ERGONOMICS, VIBRATION, MUSCULOSKELETAL DISORDERS AND CARDIOVASCULAR DISEASE IN RAILROAD MAINTENANCE-OF-WAY WORKERS:

A Report to the Brotherhood of Maintenance of Way Employes Division

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INTRODUCTION

Ergonomic hazards, also known as biomechanical hazards, increase the risk that workers will develop musculoskeletal disorders (MSDs) of the joints and the soft tissues of the upper or lower extremities (arms and legs) as well as the spine (both the neck and back). MSDs include carpal tunnel syndrome, tendinitis, back pain and pain, numbness or tingling in other body locations. Ergonomic hazards include lifting, holding, pushing, walking and reaching, as well as use of tools with excessive vibration, or requiring repetitive motions, force, and awkward postures. Job stress can also increase the risk of developing MSDs, and job stress and heavy physical job demands can increase the risk of heart disease and stroke (cardiovascular disease, CVD). These factors are often present in combination and are typical for many work situations of maintenance-of-way (MOW) workers. However, there has been little research on MSDs or CVD in MOW workers and their causes. Therefore, our Ergonomics study group conducted this study to determine how common MSDs and CVD were among MOW workers, what the possible causes of these conditions were in MOW workers, and what potential strategies might be employed for prevention of disease and injury.

METHODS

The Ergonomics study group added standard questions to the BMWED Health and Safety Survey on: musculoskeletal symptoms; diagnoses of musculoskeletal disorders, cardiovascular conditions, and diabetes; tool and vehicle use, and other working conditions questions including ergonomics, vibration and how work is organized. The group helped to clean the survey data, analyzed the survey data to determine how representative the members and retirees who answered the survey (respondents) were to all BMWED members and retirees, computed how common were musculoskeletal and cardiovascular conditions (prevalence), and examined associations between working conditions and musculoskeletal conditions, cardiovascular disease and diabetes. We also compared the results of the survey to all U.S. workers (in national surveys where the same questions were used) and to other studies of the general population or studies of workers in physically demanding jobs that used the same questions. The survey was completed by “active” BMWED members (that is, those working or available for work), those out on disability, and those known to be retired due to age or medical condition at the time of the survey. In addition, the group conducted a literature and data review and expert interviews on specific tools utilized in the rail construction industry and MOW tool vibration emissions.

SURVEY RESULTS

Working conditions

Detailed information was gathered on the vehicles and tools used by BMWED members and retirees, as well as details on a second job worked by 7.3% of survey respondents for at least 20 hours per month, and vehicles used in one’s spare time, outside of work or commuting to work. Compared to all U.S. male workers, active male BMWED members were less likely to work an evening, night or irregular schedule (14.2% vs. 28.3%). However, compared to all U.S. male workers, active male BMWED members were more likely to report that they often or always have a job that involves repeated lifting, pushing, pulling or bending (74.6% vs. 46.9%), and that often or sometimes there were not enough people or staff to get all the work done (88.1% vs. 65.2%). Compared to all U.S. male workers, active male BMWED members were much more likely to disagree that “my job allows me to make a lot of decisions on my own” (31.6% vs. 12.3%) or disagree that “I can count on my supervisor or manager for support when I need it” (39.7% vs. 9.2%) or disagree that “the health and safety of workers is a high priority where I work” (40.7% vs. 5.2%).

Self-reported musculoskeletal diagnoses

The BMWED Health and Safety survey revealed that, compared to all U.S. employed men age 18-74, active BMWED men were more likely to have been told by a doctor or a health professional that they have carpal tunnel syndrome (7.9% vs. 3.6%) (adjusted prevalence ratio (PR)=1.99, 95% CI 1.64-2.43, p<.001, adjusted for age, race/ethnicity and region). Similarly, compared to U.S. retired men age 60-105, retired BMWED men were more likely to have been told by a doctor or a health professional that they have carpal tunnel syndrome (15.2% vs. 9.1%) (adjusted PR=1.41, 95% CI 1.05-1.89, p<.001).

Musculoskeletal symptoms

Back pain

Back pain was a common condition, either lower back pain more than 3 times/year (reported by 70.6%), lower back pain lasting more than 1 week at a time (43.4%), back pain during the past week (50.4%) or always (every day) or often (4-6 days/week) low back pain during the past week (27.0%). Only in a small percent of cases (7.1%) were “severe injuries or fractures in the area of current discomfort”. Therefore, most cases of low back pain were likely chronic conditions due to day-to-day physical work demands. Only in a small percent of cases (5.3%) did members or retirees report having back problems when they started their present job. Therefore, railroad work likely contributes to many of the cases of back pain.

Comparisons to other studies. A higher percent of active BMWED members reported back pain in the past week than track maintenance workers in the UK or the general employed population in Norway, using the same or similar back pain questions.

Hand/wrist symptoms

About one-quarter of members and retirees responding to the survey reported symptoms consistent with nerves being compressed (nerve entrapment), such as carpal tunnel syndrome, or nerve damage due to vibration, daily or weekly during the past year. Such symptoms include numbness or tingling of the fingers at any time (26.3%), waking up at night with pain, tingling, or numbness in the hand or wrist (18.9%) or difficulty picking up very small objects, such as screws or buttons or opening tight jars (13.9%).

Comparisons to other studies. A higher percent of active BMWED members reported tingling or numbness in their fingers daily or weekly, these symptoms disturbing sleep daily or weekly, cold-induced “blanching” (whitening) attacks of their fingers, or blanching attacks associated with a clear edge, in the past year compared to a study of British male workers.

Other joint pain

More than half of BMWED members and retirees (52.1%) reported severe joint pain in the past year, including pain in the knees, hips, shoulders, neck, wrists/hands or elbows.

Comparisons to other studies. A higher percent of active BMWED members reported wrist/hand pain and knee pain lasting a day or more in the past year compared to pain any time in the past year in these areas in a study of French male workers.

A similar percent of active BMWED members reported wrist/hand pain, knee pain, hip pain and elbow pain lasting a day or more in the past year compared to pain any time in the past year in these areas among Scandinavian and Russian male mine workers. A similar percent of active BMWED members reported hip pain, shoulder pain and elbow pain compared to pain in these areas any time in the past year among French male workers.

A lower percent of active BMWED members reported shoulder pain or neck pain lasting a day or more in the past year compared to shoulder or neck pain in the past year among Scandinavian and Russian male mine workers, or neck pain lasting a day or more in the past year compared to neck pain any time in the past year among French male workers.

