk was 5.07 (95% CI 3.41, 7.52). In any cohort study of silica exposed workers, it is generally not knowable who has or does not have silicosis or smoking status when lung cancer is diagnosed (that is the case in our study of BMWED members). However the Liu et al. research study enables the scientific community to see that workers with silicosis and those without silicosis both have increased risks for lung cancer (Steenland and Ward, 2014; OSHA, 2016).

The large Chinese study by Liu et al. shows a similar pattern as seen by Steenland and colleagues (2001) who examined 10 large silica-exposed worker cohorts from U.S., Europe, China, and South Africa—all characterized by very high quality dust measurements and comprehensive determination of lung cancers. These authors found increasing pooled relative risks for lung cancer for cumulative quintile categories of silica dust exposure: 1.0, 1.0, 1.3, 1.5, 1.6 that spanned the lowest exposure to the highest

There is strong evidence that silica dust exposure demonstrates dose-response patterns among nonsmokers with lung cancer. Zeka and co-workers (2006) conducted a multi-centered case-control study of 223 nonsmokers with pulmonary cancer and 1039 non-lung cancer controls from 16 hospital centers throughout Europe and the UK. These authors demonstrated that exposure to silica dust produced an adjusted odds ratio (OR) from up to 8 years exposure of 1.20 (95% CI 049, 2.92) with an OR of 2.39 (95% CI 1.11, 5.15) for exposure greater than 8 years. For cumulative intensity exposure of up to 42.1 frequency index-years, the OR was 1.11 (95% CI 0.43, 2.88), while it was 2.45 (95% CI 1.15, 5.20) for greater than 42.1 1 frequency index-years. In both cases zero exposure was the referent category.

Kachuri and co-workers (2014) undertook a population-based lung cancer case-control study in eight Canadian provinces between 1994 and 1997. The authors adjusted for smoking, lifetime second-hand smoke, fuel emissions. They found a significant increased risk for exposure to silica greater than 30 years, OR=1.67 (95% CI 1.21, 2.24); the highest tertile (third category) of cumulative silica exposure produced an OR=1.81 (95% CI 1.34, 2.42). The probability of significant trends was less than 0.004. The highest levels of smoking and silica exposure produced a synergistic risk of lung cancer with an OR=42.53 (95% CI 23.54, 76, 83).

Gallagher and colleagues (2015) updated the cohort of California diatomaceous earth workers from 1993 to 2011 studied earlier by Checkoway and co-workers. These authors calculated hazard ratios (same as relative risks) for lung cancer for the period from 1942 to 2011. Their findings are very important because they had very good control for smoking, strong industrial hygiene data with high silica (cristobalite) exposure, and very low confounding from other pulmonary carcinogens. Furthermore, they examined workers' silicosis risk separately from the lung cancer analysis, so the authors excluded workers with silicosis and other chronic lung disease from their study of lung cancers. They found a borderline trend for lung cancer with increasing exposure, adjusting for ethnicity, age, and calendar year regardless of whether there was no lag, 10 year lag or 15 year lag. They did report significant hazard ratios above 2.0 for exposures greater than 5.6 mg/m3-years, lower 95% CI that did not contain the value 1.0.

OSHA (2016) in its recent workplace silica dust standard examined whether there was sufficient evidence for silica dust to be a human carcinogen, and whether silicosis could be an explanation for increased risk of lung cancer. OSHA concluded that silica dust exposure was a known human carcinogen based on hundreds of epidemiology studies and based on the authoritative assessments by IARC, the National Toxicology Program, and the National Institute for Occupational Safety and Health (NIOSH). The Agency considered the question of whether silicosis was necessary before finding silica exposure caused the lung cancer from both an experimental animal as well as epidemiology perspective. OSHA "….concluded that available animal and *in vitro* studies do not support the hypothesis that development of silicosis is necessary for silica exposure to cause lung cancer." When considering the epidemiology evidence, OSHA "….. concluded that the more recent [epidemiology] pooled and meta-analyses do not provide compelling evidence that silicosis is a necessary precursor to lung cancer."

Diesel exhaust and diesel fuel exposure

It is critical to note that diesel exhaust has been evaluated by the International Agency for Research on Cancer (IARC). Based on several studies summarized by IARC, diesel exhaust and particulate has been judged to be a known human carcinogen (Benbrahim-Tallala et al., 2012). The tumor site where this consensus finding emerged was for lung cancer (Attfield et al, 2012 and Silverman et al, 2012).

Diesel exhaust exposure and kidney cancer

Attfield and colleagues (2012) conducted a cohort mortality study of 12,315 U.S. miners exposed to diesel exhaust at eight nonmetal mines. For the total cohort, the standardized mortality ratio (SMR) for kidney cancer was 0.98 (95% CI 0.54, 1.64); for those who ever worked underground, the SMR was 1.11 (95% CI 0.53, 2.04); and for surface-only miners the SMR was 0.76 (95% CI (0.21, 1.95).

Pukkala et al. (2009) reported that transport workers had a SIR of 1.09 (95% CI 1.03, 1.16), and drivers had a SIR of 1.13 (95% CI 1.09, 1.18).

Jarvholm and Silverman (2003) studied Swedish truck drivers and heavy construction operators between 1971 and 1992. They reported an SIR for kidney cancer of 1.12 among truck drivers and 0.74 among heavy construction machinery operators.

Siemiatycki et al. (1987, 1988) conducted a case-control analysis of 181 patients with kidney cancer and 2196 controls from 19 Montreal hospitals. From questionnaire replies, occupational exposures were determined to diesel fuel and to diesel exhaust. This produced an OR of 1.4 (90% CI 0.8, 2.3) for exposure to diesel fuel; for exposure to diesel exhaust, this lead to an OR of 0.9 (90% CI 0.7, 1.3). For both risk calculations, these were adjusted for age, ethnicity, socioeconomic status, smoking, and job 'dirtiness'.

Guo and colleagues (2004) followed the Finnish population from 1971 to 1995 and examined the cancer incidence based on record linkage with the Finnish Cancer Registry. They evaluated exposure to diesel exhaust using a national job exposure matrix from 1945 to 1984. Kidney cancer incidence among men was examined for the following exposed occupations that had >1/3 of the work group exposed to diesel: locomotive engine drivers, SIR= 1.11 (95% CI 0.71, 1.66); road building vehicle drivers, SIR= 0.97 (95% CI0.50, 1.69); bus drivers, SIR=1.29 (95% CI 1.00, 1.64); taxi drivers, SIR=1.39 (95% CI 1.06,, 1.79); car mechanics, SIR=1.04 (95% CI 0.76, 1.38); forklift drivers NEC, SIR=0.92 (95% CI 0.51, 1.51); road building machine operators, SIR=1.65 (95% CI 1.11, 2.36); construction machine operators NEC, SIR=0.89 (95% CI 0.52, 1.42); dock workers, SIR=0.98 (95% CI 0.63, 1.45); freight handlers, SIR=0.97 (95% CI 0.54, 1.61); and road building laborers, SIR=1.15 (95% CI 0.37, 2.68). The authors examined exposure-response for diesel exposure, and found no trend; only the lowest level of exposure, <2.0 mg/m3 years showed a significant RR=1.17 (95% CI 1.05, 1.30).

Soll-Johanning et al. (1998) studied the cancer risk among 18,174 Danish bus and tramway drivers with diesel exposure from 1900 to 1994. Drivers' cancer was determined by record linkage to the Danish Cancer Registry. For those males employed for more than 3 months, the SIR was 1.6 (95% CI 1.3, 2.0). There was no clear trend for increasing risk according to time of first employment.

Boffetta et al (2001) examined the cancer incidence among Swedish workers of both genders exposed to diesel emissions from 1960 to 1989. For men there was a significant SIR of 1.06 for kidney cancer.

Wong et al. (1985) conducted a cohort mortality assessment among 34,156 male members of the Western states International Union of Operating Engineers (IUOE) union between 1964 and 1978. Their mortality was compared with U.S. male death rates from 1964 to 1978. This union's members use heavy diesel equipment daily. The SMR for kidney cancer was 0.74 (95% CI 0.43, 1.18).

Diesel exhaust exposure and nasopharyngeal cancer

The only specific study of this combination of exposure and cancer was by Boffetta et al. (2001). These authors reported that there was a risk of oral/pharyngeal cancer among women exposed to diesel that produced a significant SIR of 1.64; there was a suggestion of a dose-response gradient among this group. Soll-Johanning et al. (1998) studied the pharyngeal cancer risk among Danish bus and tramway drivers with diesel exposure. They reported a SIR of 1.9 (95% CI 1.2, 2.8)

Diesel exhaust exposure, farming, and prostate cancer

Attfield and colleagues (2012) undertook a cohort mortality study of 12,315 U.S. miners exposed to diesel exhaust at eight nonmetal mines. For the total cohort, the SMR for prostate cancer was 0.85 (95% CI 0.60, 1.16); for those who ever worked underground, the SMR was 1.00 (95% CI 0.66, 1.46); and for surface-only miners the SMR was 0.61 (95% CI (0.31, 1.10).

Seidler and colleagues (1998) using a case-control design of 192 cases and 210 controls, examined the risk of prostate cancer among patients from Hamburg and Frankfort, Germany. A self-administered questionnaire was used to assess diesel exposure. There was a gradient of exposure to diesel fuel and fumes that rose from 1.0 for zero exposure to 1.1 for >0 to 25 dose-years, to 3.7 for >25 dose-years (95% CI 1.4, 9.8). These results were adjusted for age, smoking and region of Germany.

Soll-Johanning et al. (1998) studied the prostate cancer risk among Danish bus and tramway drivers with diesel exposure, and they reported a SIR of 1.1 (95% CI 0.9, 1.3).

Wong et al. (1985) conducted a study of Western states International Union of Operating Engineers (IUOE) between 1964 and 1978. The standardized mortality ratio (SMR) for prostate cancer was 0.87 (95% CI 0.61, 1.20).

Fritschi and co-workers (2007) conducted a population based case-control study of prostate cancer. Study subjects were collected from the Western Australia Cancer Registry and controls were randomly selected from the Western Australia electoral rolls over the period January 2001 to August 2002. There were 606 cancer cases and 471 controls; occupational data were obtained from questionnaires. Age-adjusted ORs were 1.0 for not exposed to diesel fumes; 0.92 (95% CI 0.71, 1.19) for non-substantial exposure, and 1.07 (95% CI 0.67, 1.72) for substantial exposure.

Alavanja et al. (2003), in their Agricultural Health Study, found that several herbicides were linked with elevated risks for prostate cancer, especially so among those men with a family history of prostate cancer. The ORs ranged from 1.28 to 1.78 (95% CI 1.16, 2.73) for use of butylate thiocarbamate herbicide among North Carolina and Iowa farmers.

Parent and colleagues (2009), using the Montreal data developed by Siemiatycki at McGill (see above) studied prostate cancer risk among farmers. Their study groups included 49 men with prostate cancer and 183 controls from the 1980s, and all had to have had farming in their work history. Exposure data were obtained from face-to-face interviews. For farmers using diesel equipment, there was an OR of 5.7 (95% CI 1.2, 26.5).

Silica and diesel exposure and Chronic Obstructive Pulmonary Disease (COPD)

Wong and colleagues (1985) conducted a cohort mortality study of members of IUOE between 1964 and 1978 (see above). This union's members use heavy diesel equipment and they are exposed to silica as well, similar to BMWED members. The standardized mortality ratio (SMR) for emphysema was 1.65 (95% CI 1.36, 1.98).

Stern and Haring-Seeeney (1997) conducted a study similar to that of Wong et al. They examined 15,843 members of the IUOE who died from 1988 to 1993. These authors calculated a proportional mortality ratio (PMR), using the U.S. mortality as a referent. They found that emphysema had a significant PMR of 1.37 (95% CI 1.20, 1.55)

Goldsmith et al. (1995) followed a group of 590 workers who claimed they had silicosis (and thus high silica exposure) from 1946 to 1975, with follow-up until 1991, using data from the California Workers Compensation Appeals system. The SMR for emphysema was 3.41 (95% CI 2.02, 5.39).

Hnizdo and colleagues (1991) conducted a retrospective cohort study of emphysema in 1,553 white South African gold miners with autopsies between 1974 and 1987. The authors adjusted for smoking in their analysis. They reported that there was a 3.5 relative risk (RR) (95% CI 1.7, 6.6) that miners with 20 years of dusty employment would have a risk for emphysema at autopsy in contrast with miners without a dusty job.

These four studies are consistent with a broad body of literature that shows that miners and operating engineers with silica and diesel exposure have excess risks for emphysema (Hnizdo and Vallyathan, 2003; NIOSH, 2002).

Cancer Findings

Epidemiology studies of esophageal cancer

Esophageal cancer is the 6th most common cancer cause of death and the 8th most common cancer diagnosis in the world (Roshandel et al., 2012); and it tends to be a male disease (Blot et al., 2006). We examined the epidemiology research studies on esophageal cancer, with a particular focus on exposures to diesel exhaust, polycyclic aromatic hydrocarbons (PAHs) [including creosote], and asbestos. The interest in PAHs is because diesel exhaust is a category of PAHs, and studies of diesel exposed workers may not be sufficiently large to detect associations.

We did not find any published studies with significant links between esophageal cancer and diesel or railroad exposure.

Epidemiology research on asbestos-related cancers and asbestosis

Studies of asbestos-exposed insulation workers have led to an understanding that exposure is linked to excess mortality from asbestosis, lung cancer and mesothelioma (Selikoff et al, 1979). In addition, Selikoff and colleagues found SMRs greater than 2.00 for all cancer, for cancer of the esophagus, kidney cancer, liver cancer in the follow-up study of 17,800 unionized insulation workers. Berry and co-workers (2000) found similar results among asbestos workers in London's east end, consisting of 3700 men and women and 1400 asbestos insulators. They found the following causes of death produced SMRs greater than 2.00 for all cancers, esophageal and small intestine cancers, neoplasms of liver, lung, and ovarian and uterine cancers among female asbestos workers. These authors found excesses of mesothelioma and asbestosis as well (Berry et al., 2000).

Epidemiology studies of colon, rectal, esophageal, and colorectal cancers

Colorectal cancer is the 3rd most common cancer cause of death and in 2015, there was an expected 133,000 cases of colorectal cancer in the U.S (American Cancer Society, 2015; Giovannucci and Wu, 2006). There is an approximate ratio of 10 to 4 colon versus rectal cancers in the U.S. We examined the epidemiology research studies on colorectal cancer, colon cancer and rectal cancer with a particular focus on exposures to diesel exhaust, polycyclic aromatic hydrocarbons (PAHs), and asbestos. The interest in PAHs is because diesel exhaust is a category of PAHs, and studies of diesel exposed workers may not be sufficiently large to detect associations.

Concerns first arose about asbestos and the link with colorectal cancers from the studies of 17,800 asbestos insulation workers undertaken by Selikoff et al. (1979). There were 58 recorded deaths from colorectal cancer among the nearly 18,000 asbestos workers, while only 38.1 deaths were expected, based on the U.S. white male rates for the U.S.as a whole. This produced a standardized mortality ratio (SMR) of 1.55 (based on best clinical evidence); the authors did not calculate 95% confidence intervals.

There was one published study with significant links between colon cancer and likely diesel exposure. That was a paper by Fang et al. (2011), which assessed the odds ratio (OR) of colon cancer among rail transport equipment mechanics and repairers—having a high likelihood of exposure to diesel exhaust. They reported an OR of 3.84 (95% CI 1.82, 8.11) based on 11 cases for ever being employed in this job. For those who reported this was their usual occupation, the OR was 6.06 (95% CI 2.04, 18.00) with 6 exposed cases (Fang et al., 2011).

Arbman and coworkers (1993) conducted a case-control study of colon cancer in Sweden. Asbestos exposure was ascertained from responses by cases and controls to a standard questionnaire. They reported a logistic regression OR of 2.8, adjusted for age and physical activity with a 95% CI of 1.3, 6.0 for asbestos exposure jobs. Railroad work also produced a logistic OR of 2.1 with 95% CI 0.8, 5.3.

Aliyu and colleagues (2005) studied the risk of colorectal cancer incidence from 1984 to 2004 among 3897 U.S. men enrolled in a beta-carotene and retinol chemoprevention trial. There were 85 new cases of colorectal cancer and their risk was contrasted with the unexposed men using a Cox proportionate hazards model. The authors reported an incidence risk (IR) of 2.0 with 95% CI 1.6, 2.5 for men exposed to asbestos. The colorectal cancer risk rose by severity category of radiographic abnormality ($p=0.03$). The clearest IR was found among ship scalers exposed to asbestos, producing a risk of 3.84, with 95% CI 1.05, 14.00. Other trades had IRs exceeding 2.0 including asbestos worker/insulator, shipfitter, and shipyard electrician.

Offermans et al. (2014) conducted a follow-up study of 7,565 exposed Dutch asbestos workers compared with 19,216 workers not exposed to asbestos from a national cohort of workers. The authors calculated hazard ratios (HRs) that adjusted for age, family history of colorectal cancer, education, vocational level, body mass index (BMI), alcohol, and smoking. When they examined workers ever highly exposed to asbestos they found a significant HR for rectal cancer of 2.15 (95% CI 1.23, 3.77), and a similar adjusted HR of 2.19 (95% CI 1.04, 4.62) for colon cancer for a median of 30.5 years of high asbestos exposure. The authors showed that results from both colon and rectal cancer followed a dose-respond trend with $p<0.05$.

Gerhardsson et al. (1992) conducted a population based case-control study of males with cancers of the colon and rectum from 1986 to 1988 in Stockholm, Sweden. The authors adjusted for age, and found a RR of 2.2, 95% CI 1.0, 4.7 for exposure to asbestos among rectal cancer cases and controls.

Concerns first arose about asbestos and the link with esophageal cancer from the studies of 17,800 asbestos insulation workers undertaken by Selikoff et al. (1979). There were 17 recorded deaths from esophageal cancer among the nearly 18,000 asbestos workers, while only 7.1 were expected, based on the U.S. white male rates for the U.S.as a whole. This produced a standardized mortality ratio (SMR) of 2.53; the authors did not calculate 95% confidence intervals.

Berry and colleagues conducted a SMR study of 5100 London asbestos workers of both sexes from 1933 to 1980 (Berry et al., 2000). The authors found there were 12 deaths from esophageal cancer, while the expected number was 5.78, producing a SMR of 2.08, with 95% CI of 1.07, 3.63). The expected numbers of deaths were estimated from the death rate from England and Wales.

Lin and co-workers (2014) conducted a follow-up study of 1539 Chinese asbestos miners and millers from 1981 to 2006. The authors used multivariable hazard ratio (HR) to examine the risks for three levels of asbestos exposure, adjusted for smoking status. They reported that the esophageal cancer risk rose from 1.0 at level 1 (lowest); the risk was 20.26 (95% CI 11.89, 43.62) at level 2 (medium risk); and 3.34 (95% CI 2.10, 5.33) for level 3 (highest).

Nadine et al. (2014) conducted a follow-up study of 7,565 exposed Dutch asbestos workers compared with 19,216 workers not exposed to asbestos from a national cohort of workers in Holland. The authors calculated HRs that adjusted for age, family history of esophageal cancer, and smoking. When they examined workers ever highly exposed to asbestos they found a significant HR for esophageal cancer of 2.20 (95% CI 1.00, 4.83), and a similar HR of 2.22 (95% CI 1.00, 4.94) when adjusting for smoking.