Associations between working conditions and musculoskeletal ill health

Analyses of survey data suggest that the physical demands of BMWED work (repeated lifting, pushing, pulling, or bending), vibration exposure from vehicles and tools, and a perceived lack of a priority for health and safety by management contribute to the musculoskeletal injuries and illnesses experienced by active BMWED members. A "dose-response" trend was seen for the connection between most of our measures of ill health and many of our working conditions questions. This means that the worse the reported working conditions were, the higher the percent of members reporting a symptom or diagnosis. Such a "dose-response" trend is one piece of evidence to support the conclusion that working conditions may be causing health problems among BMWED members.

Back pain

For example, three of our measures of back pain (questions 41, 43 and 48) were all statistically significantly associated with "vehicle equipment vibration bothers me", "hand tool vibration bothers me", "job involves repeated lifting, pushing, pulling, or bending", and disagree that "health and safety of workers is a high priority with management where I work". "Statistical significance" means that the connection between the working condition and the health problem is probably not just due to chance but is a real connection.

While 28.8% of active male BMWED members reported back pain during the past week (question 41) if vehicle equipment vibration did not bother them, 47.8% of members reported this symptom if vehicle equipment vibration bothered them sometimes (1-2 hours/day), and 61.8% of members reported this symptom if vehicle equipment vibration bothered them always (8-10 hours/day).

Hand/wrist symptoms and diagnoses

All four of our measures of hand/wrist symptoms (questions 50a, 50d or 50e and 52) or carpal tunnel diagnosis (question 32) were statistically significantly associated with vehicle equipment vibration bothers me, hand tool vibration bothers me, job involves repeated lifting, pushing, pulling, or bending, and disagree that health and safety of workers is a high priority with management where I work. (However, we could not compute a prevalence for white finger symptoms for exposure question 23 and because *all* the cases of daily or weekly white finger symptoms were reported by members reporting "often/always" "job involves repeated lifting, pushing, pulling", and no one reported these symptoms if "sometimes" or "seldom/never" "job involves repeated lifting, pushing, pulling".)

While 2% of active male BMWED members reported a diagnosis of carpal tunnel syndrome if hand tool equipment vibration did not bother them, 7% of members reported this diagnosis if hand tool equipment vibration bothered them sometimes (1-2 hours/day), and 15% reported this diagnosis if vehicle equipment vibration bothered them always (8-10 hours/day).

Knee pain

Another example is for knee pain. While 10.9% of active male BMWED members reported knee pain during the past week if vehicle equipment vibration did not bother them, 24.6% of members reported this symptom if vehicle equipment vibration bothered them sometimes (1-2 hours/day), and 42.3% of members reported this symptom if vehicle equipment vibration bothered them always (8-10 hours/day).

Vehicles

Average years using high vibration vehicles (from ballast regulator to brush cutter) were significantly associated with 1 of 11 of our measures of ill health (vibration white finger), after taking age into account. This result may be due, in part, to the relatively small number of people reporting such vehicle use – which means it's harder to conclude that the connection was not due to chance. However, average years using lower vibration vehicles, such as trucks (heavy, road or hi-rail) or light trucks/vans, were significantly associated with 7 of 11 of our measures of ill health (back pain lasting more than a week, back-related injury reported, carpal tunnel syndrome, finger numbness or tingling, hand/wrist pain in past week lasting a day or more, severe joint pain in the past year, and knee pain in past week lasting a day or more). While the increased risk was lower for the lower (vs higher) vibration vehicles, the larger number of members reporting use of trucks led to more associations being statistically significant.

Tools

Average years using power tools and average years using hand-tools were both statistically significantly associated with increased risk of all 11 health problems we examined, after taking age into account. As expected, the increase in risk tended to be greater for power tools than for hand-tools. Increased risk for 10 years of tool use ranged from a prevalence ratio (PR) =1.55 (meaning 55% increased risk) to PR=3.59 for power tools and PR=1.19 to PR=2.02 for hand-tools.

Job titles

20 of 121 associations between years worked in specific job titles and ill health (11 job titles x 11 measures of ill health) were statistically significant, after taking age into account. Most associations were relatively small. Years worked as a machine operator was significantly associated with increases in risk of 7 of 11 measures of ill health, the most consistent set of associations of any job title. We did not expect large associations between reported job titles and health outcomes since members may work a variety of job titles even during the same time period. We expected larger associations between musculoskeletal symptoms and the specific hazards of the job (such as vehicles and tools) than with job titles.

Cardiovascular disease and diabetes

BMWED male members and retirees were less likely than all U.S. employed or retired men to have cardiovascular disease (CVD), such as heart disease or stroke, or risk factors for CVD, such as high blood pressure. This difference may be due, in part, to the “healthy worker effect” – the fact that most BMWED work requires a high level of physical effort, and some employed U.S. men (including some with early stages of CVD) could not handle the physical demands of BMWED work, and thus would not be employed in maintenance of way work. However, the lower risk of cardiovascular diagnoses among male BMWED members and retirees as seen on the survey compared to all U.S. employed and retired men is *not* consistent with the mortality study of BMWED members conducted by the AOEC research group, led by Dr. David Goldsmith, which found increased risks of death from CVD compared to the U.S. population.

While exercise during non-work hours may reduce a person’s risk of heart disease or stroke, recent research suggests that high occupational physical activity may actually increase a person’s risk of CVD. Therefore, the physical activity of MoW work may not protect BMWED members from heart disease and stroke.

In addition, BMWED survey respondents tended to be healthier than BMWED members and retirees who did not complete the survey, except for back pain. This might also help to explain the difference between the survey results and Dr. Goldsmith’s mortality study.

Associations between working conditions and cardiovascular disease and diabetes

There were very few statistically significant associations between working conditions, years of MOW work, or years in a specific jobtitle and cardiovascular conditions or diabetes among active BMWED members. This may have been due, in part, to the fact that cardiovascular conditions and diabetes were not common in this group of workers.

CONCLUSIONS

Consistent with past research, the BMWED Health and Safety survey results suggest that vibration from power tools and from vehicles, as well as use of hand tools, increases the risk of musculoskeletal symptoms and diagnoses.

BMWED male members and retirees were less likely than all U.S. employed or retired men to have CVD, such as heart disease or stroke, or risk factors for CVD, such as high blood pressure. However, this finding is *not* consistent with the mortality study of BMWED members conducted by the AOEC research group, led by Dr. David Goldsmith, which found increased risks of death from CVD compared to the U.S. population.

Finally, the survey results may underestimate how common various symptoms and health conditions are among BMWED members and retirees. For example, we found that survey respondents had somewhat better health than a sample of non-respondents. Members reported in interviews that fear of retribution (including possible job loss) may have led to respondents not reporting all conditions or symptoms they may have and may have also led some members and retirees to not respond to the survey at all.