Santibanez and colleagues (2008) examined the esophageal cancer risk among male patients and controls seen at Spanish hospitals in the provinces of Alicante and Valencia from 1995 to 1999. When these authors calculated the odds ratio (OR), adjusted for age, province, education, alcohol intake, and smoking, they found that exposure to high levels of asbestos (> 0.26 fibers/cm3), the OR was 3.46 (95% CI 0.99, 12.10).

Bladder cancer and railroad employment

Bladder cancer accounts for approximately 6% of new cancer cases among men and 2% among women in the U.S. (Silverman et al, 2006) In the U.S. cancers of the bladder are more common among white males than any other gender or ethnic group. It is a disease that is reflective of smoking patterns in the same way lung cancer and heart disease are. Bladder cancer is much more common among those aged 50 years and older than is the case for younger persons. Bladder cancer has been linked with many different occupations and workplace exposures, including dyestuff workers, 2-naphthylamine and benzidine workers, rubber and tire manufacturers, leather workers, painters, and drivers of trucks and other transport vehicles (Silverman et al., 2006). This review will look in more detail at the evidence for diesel exhaust and PAH exposures. Use of industrial solvents is very common for painting and bridge and building work and many other MOW jobs.

PAH and Creosote Exposures

Burstyn and co-workers (2007) examined the risk of bladder cancer and PAH exposures among a group of 7298 asphalt pavers from Denmark, Norway, Finland and Israel from 1913 to 1999. The determination of bladder cancer was sought by matching the names of these men with national tumor registries and this led to finding 48 incident diagnoses from 1953 to 2005. Although cumulative exposure to PAH (using ng of benzo-a-pyrene[BaP]/m3) do not appear to be linked with bladder cancer, higher levels of PAH exposure was related to a 1.4 risk, and that risk was greater when a 15 year lag time was applied to the data, producing a 2-fold risk in the two highest exposure levels compared to the lowest level. Thus the risks (and 95% CIs) were 1.0 for average 0 to 99 ng/BAP/m3; for average exposure of 99 to 139 ng/BAP/m3 the RR was 1.53 (95% CI 0.54, 4.38); for 139 to 204 ng/BAP/m3 the RR was 2.71 (95% CI 1.01, 7.27); and >204 ng/BAP/m3 produced a RR of 1.90 (95% CI 0.66, 5.47).

Pesch et al. (2013) used a case-control study design to examine the risk between bladder cancer and PAH among a group of 754 patients and 833 controls in the European Prospective Investigation into Cancer and Nutrition (EPIC). Controls were cancer free subjects from the EPIC cohort and both cases and controls were defined from the years from 1992 to 2001. The authors divided the cohort into four exposure groups based on exposure to PAH among controls: never, low, medium, and high. The ORs (95% CI), adjusted for sex, age, region and smoking were for never OR of 1.0; for low the OR was 1.27 (95% CI 0.94, 1.63); medium 1.09 (95%CI 0.77, 1.54); and high the OR was 1.5 (95% CI 1.09, 2.05). They repeated that assessment and also adjusted for exposure to aromatic amines. They found for never an OR of 1.0; for low the OR was 1.20 (95% CI 0.87, 1.67); for medium the OR was 1.06 (95% CI 0.72, 1.57); and for high the OR was 1.38 (95% CI 0.92, 2.08). They reported that joint exposure to PAH and a history of smoking led to an OR of 3.48 (95% CI 2.51, 4.84); p value was 0.03.

Rotta and co-workers (2014) conducted a meta-analysis for PAH and bladder cancer that consisted of 13 published papers. There was a pooled RR for bladder cancer among aluminum workers of 1.28 (95% CI 0.98, 1.38) and pooled RR of 1.38 for iron and steel foundry workers (95% CI 1.00, 1.91). For asphalt workers the pooled RR was 1.03 (95% CI 0.82, 1.30) and for carbon black workers the pooled RR was 1.10 (95% CI 0.61, 2.00), though there were only two and three studies, respectively, for each of these two meta-analyses. For overall bladder cancer incidence/mortality the pooled SIR was 1.28 (95% CI 0.98, 1.68) for aluminum workers. The authors checked for publication bias, but did not find it for bladder cancer.

Concern about the cancer risks from creosote arose when a case study of skin cancer was published over a decade ago (Carlston et al., 2005). IARC had assessed creosote (or coal tar) as a 2A carcinogen on the basis of its ability to produce skin tumors in laboratory animals (IARC, 1998). Alicandro et al. (2016), using meta-analysis found that workplace exposure to creosote produced a meta RR of 2.01 (95 % CI 0.96-4.22) for non-Hodgkin's lymphoma, though this was based on only two published studies.

Mortality Study Findings of BMWED Members

BMWED members have had or now have exposure to diesel exhaust, welding fumes, creosote, herbicides, ballast (silica), cement, and asbestos dusts, solvents, heavy equipment vibration, and extreme weather conditions. Our initial hypotheses were that these workers would be at an elevated mortality risk for chronic pulmonary disease, kidney disease, neurological ailments, as well as cancers of the respiratory and digestive tracts, prostate cancer, and lymphatic cancers. These union members are also exposed to heavy equipment on rails and thus are at risk for traumatic injury and death compared to all other workers in the U.S.

Using membership data provided by the BMWED and ascertained by records of the U.S. Railroad Retirement Board (https://www.rrb.gov/), we submitted a request to the National Death Index

(NDI) to identify and provide cause of death data for all BMWED members, both active and retired from 1979 to 2014. When a match was found for name, gender, social security number, and date of birth, these persons were reported to us and their underlying cause of death was organized into groups according to their international classification of disease (ICD) code. We limited our study to males only because there were too few women for stable mortality risk calculations.

Using BMWED membership data from 1996--the midpoint of the follow-up period--we calculated standardized mortality ratios (SMRs) and 95% confidence intervals (95% CI) for males ages 18 to 64 (Gordis, 2009). We used SAS (2012) to analyze the mortality data in this study. An SMR is a ratio, adjusted for differences in age, between the observed number of deaths of BMWED members and the number of deaths that would be expected if BMWED members had the same age distribution as the U.S. male population. A mortality ratio greater than 1.0 indicates that there were more BMWED member deaths compared to what was expected from the U.S. population, while a mortality ratio less than 1.0 indicates that there were fewer deaths compared to what was expected. A mortality ratio equal to 1.0 indicates that the observed number of BMWED member deaths were approximately the same as what was expected from the U.S. population.

For this analysis, the data were organized into 10 year age groups, and we multiplied the BMWED population in 1996 for each age category by 36 years of follow up. We used the following age groups for our SMR analysis: 15 to 24 (although we know maintenance- of-way workers generally had to be at least 18 years old to work on a railroad), 25 to 34, 35 to 44, 45 to 54, and 55 to 64. This analysis focused on 11,190 deaths among active workers, not retirees (a study to assess mortality patterns for all ages up to ages 85 was undertaken [Barlet and Goldsmith, 2018]). We were confident the age structure of the BMWED membership was accurate from the ages of 18 to 55. However, many BMWED members let their BMWED membership lapse upon retirement (around ages 60-62), which was demonstrated by the undercount of dues-paying members ages 55 to 64. Therefore, we applied a correction to the 55 to 64 age group and assumed that BMWED members had the same age distribution as was found by a 1996 Bureau of Labor Statistics (BLS) survey showing that 11.2% of unionized male workers were actively employed (BLS, 1997) in these ages. Thus, while the BMWED listed 1,419 members in the 55 to 64 age category, we corrected that number to be 4,207 in our analysis. We used the 1996 age-specific death rates for males in the U.S. to calculate expected deaths for our cohort. We also examined trends in SMRs for certain causes of death to determine whether the risk was rising, declining or remaining static over the following four time periods: 1979 to 1987, 1988 to 1996, 1997 to 2005, and 2006 to 2014.

Tables 2 and 3 include the SMRs for non-cancer and cancer causes of death for male BMWED members from 1979 to 2014. For each cause of death, the observed and expected numbers of deaths are presented, along with the SMR and 95% CIs.

All Causes of Death and Non-Cancer Findings

Table 2: SMRs for Non-Cancer Causes of Death for Ages 18 to 64 Among BMWED Members, 1979 to 2014				
Causes of Death	**Observed Deaths**	**Expected Deaths**	**SMR**	**95% CI**
All causes of death	11,190	6,847.6	1.63	(1.60, 1.66)
HIV/AIDS	132	549.8	0.24	(0.20, 0.28)
Septicemia	95	43.5	2.19	(1.75, 2.63)
Viral hepatitis	59	37.1	1.59	(1.18, 1.99)
Diabetes	266	168.9	1.57	(1.39, 1.76)
Anemias	13	8.1	1.60	(0.73, 2.47)
Parkinson's disease	7	2.3	3.09	(0.80, 5.38)
Alzheimer's disease	13	1.8	7.15	(3.26, 11.04)
Cardiovascular disease	2,739	1,691.8	1.62	(1.56, 1.68)
Hypertension	47	22.3	2.11	(1.50, 2.71)
Cerebrovascular disease	308	212.1	1.45	(1.29, 1.61)
Atherosclerosis	23	10.9	2.11	(1.25, 2.97)
Chronic lower Respiratory disease	247	130.4	1.89	(1.66, 2.13)
Pneumonia	109	96.7	1.13	(0.92, 1.34)
Chronic liver disease	388	246.3	1.58	(1.42, 1.73)
Nephritis	92	36.8	2.50	(1.99, 3.01)
Transportation accidents	1,165	356.5	3.27	(3.08, 3.46)
Non-transport accidents	624	318.5	1.96	(1.81, 2.11)
Traumatic assault	289	179.6	1.61	(1.42, 1.79)
Complications of medical and surgical care	17	9.3	1.83	(0.96, 2.69)
Suicide	579	340.8	1.70	(1.56, 1.84)

As shown in Table 2, BMWED members between 18 and 64 years old have a 1.63 times greater likelihood of dying from all causes of death compared to the U.S. male population. We found there were 11,190 deaths for all causes among Brotherhood members, though we expected 6,848 deaths, assuming BMWED members had the same death rates as the U.S. male population. Since there are so many causes of death that significantly exceed a SMR of 1.00, we will focus on those near or exceeding a doubling of risk (an SMR greater than 2.00). Septicemia shows a SMR of 2.19 (95% CI: 1.75, 2.63); Parkinson's and Alzheimer's diseases both show elevated SMRs of 3.09 and 7.15, respectively, but due to the small number of expected deaths, only Alzheimer's disease is statistically significant (95% CI: 3.26, 11.04); hypertensive and atherosclerotic heart disease both show elevated SMRs of 2.11; chronic lower respiratory disease (including chronic obstructive pulmonary disease--COPD) has a SMR of 1.89 (95% CI: 1.71, 2.19); nephritis (or kidney disease) has a SMR of 2.57 (95% CI: 2.04, 3.09); and transportation accidental deaths have a SMR of 3.27 (95% CI: 3.08, 3.46).

Table 3 includes the cancer causes of death among active male BMWED members aged 18 to 64. When combined, all malignant neoplasms show a SMR of 1.79 (95% CI: 1.73, 1.86). Stomach cancer and colorectal cancers have risk levels close to or exceeding 2.0, with SMRs of 2.06 (95% CI: 1.64, 2.47) and 1.99 (95% CI: 1.76, 2.22), respectively; liver cancer has a SMR of 2.36 (95% CI: 1.95, 2.78); pancreatic cancer produced a SMR of 2.17 (95% CI: 1.84, 2.50); pulmonary (or lung) cancer had a SMR of 1.82 (95% CI: 1.71, 1.94); prostate cancer had a SMR of 1.93 (95% CI: 1.52, 2.34); bladder cancer had a SMR of 1.95 (95% CI: 1.35, 2.55); among the blood/lymph cancers only leukemia had a SMR of 1.96 (95% CI: 1.61, 2.32); in situ cancers had a SMR of 2.11 (95% CI: 1.48, 2.74). In order to examine the role of asbestos and silica dust exposure on the health of MOW workers, we calculated SMRs for asbestosis, mesothelioma, and silicosis. The SMRs were 2.44 for asbestosis, 1.42 for mesothelioma, and 1.62 for silicosis, but all 95% CIs contained the value 1.0 (Tan and Goldsmith, 2018). Thus, these findings are all hampered by small numbers of deaths.

Cancer Findings

Table 3: SMRs for Cancer Causes of Death for Ages 18 to 64 Among BMWED Members, 1979 to 2014

Causes of Death	Observed Deaths	Expected Deaths	SMR	95% CI
All malignant neoplasms	2,813	1,568.1	1.79	(1.73, 1.86)
Cancer of the lip, oral cavity	61	47.9	1.27	(0.95, 1.59)
Esophageal cancer	115	63.1	1.82	(1.49, 2.16)
Stomach cancer	95	46.2	2.06	(1.64, 2.47)
Colorectal cancer	282	141.6	1.99	(1.76, 2.22)
Liver cancer	124	52.4	2.36	(1.95, 2.78)
Pancreatic cancer	168	77.3	2.17	(1.84, 2.50)
Lung cancer	948	519.8	1.82	(1.71, 1.94)
Melanoma	54	44.6	1.21	(0.89, 1.53)
Prostate cancer	84	43.5	1.93	(1.52, 2.34)
Kidney cancer	89	50.8	1.75	(1.39, 2.12)
Bladder cancer	41	21.0	1.95	(1.35, 2.55)
Brain cancer	118	71.1	1.66	(1.36, 1.96)
Hodgkin's disease	17	9.0	1.88	(0.99, 2.78)
Non-Hodgkin's lymphoma	116	85.7	1.35	(1.11, 1.60)
Leukemia	118	60.2	1.96	(1.61, 2.32)
In situ neoplasms	43	20.4	2.11	(1.48, 2.74)

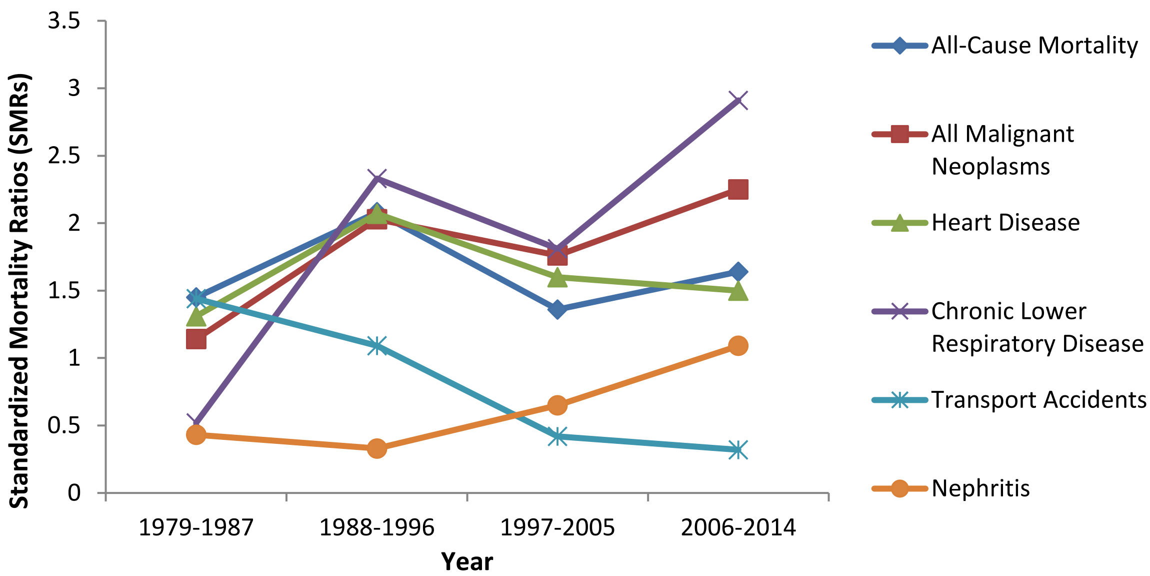

Figure 1

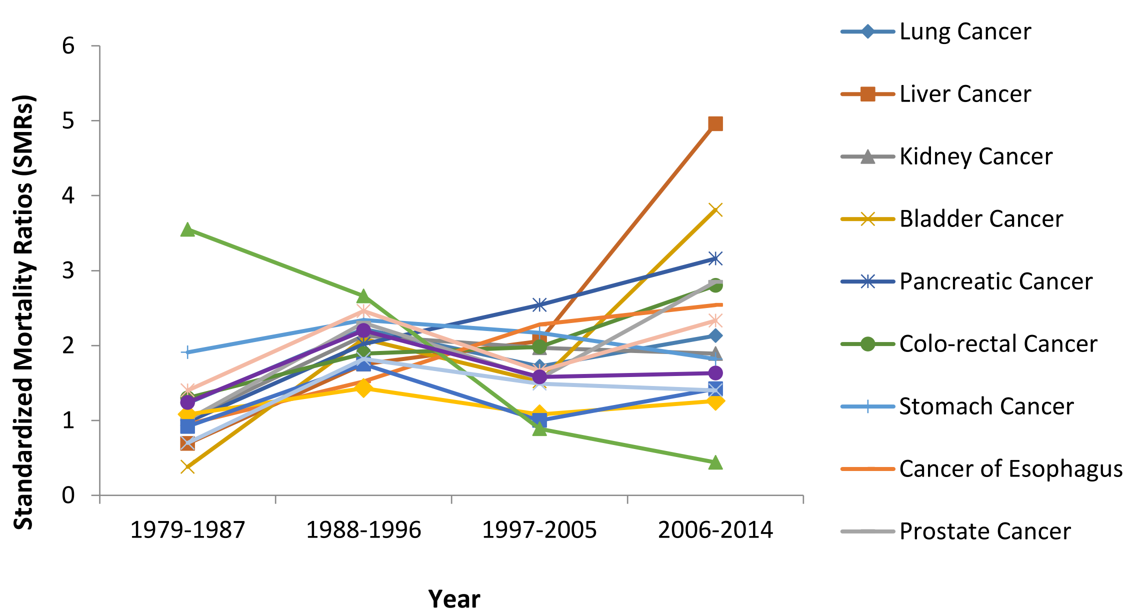

Figure 2

Figures 1 and 2 show the SMRs over time in four groups, 1979 - 1987, 1988 - 1996, 1997 - 2005, and 2006 - 2014. The first figure shows all-cause mortality, all malignant neoplasms, and non-cancer causes of death, while Figure 2 shows the trends for cancer causes of death. All-cause mortality shows no clear trends over the four time periods, with an SMR of 1.45 in the period 1979 to 1987 and an SMR of 1.64 in 2006 to 2014. Similar findings are seen for all heart disease. By contrast, the SMR risk for chronic lung disease has risen from 0.52 in 1979 - 1987 to 2.91 in 2006 - 2014. A similar trend was observed for all malignant neoplasms, although not as striking. This will be examined in further detail below. The trend for kidney disease/nephritis suggests an increasing SMR, although in the 2006 - 2014 period the SMR is barely greater than 1.00. The

SMR for transport accidents demonstrates a very clear decline, with an SMR of 1.44 in 1979 - 1987 decreasing to an SMR of 0.32 in 2006 - 2014.