I. INTRODUCTION

This study of ergonomics, vibration, musculoskeletal disorders (MSDs) and cardiovascular disease (CVD) among maintenance of way (MOW) workers is part of a larger research effort to study the occupational health and safety of MOW workers. The Ergonomics team is led by Dr. Eckardt Johanning, MD, MSc, and Dr. Paul Landsbergis, PhD. The Epidemiology team leader is Dr. David Goldsmith, and the Social and Economic team leader is Dr. Ruth Ruttenberg.

A. Ergonomics and musculoskeletal disorders

According to governmental studies (i.e., the National Institute for Occupational and Safety and Health (NIOSH), the Institute of Medicine (IOM), Occupational Safety and Health Administration (OSHA)) and Federal Railroad Administration (FRA) regulations, including 49 U.S. Code title 49 (FELA) § 20139, the 'General duty clause' of OSHA (1910 CFR), and the Accident, Incident and Reporting requirements of FRA (49 CFR Part 225), work-related musculoskeletal disorders should be documented and prevented. One tool and approach are to study workplace ergonomics. Ergonomics is a science also known as "fitting a job to a person" [OSHA, 2018] or the "fitting workplace conditions and job demands to the capabilities of the working population" [NIOSH, 1997]. Ergonomics or "human factors" is a systematic approach to studying working conditions and their interaction with human health and safety, especially in a highly complex system, such as railroads, which have many functions and employees [Ryan, et al., 2012, Wilson, 2014, Wilson, et al., 2009].

Ergonomic hazards are recognized as factors leading to or aggravating MSDs of joints and soft-tissue of the upper or lower extremities (arms and legs) as well as the spine (i.e., the neck and back). These are specifically characterized as "biomechanical" hazards such as lifting, holding, pushing, walking and reaching as well as use of tools with excessive vibration, noise or requiring repetitive motion, force or awkward postures [OSHA, 1998].

The term musculoskeletal disorders (MSDs) includes medical conditions that may involve the nerves, tendons, muscles, joints, bones or soft-tissue of the body, or a combination of these. The expert panel members of NIOSH and of the Institute of Medicine have recognized that MSDs of the neck, back and upper extremities are important national health problems [Bernard, et al., 1997, Panel on Musculoskeletal Disorders and the Workplace, 2001]. NIOSH and IOM considered "repetition, force, posture and vibration" as causal risk factors in (part of the cause of) the development of upper or lower extremity conditions or body parts. NIOSH also considered "lifting/forceful movement, awkward posture, heavy physical work and whole-body vibration" as important causal risk factors for back disorders. These factors are often present in combination and are typical for many work situations of MOW workers.

Both expert panels of NIOSH and IOM concluded that there is strong evidence of a causal relationship of hand-arm vibration syndrome (HAV) and vibration exposure and for carpal tunnel syndrome a combination of repetition, force, posture and vibration. Based on their literature review, the expert panels concluded that there is strong evidence that whole-body vibration is a cause of back disorders. In its executive summary, the panel of the Institute of Medicine states (page 9) that there is "*a clear relationship between back disorders and physical load, i.e., manual material handling, frequent bending and twisting, heavy physical work, and whole-body vibration. For disorders of the upper extremities repetition, force and vibration are particular important work-related factors*." Furthermore, they stated that individual "*vulnerability to work-related musculoskeletal disorders*" is related to "*increasing age, gender, body mass index and a number* *of individual psychosocial factors*". The panel emphasized that "*modification of the various physical factors could reduce substantially the risk of symptoms of low back and upper extremity disorders*". The panel members of the IOM furthermore recommended "*characterization of exposures associated with musculoskeletal disorders should be refined, in including enhanced quantification of risk factors*". Musculoskeletal disorders of the upper extremities and low back pain/disorders have been studied primarily in the construction industry and a number of publications summarize study findings [Erdil, 1997, Harris-Adamson, 2017, Kittusamy and Buchholz, 2001, Morse, et al., 2007]. In a recent review of musculoskeletal symptoms in the construction industry, primarily disorders of the lower back (lumbar spine), knees, shoulders, and wrists were identified [Umer, et al., 2017].

More recent research has also shown that sources of psychosocial stress in the work environment, such as low job control, low social support, low job security, and highly monotonous work, can also increase the risk of a worker developing an MSD, even after taking into account the physical demands of the job [Lang, et al., 2012].

B. Ergonomics and musculoskeletal disorders among maintenance-of-way workers

Little has been published about maintenance-of-way (MOW) workers, also known as track maintenance workers. They sometimes work alone (i.e., track inspectors) but often work in teams (gangs) ranging in size from two to 10, or sometimes multiples of 10 (some large gangs can consist of 50-100 employees or more). They must travel with road or off-road vehicles to the work site throughout large territories and different terrains of the US. Although the work characteristics and job duties of MOW-workers are often compared to workers in general construction, there are several specific and important differences. MOW workers are generally involved in maintenance and repairing track defects and track conditions, emergency repair as well as new track construction, bridges, buildings and other structures, as well as right-of-way maintenance operations. This work often entails use of heavy hand-tools and of powered tools and automated equipment/vehicles that expose workers to vibration and other ergonomic physical hazards. Many of these tools and vehicles are unique and different from the general construction industry [Armstrong, 1998, Solomon, 2001]. MOW workers typically have experience with working on different materials including steel, timber and concrete and with a variety of tasks, including ground preparation, ballast and earth handling, welding, grinding, cutting, sawing, drilling, bending, lifting of tracks and ties, spiking, hammering, nails, nuts and bolts manipulation.