Figure 2 shows that the risk trends for cancers of the bladder, pancreas, esophagus, liver, prostate and lung are rising during the four time periods of the study. The SMR for Hodgkin's disease is clearly trending down over the four time periods, and other cancers, including brain, leukemia, melanoma, stomach, non-Hodgkin's lymphoma, and oral cancers show no clear trends.

Proportionate Mortality Ratio Findings

The next phase of the mortality analysis was the proportionate mortality ratio (PMR) assessment (Barlet and Goldsmith, 2018) using all deaths and all ages at death. A PMR study is very similar to an SMR, with the exception that there is no underlying denominator of age specific BMWED membership, and what is being calculated is whether the proportion of BMWED deaths is greater or lesser than the proportional fraction of deaths in the U.S. male population (see Gordis 2009 and Breslow and Day, 1987). Calculating PMRs is relevant for two additional reasons: we wanted to examine whether the elevated SMRs parallel the PMRs and we wanted to analyze the very large numbers of deaths occurring in BMWED members aged 65 to 85+ years of age, keeping in mind we did not know the age distribution among union retirees.

Tables 4 and 5 summarize the PMR findings among BMWED members, with Table 4 listing all causes and noncancer causes of death, and Table 5 describing the cancer causes of death.

Table 4: PMRs for Non-Cancer Causes of Death for Ages 18 to 85+ Among BMWED Members, 1979 to 2014

Causes of Death	Observed Deaths	Expected Deaths	PMR	95% CI
All causes of death	37,661	37,661	1.00	(----, ----)
HIV/AIDS	139	360.0	0.39	(0.32, 0.45)
Septicemia	459	380.0	1.21	(1.10, 1.32)
Viral hepatitis	69	80.9	0.85	(0.65, 1.05)
Diabetes	1,206	886.9	1.36	(1.28, 1.44)
Anemias	72	59.0	1.22	(0.94, 1.50)
Parkinson's disease	234	239.3	0.98	(0.85, 1.10)
Alzheimer's disease	461	445.5	1.03	(0.94, 1.13)
Cardiovascular disease	11,216	12,023.3	0.93	(0.92, 0.95)
Hypertension	236	227.2	1.04	(0.91, 1.17)
Cerebrovascular disease	1,937	2,060.4	0.94	(0.90, 0.98)
Atherosclerosis	202	227.1	0.94	(0.77, 1.01)
Chronic lower Respiratory disease	1,919	1,850.7	1.04	(0.99, 1.08)
Pneumonia	963	1,058.3	0.91	(0.85, 0.97)
Chronic liver disease	598	575.1	1.04	(0.96, 1.12)
Nephritis	628	534.1	1.18	(1.08, 1.27)
Transportation accidents	1,331	783.0	1.70	(1.61, 1.79)
Non-transport accidents	1,068	1,009.5	1.06	(0.99, 1.12)
Traumatic assault	308	363.7	0.85	(0.75, 0.94)
Complications of medical and surgical care	48	41.9	1.15	(0.82, 1.47)
Suicide	716	718	1.00	(0.92, 1.07)

Table 5: PMRs for Cancer Causes of Death for Ages 18 to 85+Among Male BMWED Members, 1979 to 2014				
Causes of Death	**Observed Deaths**	**Expected Deaths**	**PMR**	**95% CI**
All malignant neoplasms	9,186	8,942.9	1.03	(1.01, 1.05)
Lip & oral cancers	148	177.3	0.83	(0.70, 0.97)
Esophageal cancer	305	278.2	1.10	(0.97, 1.22)
Stomach cancer	317	250.7	1.26	(1.13, 1.40)
Colorectal cancer	963	905.1	1.06	(1.00, 1.13)
Liver cancer	265	257.1	1.03	(0.91, 1.15)
Pancreatic cancer	452	463.6	0.98	(0.89, 1.06)
Lung cancer	2,947	2,806.6	1.05	(1.01, 1.09)
Melanoma	107	144.6	0.74	(0.60, 0.88)
Prostate cancer	1,073	1,016.9	1.06	(0.99, 1.12)
Kidney cancer	251	219.4	1.14	(1.00, 1.29)
Bladder cancer	237	278.3	0.85	(0.74, 0.96)
Brain cancer	183	203.3	0.90	(0.77, 1.13)
Hodgkin's disease	21	26.1	0.80	(0.46, 1.15)
Non-Hodgkin's lymphoma	338	330.4	1.02	(0.91, 1.13)
Leukemia	323	345.3	0.94	(0.83, 1.04)
In situ neoplasms	172	164.5	1.05	(0.89, 1.20)

It does appear from Tables 4 and 5 that for certain diseases and cancers the SMR and PMR findings have parallel mortality excesses. Examples include septicemia (SMR=2.19; PMR=1.21); anemias (SMR=1.60; PMR=1.22); diabetes (SMR=1.57; PMR=1.36); chronic lower respiratory disease (SMR=1.89; PMR=1.04 [borderline]); nephritis (SMR=2.50; PMR=1.18); transport accidents (SMR=3.27; PMR=1.70). Among cancers, we found all malignant neoplasms (SMR=1.79; PMR=1.03 [borderline]); esophageal cancer (SMR=1.82; PMR=1.10); stomach cancer (SMR=2.06; PMR=1.26); colorectal cancers (SMR=1.99; PMR=1.06); lung (SMR=1.82; PMR =1.05); prostate (SMR=1.93; PMR=1.06 [borderline]); kidney (SMR=1.75; PMR=1.14) and in situ cancers (SMR=2.11; PMR=1.05 [borderline]). Two very interesting excess SMRs were not seen in the PMR assessment—Alzheimer's and Parkinson's disease. However, almost every PMR produced a lower risk than was found using the SMR methods, which focused on active workers who were less than 65 years old.

Membership Survey Results

Close collaboration with BMWED leadership, study researchers, and BMWED safety officials led to the development of a health, safety and vibration survey that was administered to membership in 2016 and 2017. It was intended that the survey be completed online, but some members took the survey with the help of staff from Dr. Ruth Ruttenberg's research operation by phone. We used as a denominator for the survey the 3,851 members who completed the survey up to page 4. The first set of data focuses on replies to illnesses and health conditions according to active, disability, retired and retired with a medical condition status, and Table 6 includes the odds ratio (OR) findings. The results on conditions such as cardiovascular (heart disease), diabetes, carpel tunnel, and arthritis are addressed by Drs. Landsbergis and Johanning.

Thus, question 26 of our survey asks if the member has had surgeries since beginning work for the railroad. Those responding yes included 860 active members (28.4%); 65 out on (current) disability (76.5%) 385 retired members (68.4%); and 26 retired with medical conditions (86.7%). The total included 1,336 who replied yes to surgery (36.1%). The chi-squared test was highly significant with $p<0.001$. The survey asked members to list the specific surgeries they had. For active members 64 replied they had back surgery (2.1%); 18 had back surgery who were out on disability (20.7%); 37 had back surgery who were retired (6%); and 4 had had back surgery who were retired with medical disability (13.3%). There were a total of 123 BMWED members (3.2%) who had back procedures. The Fisher Exact p-value was <0.0001.

For active members 20 replied they had colon surgery (2.1%); 4 had colon surgery who were out on disability (20.7%); 13 had colon surgery who were retired (6%). There were a total of 38 BMWED members (1%) who had colon surgeries. The Fisher Exact p-value was 0.0001.

For active members 45 replied they had elbow surgery (1.5%); 2 had elbow surgery who were out on disability (20.7%); 12 had back surgery who were retired (1.9%); and zero members had had elbow surgery who were retired with medical disability. There were a total of 59 BMWED members (3.2%) who had elbow procedures. The Fisher Exact p-value was <0.5772.

For active members 32 replied they had eye surgery (1%); 7 had eye surgery who were out on disability (8.1%); 28 had eye surgery who were retired (4.5%); and 2 had had eye surgery who were retired with medical disability (6.7%). There were a total of 69 BMWED members (1.8%) who had eye procedures. The Fisher Exact p-value was <0.0001.

For active members 17 replied they had hip surgery (0.7%); 4 had hip surgery who were out on disability (4.6%); 13 had hip surgery who were retired (2.1%); and 2 had had hip surgery who were retired with medical disability (6.7%). There were a total of 36 BMWED members (1%) who had hip procedures. The Fisher Exact p-value was <0.0001, highly significant.

For active members 21 replied they had kidney surgery (0.7%); 3 had kidney surgery who were out on disability (3.5%); 14 had kidney surgery who were retired (2.3%); and no one had had kidney surgery who was retired with medical disability (0%). There were a total of 38 BMWED members (1%) who had kidney procedures. The Fisher Exact p-value was =0.0011.

For active members 190 replied they had knee surgery (6.2%); 17 had knee surgery who were out on disability (19.5%); 57 had knee surgery who were retired (9.2%); and 3 had knee surgery who were retired with medical disability (10.0%). There were a total of 267 BMWED members (3.2%) who had knee procedures. The Fisher Exact p-value was <0.0001.

There were 26 active members who had neck surgery (0.9%); 8 had neck surgery who were out on disability (9.2%); 9 had neck surgery who were retired (1.5%); and 2 had neck surgery who were retired with medical disability (6.7%). Based on this survey there were a total of 45 BMWED members (1.2%) who had neck procedures. The Fisher Exact p-value was <0.0001.

For active members 82 reported they had shoulder surgery (2.7%); 12 had shoulder surgery who were out on disability (13.8%); 54 had shoulder surgery who were retired; there were 2 workers who were retired with medical disability (6.7%). There were a total of 150 BMWED members (3.2%) who had shoulder procedures (3.9%). The Fisher Exact p-value was <0.0001.

For active members 37 replied they had melanoma (1.2%); 9 had skin cancer/melanoma who were out on disability (10.3%); 40 had melanoma who were retired (6.5%); and 2 had melanoma who were retired with medical disability (13.3%). There were a total of 87 BMWED members (2.3%) who had melanoma. The Fisher Exact p-value was <0.0001.

For active members 64 replied they had stomach surgery (2.1%); 9 had stomach surgery who were out on disability (10.3%); 22 had back surgery who were retired (3.6%); and 1 had had stomach surgery who was retired with medical disability (3.3%). There were a total of 96 BMWED members (2.5%) who had stomach procedures. The Fisher Exact p-value was =0.0002.

For active members 445 replied they had other types of surgery (14.5%); 37 had other types of surgery who were out on disability (42.5%); 212 had other surgeries who were retired (6%); and 4 had other types of surgery who were retired with medical disability (13.3%). There were a total of 708 BMWED members (18.6%) who had other types of surgical procedures. The chi-squared test was highly significant with p<0.001.

For question 27 we asked if any illnesses or symptoms had been recognized by a physician as being work-related. For active members 500 replied yes (17.1%); 49 answered affirmatively who were out on disability (60.5%); 218 responded yes who were retired (41.4%); and 19 responded affirmatively who were retired with medical disability (67.9%). There were a total of 786 BMWED members (22.1%) who answered yes to this question. The chi-squared test was highly significant with p<0.001.

Question 28 asked if the railroad disputed your physician's diagnosis of work relatedness (from question 27). BMWED members who were active 118 replied yes (4.2%); 14 answered affirmatively who were out on disability (18.7%); 34 responded yes who were retired 7.8%); and 11 responded affirmatively who were retired with medical disability (39.3%). There were a total of 177 BMWED members (5.3%) who answered yes to this question. The chi-squared test was significant with p<0.001.

Smoking

In question 29, we asked if union members smoked at least 100 cigarettes during their lifetime (this is identical to national questions about smoking habits). A total of 1354 active members replied yes (45.5%); 53 answered affirmatively who were out on disability (66.3%); 320 responded yes who were retired (60.4%); and 16 responded affirmatively who were retired with medical disability (61.5%). There were a total of 1743 BMWED members (48.3%) who answered yes to this question. The chi-squared test was highly significant with p<0.001. We then asked in question 30 if they now smoke cigarettes, with possible answers being every day, not at all or some days. For active workers, the answers were 282 every day (9.3%); 75 not at all (84.4%) and 193 some days (6.4%); for those out on disability the answers were 6 every day (7.1%); 75 not at all (89.3%) and 3 some days (3.6%); for those who are retired the answers were 31 every day (5.2%); 551 not at all (91.7%) and 19 some days (3.2%); for members retired on medical disability the answers were 5 every day (17.2%); 22 not at all (75.9%) and 2 some days (6.9%). There was a total of 3754 BMWED members who replied to this question and the answers were 324 every day (8.6%); 3213 not at all (85.6%) and 217 some days (5.8%). The chi-squared test was highly significant with p=0.0002. We then asked how many cigarettes they smoked per day, with ranges of answers from 1 to 20 (1 pack); 21 to 40 per day (up to 2 packs); and 41 to 230 per day (>2 packs). For active workers, the answers were 406 smoked up to 1 pack per day (91.7%); 34 smoked up to 2 packs per day (7.7%); and 3 members smoked greater than 2 packs per day (0.7%); for those currently on disability there were 6 who smoked up to one pack per day (75.0%); and one subject who smoked up to 2 packs per day (12.5%) and one who smoked >2 packs per day (12.5%); for those who are retired there were 39 who smoked 1 pack per day (86.7%) and 6 who reported to smoke > 1 pack per day (13.3%); there were no subjects > 2 packs per day; for members retired on medical disability there were only 6 members who smoked up to one pack per day (100%). There was a total of 502 BMWED members who replied to this question and there were 457 who smoked <= 1 pack per day (91%); 41 who smoked > 1 pack per day (8.2%); and 4 who smoked > 2 packs per day (0.8%). The Fisher Exact test produced p=0.1202, (not significant).

Health problems or illnesses diagnosed by a physician or other health care professional

We next asked BMWED members in question 32 if they have a number of illnesses and conditions <u>diagnosed by a physician or other health care professional</u> that are relevant to railroad work. Below we will present the findings according to active, retired, those on disability and those on retired disability status. We will use the positive replies as a basis for calculating odds ratios (OR) and adjusted ORs in the next section of this report. The first question we asked was have you ever been told by a physician or other health professional that you had chronic obstructive pulmonary disease/COPD? COPD is a basket of chronic pulmonary diseases that is used to describe progressive lung disorders including emphysema, chronic bronchitis, and refractory (non-reversible) asthma. This disease is characterized by increasing breathlessness and is often linked with long term smoking.

For active BMWED members 37 replied they had COPD (1.2%); 8 had COPD who were out on disability (9.2%); 29 had COPD who were retired (4.7%); and zero members had COPD who were retired with medical disability. There were a total of 74 BMWED members (2.3%) who stated that a physician diagnosed them with COPD. The Fisher Exact p-value was <0.0001.

We next asked if members had asthma diagnosed by a health care professional. For active members 144 replied they had asthma (4.7%); 7 had asthma who were out on disability (8.1%); 27 had asthma who were retired (4.4%); and no one had asthma who was retired with a medical disability. There were a total of 178 BMWED members (4.7%) who had asthma. The Fisher Exact p-value was 0.3219 (nonsignificant).

We asked if members had a physician diagnose silicosis, but there were too few cases (3) and this chronic condition was not analyzed further.

At the time of the survey, we asked if a physician (or other health professional) had diagnosed BMWED member with gout. For active BMWED members 122 replied they had gout (4%); 3 had gout who were out on disability (3.4%); 44 had gout who were retired (7.1%); and 1 member had gout who were retired with medical disability (3.3%). There were a total of 170 BMWED members (4.5%) with gout. The Fisher Exact p-value was <0.0001.

We asked if members had a physician diagnose lupus and/or fibromyalgia but there were too few cases (6 of each condition) and these chronic diseases were not analyzed further.

At the time of the survey, we asked if a physician or other health professional had diagnosed BMWED member with weak or failing kidneys--symptoms of nephritis. For active BMWED members 39 replied they had weak or failing kidneys (1.2%); 9 had weak or failing kidneys who were out on disability (15.8%); 18 had gout who were retired (6.1%); and 2 members reported they had weak or failing kidneys who were retired with medical disability (13.3%). There were a total of 65 BMWED members (2%) with weak or failing kidneys. The Fisher Exact p-value was <0.0001.

Question 33 asked members to respond to a group of questions designed to measure neurological symptoms such as might be found among patients with Parkinson's or Alzheimer's diseases; we will examine some of them, but other symptoms were too infrequent for analysis purposes. We defined all CNS symptoms and combined them for case-control analyses and these will be presented below. We asked members if a physician or health professional had told them they suffered from memory issues (such as might be the case for early Alzheimer's disease). For active BMWED members 27 replied they had memory issues (0.9%); 1 reported he had memory problems (1.2%); and 2 members reported they had memory issues who were retired with medical disability (0.3%). There were a total of 31 BMWED members (0.8%) with memory problems. The Fisher Exact p-value was <0.0001.

There were too few cases (7 or less) of dementia and Parkinson's disease each to examine the distribution by active or retired or disability status. The same was true for responses related to multiple sclerosis (MS), lead poisoning, and mercury poisoning.

At the time of the survey, we asked if a physician or other health professional had diagnosed BMWED member with tremor in hands or legs (symptoms of early Parkinson's). For active BMWED members 11 replied they had tremor in hands/legs (0.4%); 79 reported tremor in hands/legs who were out on disability (8.1%); 11 had tremor in hands/legs who were retired (1.8%); and 2 members reported they had tremor in hands/legs who were retired with medical disability. There were a total of 31 BMWED members (0.8%) with tremor in hands/legs. The Fisher Exact p-value was <0.0001.

At the time of the survey, we asked if a physician or other health professional had diagnosed BMWED member with tingling/numbness in hands. For active BMWED members 117 replied they had tingling/numbness in hands (3.7%); 20 reported tingling/numbness in hands who were out on disability (23%); 46 had tingling/numbness in hands who were retired (7.4%); and 6 members reported they had tingling/numbness in hands who were retired with medical disability (20%). There were a total of 186 BMWED members (4.9%) with tingling/numbness in hands. The Fisher Exact p-value was <0.0001.

Cancers

The next set of questions focus on cancer diagnosed by either a physician or other health care professional, by work or disability status. Several types of cancer had too few (7 or less) members responding related to active, retired or disability status, including brain, leukemia, lung, pancreatic, and stomach cancers. We asked if a physician had informed members that they had bladder cancer. For active BMWED members 3 replied they had bladder cancer (0.1%); 2 reported bladder cancer who were on disability (2.3%); 10 had bladder cancer who were retired (1.6%); and 1 member reported he had bladder cancer who was retired with medical disability (3.3%). There were a total of 16 BMWED members (0.4%) bladder cancer. The Fisher Exact p-value was <0.0001.

At the time of the survey, we asked if a physician or other health professional had diagnosed BMWED member with kidney cancer. For active BMWED members 4 replied they had kidney cancer (0.1%); 1 person reported kidney cancer who was out on disability (1.2%); 5 had kidney cancer who were retired (0.8%); and 2 members reported they kidney cancer who were retired with medical disability (6.7%). There were a total of 12 BMWED members (0.3%) with kidney cancer. The Fisher Exact p-value was <0.0001.

We asked if a physician had informed members that you had lymphoma, a type of immune system cancer. For active BMWED members 6 replied they had lymphoma (0.2%); 1 reported lymphoma who was on disability (1.2%); 1 had lymphoma who was retired (0.2%); and zero reported lymphoma among those who were retired with medical disability. There were a total of 8 BMWED members (0.2%) with lymphoma. The Fisher Exact p-value was 0.2452, nonsignificant.