Based on earlier internal industry studies, including a job analysis of "section labor/trackman" [Lawshe, 1977] and an ergonomic assessment of a Northeastern metropolitan railroad [Biomechanics Corporation of America, 1993], as well as other railroad job descriptions, the following typical physical demands and environmental conditions are specifically recognized:

- Standing (on uneven footing and surfaces, ballast)
- Walking (on uneven surfaces and ballast)
- Sitting (on firm seats without suspension systems)
- Lifting (of ties with tongs; exerting up to 100 pounds of force occasionally, and/or up to 50-70 pounds of force frequently, and/or up to 20 pounds of force constantly to move objects)
- Carrying (equipment to/from worksite)

- Pushing
- Pulling (of spikes and pins)
- Very heavy work
- Climbing
- Balancing
- Stooping
- Kneeling
- Crouching
- Crawling
- Reaching
- Handling
- Use of hands and fingers
- Use of ballast fork
- Use of mall to drives spikes
- Use of lining bar
- Use of wacker
- Climbing on and off platforms; working under platforms
- Communication, visual tasks and hearing
- Outdoor work primarily (all seasons with extremes of hot, cold, rain, wetness and humidity)
- Use of power tools and equipment
- Noise
- Vibration
- Conditions in which there is danger to life, health and bodily injury
- Chemicals fumes, gases and fumes, pesticides, and herbicides
- Dust and particulates
- Cleaning and landscaping tasks
- Shift work schedules involve overtime including nights, weekends and holidays
- Operation of earthmoving equipment, road/off-road/track heavy vehicles
- Exposure to equipment that intensifies the heat factor on an occasional basis
- Demonstrate auditory and visual acuity/tracking/inspection

In the study of the Northeastern metropolitan railroad [Biomechanics Corporation of America, 1993], the ergonomic risks to the hands, wrists, elbows, shoulders, back, neck and legs were studied using medical data, an employee survey and an ergonomic risk prioritization, including jobs such as carrying off equipment, use of ballast fork, pulling of spikes and pins, lifting/maneuvering of ties, tamping ballast, use of spike and maul, maintaining right-of-way, climbing on and off and driving of trucks.[Biomechanics Corporation of America, 1993] Based on this risk analysis the following priority ranking was established, which involved primarily the back and upper extremity (a higher risk number means a higher risk):

Priority Ranking

Job Name	Job ID	Highest Risk	Body Part
Pulling Spikes & Pins	3	10.5	Back, Shoulders, Rt. Elbow
Lifting & Maneuvering Ties	4	9.5	Back, Legs, Lft. Shoulder, Neck
Tamping Ballast	6	9.5	Back, Hands/Wrists, Elbows, Lft. Shoulder, Neck
Use of Spike and Maul	5	9.5	Back, Shoulders, Neck
Use of Ballast Fork	2	9.5	Back, Elbows, Lft. Shoulder
Carrying Equipment To Worksite	1	9.33	Back, Legs
Maintaining Right-of-Way (ROW)	7	9.2	Back, Lft. Shoulder, Legs
Climbing On/Off and Driving in Truck	8	8.33	Back, Legs

Source: Table 3.1 [Biomechanics Corporation of America, 1993]

Based on this worksite analysis, several ergonomic opportunities were listed to reduce physiologic and musculoskeletal hazards. These included administrative controls, work practices and improved engineering design, considering ergonomics principles. Cost reduction opportunities were also identified. [Biomechanics Corporation of America, 1993]

In summary, track maintenance and renewal tasks of MOW workers are generally considered as unique, physically strenuous in nature and performed in all weather conditions. The use of hand-tools, hand-held powered tools, vibrating machines and vehicles are typically required, as well as transportation over long distances.

C. Tools used by maintenance-of-way workers

MOW workers typically use a combination of hand-tools, powered-hand-tools and heavy machinery and vehicles. The hazards of hand-tools have been well recognized and described. Workers using hand-tools are typically exposed to hazards of abrasive and flying objects, harmful dusts, and vibration/shock. Repetitive use, tool defects or improper maintenance can be a problem and pose a risk for injury or illness [OSHA, 2002]. Hand-tools are likely to expose the user to awkward (non-neutral) postures and joint deviations (i.e., from a short or straight handle tool design) and vibration or shocks (that is, hammering). Prolonged and intense use of tools powered by hydraulics, air, gasoline motors or electric power, called powered-hand-tools, are likely to cause excessive vibration exposure and may lead to hand-arm vibration syndrome (HAVS) and/or carpal tunnel syndrome (CTS). Powered hand-tools can also produce exposures to fumes, mists, vapors and gases.

Some examples of typical and unique hand-tools of a section gang are illustrated below:

Figure 1 Spike driver, spikes, tie plates, clips, bolts and tong

Figure 2 Sledge Hammer

Figure 3 Spike Maul

Figure 4 Claw bar

Figure 5 Lining bar

Figure 6 Spike lifter (used in conjunction with a claw bar)

Figure 7 Ballast fork

Figure 8 Tie plate removal tool

Figure 9 Track wrench

Figure 10 Rail tong

Figure 11 Adze

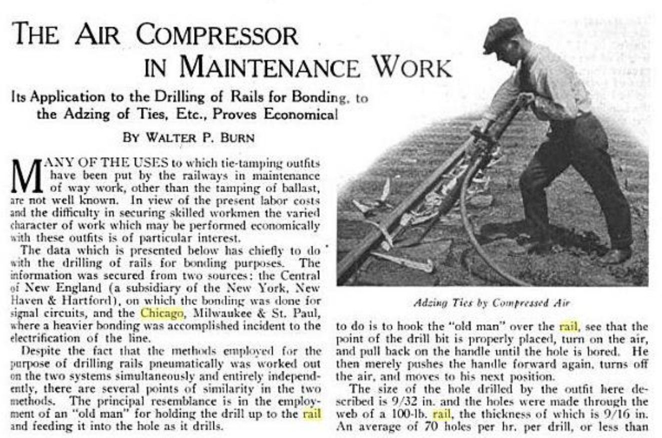
Figure 12 Clay pick

Figure 13 Track spike lifter

Figure 14 Rail anchor applicator

For other examples of hand-tools see also [source: https://www.aldonco.com/store/c/261-Track-Hand-Tols.aspx#Timber]

Figure 15 Gardner Denver GD 33-1 Rotary rock Drill



THE AIR COMPRESSOR IN MAINTENANCE WORK

Its Application to the Drilling of Rails for Bonding, to the Adzing of Ties, Etc., Proves Economical

BY WALTER P. BURN

MANY OF THE USES to which tie-tamping outfits have been put by the railways in maintenance of way work, other than the tamping of ballast, are not well known. In view of the present labor costs and the difficulty in securing skilled workmen the varied character of work which may be performed economically with these outfits is of particular interest.

The data which is presented below has chiefly to do with the drilling of rails for bonding purposes. The information was secured from two sources: the Central of New England (a subsidiary of the New York, New Haven & Hartford), on which the bonding was done for signal circuits, and the Chicago, Milwaukee & St. Paul, where a heavier bonding was accomplished incident to the electrification of the line.

Despite the fact that the methods employed for the purpose of drilling rails pneumatically was worked out on the two systems simultaneously and entirely independently, there are several points of similarity in the two methods. The principal resemblance is in the employment of an "old man" for holding the drill up to the rail and feeding it into the hole as it drills.