We next asked BMWED members about melanoma or other skin cancers. For active BMWED members 41 replied they had melanoma or other skin cancers (1.3%); 9 reported melanoma/skin cancers who were on disability (10.3%); 56 had melanoma/skin cancers who were retired (9.1%); and 3 members reported melanoma/skin cancers who were retired with medical disability (10%). There were a total of 109 BMWED members (2.9%) with melanoma/skin cancers. The Fisher Exact p-value was <0.0001.

We asked BMWED members about prostate cancers. For active BMWED members 14 replied they had prostate cancer (0.5%); 5 reported prostate cancer who were on disability (5.8%); 30 had prostate cancer who were retired (4.9%); and 2 members reported prostate cancers who were retired with medical disability (6.7%). There were a total of 51 BMWED members (1.3%) with prostate cancer. The Fisher Exact p-value was <0.0001.

Lastly we asked if a physician had informed members that they had other cancers. For active BMWED members 16 replied they had other cancers (0.5%); 2 reported other cancers while was on disability (2.3%); 11 had other cancers who were retired (0.2%); and 1 reported other cancer among those who were retired with medical disability (3.3%). There were a total of 30 BMWED members (0.8%) with other cancers. The Fisher Exact p-value was 0.0014.

Workplace Trauma Injuries

The next section of the BMWED survey asked about traumatic injuries and active, retired and disability status. We asked BMWED members about whether they had suffered crushed hand, wrist or fingers. For active BMWED members 78 replied they had crushed hand, wrist or fingers (2.5%); 3 reported crushed hand, wrist or fingers who were on disability (3.5%); 42 crushed hand, wrist or fingers who were retired (6.8%); and 1 member reported crushed hand, wrist or fingers who was retired with medical disability (3.3%). There were a total of 124 BMWED members (3.3%) with crushed hand, wrist or fingers. The Fisher Exact p-value was <0.0001

We next asked BMWED members about injuries to the back. For active BMWED members 198 reported they had back injuries (6.4%); 24 reported back injuries who were on disability (27.6%); 115 had injuries to the back who were retired (18.6%); and 10 members reported injury to the back who were retired with medical disability (33.3%). There were a total of 347 BMWED members (9.1%) with back injuries. The Fisher Exact p-value was <0.0001.

The next part of the survey asked BMWED members about injuries to the neck. For active BMWED members 51 reported they had neck injuries (1.7%); 8 members reported neck injuries who were on disability (9.2%); 22 had injuries to the back who were retired (3.6%); and 3 members reported injury to the neck who were retired with medical disability (10%). There were a total of 84 BMWED members (2.2%) with back injuries. The Fisher Exact p-value was <0.0001.

We next asked BMWED members about injuries to their head. For active BMWED members 35 reported they had traumatic head injuries (1.1%); 1 member reported head injury who was on disability (1.2%); 17 had injuries to the head who were retired (2.8%); and 1 member reported injury to the head who was retired with medical disability (3.3%). There were a total of 54 BMWED members (1.4%) with back injuries. The Fisher Exact p-value was 0.0148.

We asked BMWED members about traumatic injuries to their feet and ankles. For active BMWED members, 93 reported they had injuries to feet and ankles (3%); 7 reported feet and ankle injuries who were on disability (8.1%); 48 had injuries to their feet and ankles who were retired (7.8%); and 6 members reported injury to the feet and ankles who were retired with medical disability (20%). There were a total of 154 BMWED members (4%) with feet and ankle injuries. The Fisher Exact p-value was 0.0121.

We next asked BMWED members about serious injuries to their hips. For active BMWED members 17 reported they had hip injuries (0.6%); 1 member reported hip injury who was on disability (1.2%); 8 had injuries to their hips who were retired (1.3%); and 1 member reported hip injury who was retired with medical disability (3.3%). There were a total of 27 BMWED members (0.7%) with hip injuries. The Fisher Exact p-value was <0.0001.

We asked about serious traumatic injuries to their shoulders. For active BMWED members 69 reported they had shoulder injuries (2.3%); 7 members reported shoulder injuries who were on disability (8.1%); 32 had injuries to their shoulders who were retired (5.2%); and 2 members reported shoulder injuries who were retired with medical disability (6.7%). There were a total of 110 BMWED members (2.9%) with severe shoulder injuries. The Fisher Exact p-value was <0.0001.

The associations between MOW jobs/work areas and illnesses and injuries

In order to examine patterns of workplace illness and injury, we have calculated case-control estimates linking specific jobs and positive responses to the question about whether a physician or other care health provider indicated the BMWED member had a selected group of conditions (Frasketi and Goldsmith, 2018). The measure we are calculating is called the odds ratio (OR); OR is a very good approximation of the relative risk (RR). The RR is the risk of illness among the exposed compared to the same risk among the unexposed (the best example is the lung cancer relative risk of 10-15 times greater for smokers compared to nonsmokers). However when calculating the OR, we are asking if the cases of disease have more exposure to a work area than the controls. And for this analysis, controls are all BMWED members who do not have the disease or condition we are analyzing. In this presentation, we have calculated two types of OR, one is labeled 'crude' because we are simply asking if the cases have spent more time in the job/work area than controls; the second is 'adjusted' for known/assumed confounding factors. Those include, current age of BMWED member, ethnicity, and smoking. There are some conditions such as prostate cancer, melanoma, and Parkinson's disease where smoking plays no role and has not been adjusted. We also decided not to calculate the OR when there were fewer than 7 cases because that would lead to very small numbers of study subjects producing completely unreliable findings. Tables 6, 7 and 8 includes only statistically significant findings, but the text will focus only on results producing a risk above 1.0 (i.e., only those with excess risk in work areas shown in red) with 95% CIs.

For the Surfacing Gang Equipment Operators gout was shown to be a health risk for workers in this area, with a crude OR of 1.47 (95% CI 1.08, 2.00) and an adjusted OR of 1.39 (95% CI 1.02, 1.90).

Table 6: Neurological Symptoms							
					Mean Years on Job		
Question	**Job Description**	**Condition**	**Crude OR and 95% CI**	**Adjusted OR and 95% CI**	**Case**	**Controls**	**p-value**
Q34	Surfacing Gang Equipment Operators	Tingling or numbness in your hands or legs	1.38 (1.03, 1.85)	1.267 (0.94, 1.71)	10.63	7.92	0.011
	Welder/welder	Memory issues, Forgetfulness	2.83 (1.30, 6.16)	2.789 (1.27, 6.12)	7.32	6.62	0.6979
	Foreman	Tingling or numbness in your hands or legs	1.36 (1.00, 1.85)	1.28 (0.94, 1.75)	11.73	8.52	0.0006
	Track Inspector	Tingling or numbness in your hands or legs	1.50 (1.10, 2.04)	1.30 (0.95, 1.78)	8.09	6.79	0.2264
	Bridge and Building employee	Memory issues, Forgetfulness	2.22 (1.04, 4.73)	2.06 (0.96, 4.45)	7.02	9.48	0.4866

The next set of findings focus on neurological symptoms. We found for Surfacing Gang Equipment Operators a crude OR for tingling or numbness in hands or legs of 1.38 (95% CI 1.03, 1.85) and an adjusted OR of 1.27 (95% CI 0.94, 1.71); we found among welders a crude OR of 2.83 for memory issues, forgetfulness and an adjusted OR of 2.79 (95% CI 1.27, 6.12); for Foremen a crude OR of 1.36 (95% CI 1.00, 1.85) for tingling or numbness in hands or legs the adjusted OR was 1.28 (0.94, 1.75); for Track Inspector jobs produced a crude OR of 1.50 (95% CI 1.10, 2.04) for tingling or numbness in hands or legs. By contrast the adjusted OR was 1.30 (95% CI 0.95, 1.78). For Bridge and Building employees we found a crude OR of 2.22 (95% CI 1.04, 4.73) and an adjusted OR equal to 2.06 (95% CI 0.96, 4.45) for memory issues, forgetfulness.

Table 7: Cancers							
					Mean Years on Job		
Question	**Job Description**	**Condition**	**Crude OR and 95% CI**	**Adjusted OR and 95% CI**	**Case**	**Controls**	**p-value**
Q35	Foreman	Melanoma or other skin cancers	1.75 (1.16, 2.65)	1.50 (0.98, 2.28)	14.60	8.49	0.0001
	Track Inspector	Bladder cancer	2.70 (1.01, 7.21)	2.04 (0.76, 5.53)	9.00	6.86	0.4945
		Melanoma or other skin cancers	2.25 (1.53, 3.31)	1.80 (1.21, 2.66)	10.60	6.69	0.0017
	Bridge and Building employee	Prostate cancer	1.94 (1.06, 3.58)	2.20 (1.17, 4.12)	18.21	9.25	0.0027
	Roadway equipment mechanic/repairman	Prostate cancer	2.58 (1.09, 6.13)	2.32 (0.95, 5.70)	18.67	10.56	0.0795

The next set of work area findings focus on cancer. Foreman have a crude OR for melanoma of 1.75 (95% CI 1.16, 2.65) and an adjusted OR of 1.50 (9%% CI 0.98, 2.28). Track Inspector jobs have crude excess of bladder cancer of 2.70 (95% CI 1.01, 7.21) and an adjusted OR of 2.04 (95% CI 0.76, 5.53). Track Inspectors also had crude OR of 2.25 for melanoma/other skin cancers (95% CI 1.53, 3.31) and an adjusted OR of 1.80 (95% CI 1.21, 2.66). Among Bridge and Building employees there was a crude OR of 1.94 for prostate cancer and an adjusted OR of 2.20 (95% CI 1.70, 4.12). We found an excess of prostate cancer among Roadway Equipment mechanic/ repairman, producing a crude OR of 2.58 (95% CI 1.09, 6.13) and an adjusted OR of 2.32 (0.95, 5.70).