Adzing Ties by Compressed Air

to do is to hook the "old man" over the rail, see that the point of the drill bit is properly placed, turn on the air, and pull back on the handle until the hole is bored. He then merely pushes the handle forward again, turns off the air, and moves to his next position.

The size of the hole drilled by the outfit here described is 9/32 in. and the holes were made through the web of a 100-lb. rail, the thickness of which is 9/16 in. An average of 70 holes per hr. per drill, or less than

Figure 16 historical view of air compressor application

Figure 17 Body postures and tools (source: www.nymtmuseum.org)

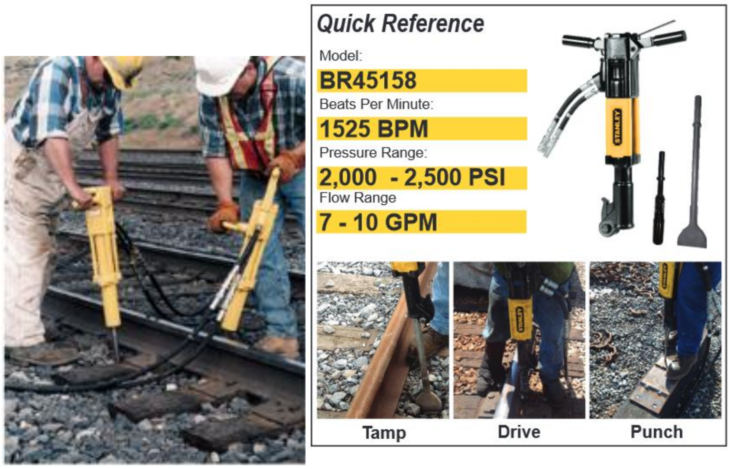


Figure 18 Tamping tool

Figure 19 Impact wrench and hand-tools of track inspector

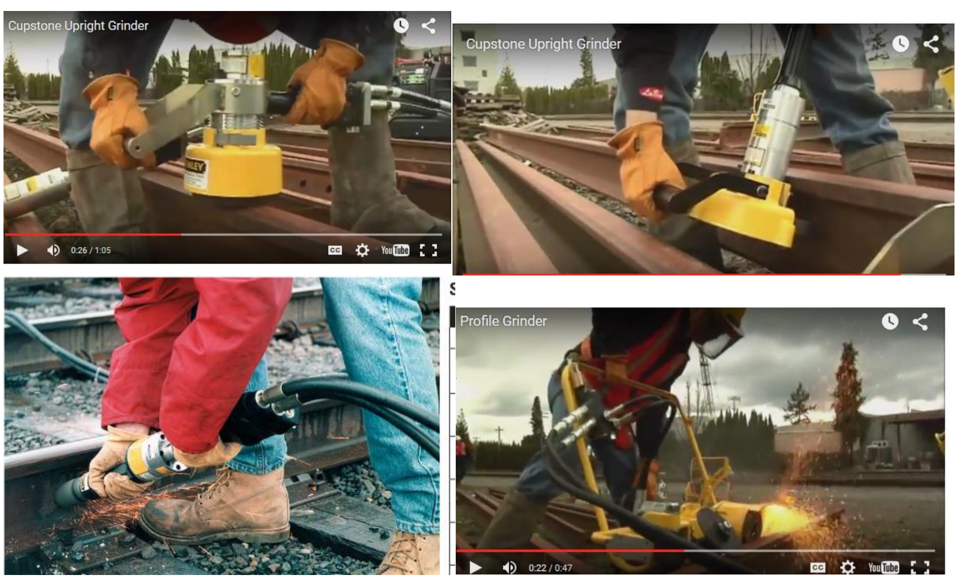


Figure 20 Cupstone -, bull nose – and profile Grinder

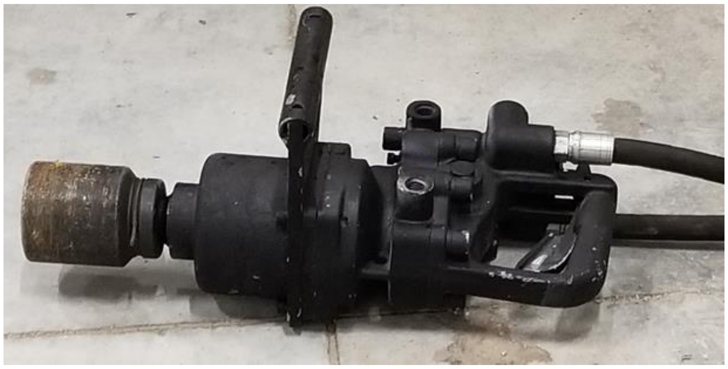


Figure 21 Impact wrench (rail bolts)

Figure 22 Chain Saw

Figure 23 Pneumatic Tools in rail construction and maintenance

Examples of Maintenance of Way track equipment include the following:

Figure 24 Ballast regulator and operator seat (Hasco 6700)

Figure 25 Tamper (Harsco 6700) and operator seated posture

Source: [Johanning, 2011]

Figure 26 Vibrating tamping and lifting tool of tamper (Harsco 6700)

Figure 27 Tie crane vehicle (Speed Swing®)

Figure 28 Anchor applicator

Figure 29 Tamper

Figure 30 Spikers Hammer

Figure 31 Tie exchanger

Figure 32 Crane

Figure 33 Machine and hand tool use; note body postures (field observation – typical night work)

Figure 34 Body posture of track workers with hand-tools (night work)

D. Vibration exposure

There are two forms of vibration exposure relevant for acute (short-term) or chronic (long-term) occupational health problems: 1) segmental or hand-transmitted vibration and 2) whole-body vibration.

1. Segmental vibration and hand-tools

Working with vibrating hand-tools can cause vascular and nerve-damage, recognized in the USA by the early 1900s by Dr. Alice Hamilton, who described the effects of air hammers on the hands of stonecutters [Taylor, et al., 1984]. Nevertheless, in the North-American market, there is still little information in product descriptions available about the risk of powered hand-tools contributing to hand-arm vibration (HAV) (also known as segmental vibration) emissions. Occupational hand-arm vibration exposure in construction and other industries has been associated with vascular, neurological and inflammatory conditions of the upper extremities, wrist or hand and has been described as a *hand-arm vibration syndrome*, which includes white-finger syndrome (Raynaud's disease), carpal tunnel syndrome (CTS) and painful bony conditions ("arthritis") [Bovenzi, 2006, Palmer and Collin, 1993, Pelmear and Taylor, 1994].

In the U.S., occupational exposure to hand-arm vibration (HAV) has been recognized by NIOSH and criteria for reducing the risk of developing vibration-induced injuries have been established in the 1980s [NIOSH, 1989] NIOSH emphasized that "*prevention is critical"* and *"adherence to exposure controls"* are recommended (page 5). NIOSH stated already in 1983 that "*Where jobs cannot be redesigned to eliminate vibrating tools such as pneumatic hammers, gasoline chain saws, and other powered handtools, engineering controls, work practices, and administrative controls should be employed to minimize exposure*" [NIOSH, 1983]. In a recent study from NIOSH it was emphasized that the combination of mechanical loads and vibration are major contributing factors for MSDs, including the shoulder and neck [Xu, et al., 2017]

Within the European Union (EU) market, the 'Machinery Directive' mandates since the early 1990s that manufacturers and distributors inform buyers and users of tools and equipment about vibration emission values exceeding an action level of 2.5 m/s^2 for hand-tools, following specific declaration and testing procedures [Kaulbars, 2016]. Methodological problems with emissions tests under laboratory conditions and enhancements have been described elsewhere [Dong, et al., 2001, McDowell, et al., 2012]. Some of these tools may have been previously investigated and reference data has been published [Christ, 2006, EU Directive, 2006, NetworkRail, 2017]. The daily exposure action limit (AL) for an 8-hour work day is set in the EU to be 2.5 m/s^2 and the daily exposure limit (EL) 5 m/s^2 [Griffin, 2006]. These action limits and exposure limits have been adopted in a US standard (American National Standard: Guide for the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the hand) (ANSI S2.70, 2006).

One goal of the current research study of BMWED members was to also investigate HAV exposure from powered hand-tools used in MOW applications (field measurements) and study health outcomes from the survey. However, due to logistical, access and other reasons, this was not possible and therefore data of manufacturer and field measurements from independent investigators were considered and compared for a categorical assessment of low, medium and high vibration emission from powered hand-tools.

2. Whole-body vibration from vehicles/equipment

Prolonged and intense whole-body vibration (WBV) is considered a general physical stressor and has been associated with a variety of occupational health disorders, especially of the musculoskeletal system, the spine and lower back [Bovenzi and Hulshof, 1999, Dupuis and Zerlett, 1987, Hinz, et al., 2006, Pope, et al., 1999, Schwarze, et al., 1998, Seidel, 2005]. Long-term whole-body vibration stemming from engines and vehicles has been identified as an important mechanical stressor causing early and accelerated degenerative spine diseases, leading to back pain and prolapsed discs [Bovenzi and Hulshof, 1999, Seidel, 2005]. Poor body posture, inadequate seat support and muscle fatigue have been described as co-factors in the pathogenesis (disease development) of musculoskeletal disorders of the spine in operators/drivers [Hinz, et al., 2008, Pope, et al., 2002, Rehn, et al., 2005, Wilder, 1993]. A high prevalence of back pain, early degenerative changes of the spine and herniated lumbar disc problems have been consistently reported among vibration-exposed occupational groups: tractor drivers, truckers and interstate bus drivers, crane or earth moving equipment operators and helicopter pilots [Christ, 2006] [Hulshof and van Zanten, 1987, Tiemessen, et al., 2008]. An epidemiological review of the scientific evidence of the whole-body vibration literature and back disorders for the Worker's Compensation Board of British Columbia concluded that there was: *...overwhelming evidence of a relationship that is consistent and strong, increases with increasing exposure, temporally precedes exposures, and is biologically plausible* [Teschke, et al., 1999](p. 15).

Also among operators of rail-vehicles (such as railroad and subway trains) with relatively low vertical (up and down) but higher lateral (side-to-side) vibration, and frequent high shocks (irregular vibration) the prevalence of back disorders appears to be high [Birlik, 2009, Johanning, 1991, Johanning, 2011, Johanning, et al., 2002, Johanning, et al., 2006, Sorainen and Rytkonen, 1999, Wilder, 2009]. Whole-body vibration and health studies for which epidemiological data exists conclude that typically there is an increasing risk of adverse spinal health effects and injury of the spine with longer and higher WBV exposure. An epidemiological study among locomotive engineers showed that this group had more complaints about seating ergonomics and a higher risk of neck and lower back disorders compared to a control group of civil engineers [Johanning, et al., 2004]. The analysis of field measurements has shown that the vibration signal of rail-bound vehicles contains frequently high shocks (or jolts) or peak values in all directions (x, y and z-axis) and therefore additional risk factors need to be considered in addition to the so-called "basic vibration values" (rms-value). Furthermore, the vehicle operator may be frequently in a static position (not moving) or an awkward (non-neutral) body posture during vibration and shock exposures due the design and layout of the cab, the control handles, or poorly retrofitted seat design, which may be additional stressors. In some European countries certain back disorders of professional drivers and heavy equipment operators are recognized as occupational diseases depending on certain criteria that include medical findings and documented significant life-time vibration exposure (typically more than 15 years) [Hulshof, et al., 2002, Johanning, 2015]. Although vibration should be kept to a minimum as per general guidance in the EU the action level for an 8 hour work day is set at 0.5 m/s^2 (AL) and the daily exposure limit value (EL) should not exceed 1.15 m/s^2 (0.8 m/s^2 in some EU-member countries) [EU The Directorate-General for Employment and Fischer, 2008, Griffin, 2006]. As a clear dose-response relationship has not been established and no definite threshold limits are known because of individual biological differences, these levels are for guidance only. Whole-body vibration is measured according to the methods published in an international standard ISO 2631-1 (1997) [ISO, 1997].

WBV related exposure risks can be prevented and managed through administrative and technical controls. A program that detects and controls hazards or exposures can play an important part in the early recognition of MSDs, including back disorders, caused by vibration and other ergonomic risk factors [Griffin, 2004, Johanning, 2000, Kilbom, et al., 1996, Matoba, 2015, Pelham, et al., 2005, Pope, et al., 2002, Tiemessen, et al., 2007, U.S. Department of Labor, 2018].

Another goal of the current study was to investigate WBV-exposure of MOW equipment/ vehicles under field conditions and study health outcomes from the survey. However, due to logistical, access and other reasons, this was not possible at this time and therefore data of manufacturer and field measurements from independent investigators were considered and compared for a categorical assessment of low, medium and high vibration emissions and exposures. Examples of WBV-results in rail-bound and off-road vehicles from prior studies are listed in section V.