Table 8: Traumatic Injury

					Mean Years on Job		
Question	**Job Description**	**Condition**	**Crude OR and 95% CI**	**Adjusted OR and 95% CI**	**Case**	**Controls**	**p-value**
Q36	Machine Operator	Injury to neck	2.07 (1.06, 4.02)	2.45 (1.25, 4.81)	15.09	9.83	<.0001
		Injury to shoulders	1.89 (1.08, 3.34)	2.24 (1.26, 3.98)	15.38	9.78	<.0001
	Surfacing Gang Equipment Operators	Injury to back	1.39 (1.11, 1.73)	1.27 (1.01, 1.59)	12.32	7.60	<.0001
	Welder/welder	Injury to knees	1.62 (1.16, 2.26)	1.91 (1.40, 2.69)	12.11	6.36	<.0001
	Foreman	Injury to back	1.63 (1.29, 2.06)	1.51 (1.19, 1.92)	13.63	8.13	<.0001
		Injury to head	2.16 (1.17, 3.99)	2.02 (1.09, 3.74)	17.35	8.54	<.0001
		Injury to shoulders	1.71 (1.13, 2.56)	1.60 (1.06, 2.42)	12.85	8.55	0.0003
	Track Inspector	Injury to back	1.91 (1.52, 2.40)	1.67 (1.33, 2.11)	8.77	6.59	0.0116
		Injury to neck	1.82 (1.17, 2.82)	1.70 (1.07, 2.61)	7.33	6.86	0.7460
		Injury to head	2.53 (1.48, 4.34)	2.24 (1.30, 3.87)	9.71	6.80	0.0886
		Injury to knees	1.48 (1.05, 2.09)	1.29 (0.91, 1.83)	8.08	6.82	0.3123
		Injury to foot/ankle	1.61 (1.15, 2.25)	1.42 (1.01, 2,00)	8.51	6.78	0.1371
		Injury to hips	2.16 (1.01, 4.63)	1.87 (0.87, 4.04)	8.91	6.85	0.4114
		Injury to shoulders	1.75 (1.19, 2.59)	1.55 (1.04, 2.30)	7.90	6.83	0.4229
	Electric Traction employee	Injury to trunk	9.62 (2.14, 43.14)	14.88 (3.09, 71.72)	23.50	6.91	0.0012

This last set of finding is focused on traumatic injuries by work area. Machine Operators showed crude OR for injury to the neck, OR of 2.07 (95% CI 1.06, 4.02) and an adjusted OR of 2.45 (95% CI 1.25, 4.81). Machine Operators demonstrated a crude OR of 1.89 (95% CI 1.08, 3.34) for shoulder injury and an adjusted OR of 2.24 (95% CI 1.26, 3.98). Surfacing Gang Equipment Operators showed a crude OR of 1.39 (95% CI 1.11, 1.73) for back injuries and an adjusted OR of 1.27 (95% CI1.01, 1.60). Welders produced a crude OR of 1.62 (95% CI 1.16, 2.26) for traumatic knee injury and an adjusted OR of 1.91 (95% CI 1.36, 2.69). Foreman had a crude OR of 1.63 (95% CI 1.29, 2.06) for back injuries and an adjusted OR of 1.51 (95% CI 1.19, 1.92). Foremen had a crude OR of 2.16 (95% CI 1.17, 3.40) for head injuries and an adjusted OR of 2.02 (95% CI 1.09, 3.74). Lastly, Foremen had a crude OR of 1.70 (95% CI 1.30, 2.56) for shoulder injury and an adjusted OR of 1.60 (95% CI 1.06, 2.42). Track Inspectors showed a crude OR of 1.91 (95% CI 1.52, 2.39) for back injuries and an adjusted OR of 1.67 (95% CI 1.33, 2.11). Track Inspectors produced a crude OR of 1.82 (95% CI 1.17, 2.82) for neck injuries and an adjusted OR of 1.67 (95% CI 1.07; 2.61). Track Inspectors had a crude OR of 2.53 (95% CI 1.48, 4.34) for head injuries and an adjusted OR of 2.24 (95% CI 1.30, 3.87). Track Inspectors had a crude OR of 1.48 (95% CI 1.05, 2.09) for knee injuries and an adjusted OR of 1.29 (95% CI 0.90, 1.83). Track Inspectors had a crude OR of 1.61 (95% CI 1.15, 2.25) for foot and ankle injuries and an adjusted OR of 1.42 (95% CI 1.01, 2.00). Track Inspectors produced a crude OR of 2.16 (95% CI 1.01, 4.63) for hip injuries and an adjusted OR of 1.87 (95% CI 0.87, 4.04). Track Inspectors had a crude OR of 1.75 (95% CI 1.19, 2.59) for shoulder injuries and an adjusted OR of 1.55 (95% CI 1.04, 2.30)

Lastly Electric Traction workers had a crude OR of 9.62 (95% CI 2.14, 43.14) for injuries to the trunk and an adjusted OR of 14.88 (95% CI 3.09, 71.72).

In summary from the survey of membership shows that several job classifications had links with multiple health conditions. We found that the Surfacing Gang and Track Inspectors had an elevated OR for tingling in hands and legs; Welders and Bridge and Building had higher risks for memory issues and forgetfulness. Track Inspectors and Foreman had elevated risks for melanoma, and Track Inspectors had an increased risk for bladder cancer. Prostate cancer showed elevated ORs for Bridge and Building and Roadway equipment mechanics. There were a variety of severely elevated injury ORs for all work areas for foot/ankle, back, shoulder, knee, head, and neck. The most striking was an adjusted OR of 14.88 for injuries to the trunk among Electric Traction workers (Frasketi and Goldsmith, 2018).

Summary and Conclusion

This report summarized the most serious exposures linked to adverse health among BMWED-represented MOW workers. BMWED workers are exposed to diesel fuel and exhaust emissions, creosote, asbestos and silica from ballast and cement dusts, petroleum solvents, electromagnetic fields, welding fumes, high levels of vibration, PCBs, and herbicides sprayed on the railroad right of way. We know these workers are exposed to vibration and rolling equipment that can produce death and traumatic injury to backs, arms, feet and head. We conducted a standardized mortality ratio (SMR) analysis of BMWED members who died from 1979 to 2014 of over 11.000 deaths. We found a doubling of many causes of death among active workers aged 65 years or less, including septicemia with a SMR of 2.19, Parkinson’s and Alzheimer’s diseases both show elevated SMRs of 3.09 and 7.15, respectively, hypertensive and atherosclerotic heart disease both show elevated SMRs of 2.11; chronic respiratory disease including chronic obstructive pulmonary disease—COPD produced an SMR of 1.89; kidney disease had a SMR of

2.57; and accidental transport deaths have a SMR of 3.27. When focusing on cancer causes of death we found that all cancers show a SMR of 1.79. Stomach cancer and colorectal cancers have risk levels close to or exceeding 2.0, with SMRs of 2.06 and 1.99, respectively; liver cancer has a SMR of 2.36; pancreatic cancer produced a SMR of 2.17; lung cancer had a SMR of 1.82; prostate cancer had a SMR of 1.93; bladder cancer had a SMR of 1.95; among the blood/lymph cancers only leukemia showed a SMR of 1.96; in situ cancers produced a SMR of 2.11. We tried to examine the role of asbestos and silica dust exposure on the health of BMWED workers, and the SMRs were 2.44 for asbestosis, 1.42 for mesothelioma, and 1.62 for silicosis, but all were hampered by small numbers of deaths. Using a proportionate mortality ratio (PMR) analysis to include all ages of workers we compared the SMRs and the PMRs. We found that certain diseases the SMR and PMR findings have parallel mortality excesses. Examples include septicemia (SMR=2.19; PMR=1.21); anemias (SMR=1.60; PMR=1.22); diabetes (SMR=1.57; PMR=1.36); chronic lower respiratory disease (SMR=1.89; PMR=1.04 [borderline]); nephritis (SMR=2.50; PMR=1.18); transport accidents (SMR=3.27; PMR=1.70). Among cancer causes of death, we found all malignant neoplasms (SMR=1.79; PMR=1.03 [borderline]); esophageal cancer (SMR=1.82; PMR=1.10); stomach cancer (SMR=2.06; PMR=1.26); colorectal cancers (SMR=1.99; PMR=1.06); lung (SMR=1.82; PMR =1.05); prostate cancer (SMR=1.93: PMR=1.06 [borderline]); kidney (SMR=1.75; PMR=1.14) and in situ cancers (SMR=2.11; PMR=1.05 [borderline]). Two very interesting excess SMRs were <u>not</u> elevated in the PMR assessment—Alzheimer's and Parkinson's disease.

From the survey of active and retired BMWED workers, we calculated odds ratio (ORs) for several self-reported conditions and employment work areas, adjusted for age, race and smoking. We found that the Surfacing Gang and Track Inspectors had an elevated OR for tingling in hands and legs; Welders and Bridge and Building employees had higher risks for memory issues and forgetfulness; Track Inspectors and Foreman had elevated risks for melanoma; and Track Inspectors had an increased risk for bladder cancer. Prostate cancer showed elevated ORs for Bridge and Building and Roadway equipment mechanics. There were many severely elevated injury ORs for all work areas for foot/ankle, back, shoulder, knee, head, and neck. The most striking was an adjusted OR of 14.88 for injuries to the trunk among Electric Traction workers.

Many of these findings for traumatic injury re-enforce the concern that MOW work is hazardous, but the specific work areas need to be replicated in future studies. Some of our findings for lung cancer and chronic lung disease are consistent with prior studies of railroad workers who are exposed to diesel and silica (and other) dusts. Other findings such as the many elevated cancer findings should be replicated in future research of MOW workers.

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