E. Cardiovascular disease

Cardiovascular disease (CVD), including heart disease and stroke, is the leading cause of death in the U.S. [Kochanek, et al., 2017] and worldwide [Gaziano and Gaziano, 2012]. Several risk factors for CVD are well known, including smoking, hypertension, serum cholesterol and diabetes. However, the public is less aware that lower socioeconomic status increases risk of CVD [Singh, et al., 2015], that is, blue-collar workers have higher rates of heart disease than white-collar workers. In addition, a stressful organization of work, including high demand-low control work, low social support and long work hours [Schnall, et al., 2016] as well as physically demanding work [Coenen, et al., 2018, Holtermann, 2015, Holtermann, et al., 2018, Holtermann, et al., 2016, Krause, et al., 2017, Krause, et al., 2015] can increase a workers' risk of CVD. Also, standing work postures typical of MoW work speed up progression of atherosclerosis (that is, fatty deposits that can clog arteries) [Krause, et al., 2000] and increases the risk of developing varicose veins [Tüchsen, et al., 2000] and CVD [Smith, et al., 2018]. A stressful organization of work can also contribute to the development of musculoskeletal disorders [Lang, et al., 2012], and to diabetes [Leynen, et al., 2003], another important cause of morbidity and mortality in the U.S. [Kochanek, et al., 2017].

Therefore, questions were included in the BMWED Health and Safety Survey on heart disease, stroke, hypertension, other cardiovascular conditions, and diabetes. In addition, several questions on the organization of work, as potential risk factors for CVD, diabetes and for musculoskeletal disorders, were added to the survey.

F. Study goals

This study of ergonomics, vibration, musculoskeletal disorders and cardiovascular disease among maintenance of way (MOW) workers was designed to:

1) Collect information about ergonomics, vibration and work organization exposures faced by MOW workers and retirees, by self-report survey, a literature review and through analysis of tool and vehicle product information.

2) Collect information about the prevalence of musculoskeletal disorders and cardiovascular conditions among MOW workers and retirees by self-report survey.

3) Compare the prevalence of musculoskeletal and cardiovascular conditions, and selected working conditions between MOW workers and retirees and U.S. workers and retirees (from national surveys), to determine whether MOW workers are at increased risk of these health conditions, or unhealthy working conditions.

4) Determine the association between working conditions (including vehicles and tools) and musculoskeletal disorders, cardiovascular disease and diabetes through analysis of survey data.

II. METHODS

A. Literature Review on Ergonomics and Vibration of Tools and Equipment

A literature and data review was performed utilizing Medline (the U.S. National Library of Medicine) and other online resources (i.e., google search) with search terms related to Maintenance-of-Way (MOW) tool vibration emissions and specific tools utilized in the rail construction industry. In addition, data was collected through expert interviews and data published by independent or governmental agencies (i.e., NIOSH-US, DGAUM/IFA-Germany, Italian, French or British databanks) and compared with manufacturer information listed in online resources (such as sales catalogues, machine specifications, and manufacturer web sites for US and EU market utilizing VPN technology to avoid country-blocking).

B. Survey

While each of the three research groups worked independently, they were bound together by a common survey which was sent to approximately 35,000 current BMWED members and 4,000 active retirees (those with whom BMWED has on-going contact information). (See Appendix 3 for a copy of the survey and the cover letter they received.) The survey was completed by "active" BMWED members (that is, those working or available for work), those out on disability, and those retired due to age or medical condition at the time of the survey. Each person received a letter by postal mail from BMWED President Freddie Simpson explaining the overall study and the importance of the survey, a cover memo explaining the survey to participants, and the survey itself, if a retiree, and an on-line link to the survey if they were an active member. All were given a security protected URL to access the survey. They were required to sign in at a BMWED site to verify their birthdate, zip code, and the last four digits of their social security number, to assure that the respondents were actual members and that no one provided more than one set of responses. They then gained access to the survey at the secure site. No personal identifiers followed the respondent from the BMWED site to the survey site.

Participants were encouraged to fill out the survey on-line, in either English or Spanish, but it was also available in hard copy, or they could complete the survey through a confidential telephone interview (in English or in Spanish). Retirees, while also encouraged to complete the survey on-line, were mailed a hard copy of the survey with a postage-paid mailer for its return. Participants had several months to complete the survey. Current working members could also call or email the research staff for a written survey in English or in Spanish.

Answering the survey questions took 30 to 45 minutes. The survey ascertained work history, injuries and illnesses, and the social and economic impact of work-related injuries and illnesses. Respondents could skip questions and could submit with any degree of completion.

The survey results were recorded anonymously on-line; by mail, the survey was similarly returned without personal identifiers. Confidentiality for those who took the survey orally by telephone was maintained. The interviewer did ask for the person's identifying information to verify them in the BMWED system. However, this information was never recorded on the survey, and this identifying information was destroyed as soon as the verification was made.

A few mail surveys were returned with an individual's return address on the outside envelope. When this happened, the outside envelope was destroyed before the survey was put in a stack of surveys needing data input. No identifiers followed the survey unless individuals identified themselves within the survey because they had a question they wanted answered. This question was separated from survey and passed on to the appropriate person at BMWED or, in 2 cases, an occupational health clinic near to respondents was located and clinic information was forwarded to that respondent. No identifying information was put into the data base and the written surveys were destroyed once their data were inputted. Thus, for both phone surveys and mail surveys, a participant's name and identity would not be revealed.

Institutional Review Board (IRB) approvals came from both Cook County Hospital and the State University of New York-Downstate Medical Center. To ensure that the identity of all survey participants would be legally protected from discovery, a Certificate of Confidentiality issued by the National Institutes of Health (NIH) was obtained. Results of this survey contain no individual or identifiable personal information.

Of the 5,445 members and retirees who logged in to the survey, 4,816 answered the survey questions in full or in part. There appears to have been some "survey fatigue," as more questions were answered at the beginning of the multi-page survey (6 pages on-line, with follow-up questions not appearing if they were not relevant, and 15 pages in written form) than at the end. As a result, the number of subject responses for analysis also was smaller for many of the later questions.

1. Cleaning survey data

Cleaning the survey data and preparing datasets for analysis was conducted by Dr. Paul Landsbergis of the Ergonomics team and his graduate students, and by Ms. Grace Barlet of the Epidemiology team. The following steps were taken:

a. Yes/no questions. There were several yes/no questions in the on-line survey that did not have a "no" option (in order to make the on-line survey easier to read). These were question 25 (health problems), question 32 (various chronic diseases), question 34 (central nervous system condition), question 35 (cancer), question 36 (traumatic work injury), question 55 (illnesses or symptoms caused significant financial or other family burden), question 56, and question 57. Therefore, we assessed whether a missing answer meant "no" or was actually missing. To make this assessment, we determined the number of people who answered at least one question on that page of the survey. The result was:

Page number of survey	Questions on that page	Number of respondents answering at least one question on that page
1	questions 1-10	4,816
2	questions 11-16	4,202
3	questions 17-24	4,070
4	questions 25-52	3,821
5	questions 53-57	3,497
6	questions 58-61	3,538

For questions on each page of the survey, we divided the number responding "yes" to a specific health problem by the number of respondents answering at least one question on that page to determine the percent of people with a particular health problem or other condition. These were our best estimates of the percent of members with those problems or conditions. If, instead, we had divided all these health and other questions by 4,816, the resulting percentages of illnesses and other conditions on pages 2-6 of the survey would be smaller than our best estimate.

b. Out-of-range answers. Because of feasibility issues, none of the questions that asked about a year, an age or hours/week (questions 4-8, 15, and many parts of questions 9, 11, 16, 25, 32-36) used a drop-down menu. Members typed in their answers. Several survey respondents typed in answers that were "out of range", that is, not possible, for example, a "start work" year of 12 or 1898, or "how many years in a job title" as 2014. We examined each typographical error and recoded it based on what appeared to be the members' intention (for example, we recoded "12" as "2012", and "1898" as "1998", and "2014" years worked as "2"). Or, we recoded the error as "missing" if it was not possible to make an informed judgement about the members' intent.

In addition, for questions 34-36, the following rules were used for coding text responses: if 2 dates were listed, the first one was picked; a check mark was coded as "yes"; "don't know", "IDK", "unknown", or "?" were coded as "no"; "0" or "N/A" were coded as missing; and "possibly", "could be", or "inconclusive" were coded as "maybe".

c. Coding open text answers. Question 25 (Health problems possibly related to railroad work) was an open text question (no menu of options) for which we had to create categories of health problems and code, since the same health problem could be and was described in slightly different words. We created 46 categories of health problems, plus an "other" category.

C. Working conditions (exposure measures)

1. Biomechanical exposures

We examined the following hazardous physical working conditions:

1) Hours/day "vehicle/equipment vibration bothers me" (question 17).

2) Hours/day "hand tool vibrations bother me" (question 17).

From the 2015 National Health Interview Study-Occupational Health Supplement, http://www.cdc.gov/niosh/topics/nhis/, https://wwwn.cdc.gov/Niosh-whc/source/ohs:

3) Job involves repeated lifting, pushing, pulling, or bending? (often/always, sometimes, seldom/never) (question 18).

2. Vehicle and tool exposure duration

We also examined the total number of years BMWED members reported having done MOW work, and number of years worked in each of the job titles listed in question 9, each of the vehicles listed in question 11, and each of the tools listed in question 16. For vehicles and tools, we also multiplied by the fraction of the day BMWED members reported using those vehicles or tools (hours per day divided by 8). For question 16, the answering options were coded with the following hours: always (8), often (6), sometimes (4), rarely (2), never (0). The maximum number of years worked was set as 56 and the maximum number of hours per day worked was set at 16. In addition, we coded all vehicles listed in question 11 from "ballast regulator" to "brush cutter" as "high" vehicle vibration exposure and "trucks: heavy" or "light truck/van" as "low" vehicle vibration exposure. We also coded all power tools listed in question 16 as "high" tool vibration exposure and all hand-tools listed in question 16 as "low" tool vibration exposure. Finally, we divided all these continuous measures of years of exposure by 10 so that the resulting associations with health problems can be interpreted as the "effect" of 10 years of exposure.

3. Stressful work organization exposures

We examined the following stressful features of work organization:

From the 2015 National Health Interview Study-Occupational Health Supplement, http://www.cdc.gov/niosh/topics/nhis/, https://wwwn.cdc.gov/Niosh-whc/source/ohs:

1) Which of the following best describes the hours you usually work? Night shift, evening shift, irregular schedule vs. day shift (question (20)

2) My job allows me to make a lot of decisions on my own (strongly disagree, disagree, agree, strongly agree) (question 21).

3) I can count on my supervisor or manager for support when I need it (strongly disagree, disagree, agree, strongly agree) (question 22).

4) Health and safety of workers is a high priority with management where I work (strongly disagree, disagree, agree, strongly agree) (question 23).

From the 2014 NIOSH Quality of Work Life (QWL) survey, http://www.cdc.gov/niosh/topics/stress/qwlquest.html:

5) How often are there not enough people or staff to get all the work done? (strongly agree, agree, disagree, strongly disagree) (question 24).

D. Potential confounders

In addition, we looked at other factors which might explain some of the connections between working conditions, job titles, equipment or tools and health problems. For musculoskeletal disorders, we examined the following potential confounders:

1) age of BMWED member

2) region of the country where the individual performed the majority of his/her railroad work (northeast, southeast, central, western)

3) race/ethnicity (African American, Hispanic, White, Native American or Asian, and Other)

4) work a second job more than 20 hours per month (yes/no)

5) potential for vehicle vibration exposure at a second job (car, van, bus or coach coded "low"; train or motorcycle coded "medium"; rock crusher through off road forestry vehicle coded as "high")

6) potential for vehicle vibration exposure in spare time activity (car, van, bus or coach coded "low"; commuter train or motorcycle coded as "medium"; snowmobiles through tractor coded as "high")

For cardiovascular disease and diabetes, we examined potential confounders 1-4 listed above, plus an additional two:

5) second job car, van or motorcycle use (yes/no)

6) spare time car, van or motorcycle use (hours/week)

7) smoking (never smoker, past smoker, some current smoking, daily current smoker)

E. Health outcomes

Musculoskeletal symptom questions were taken from established validated questionnaires. References for these questions are contained in Appendix 1. Questions on "Have you EVER been told by a doctor or other health professional that you had having received a diagnosis of" cardiovascular conditions, diabetes and carpal tunnel syndrome were taken from the 2015 U.S. National Health Interview Survey-Occupational Health Supplement (NHIS-OHS) (https://www.cdc.gov/nchs/nhis/index.htm, https://wwwn.cdc.gov/Niosh-whc/source/ohs).

F. Data analysis

1. Prevalence of working conditions and ill health

The prevalence of specific working conditions and measures of ill health were computed by dividing the number of respondents reporting that working condition, symptom or diagnosis by the number of respondents who completed at least one question on that page of the survey.

2. Comparisons to U.S. national averages

Questions from the 2015 U.S. National Health Interview Survey-Occupational Health Supplement (NHIS-OHS) and from the 2014 U.S. National Institute for Occupational Safety and Health Quality of Work Life (QWL) survey were designed to estimate the proportion of the U.S. population who have specific working conditions or health problems. We compared active male BMWED members to U.S. employed men of the same age range (18-74 years), and we compared retired BMWED men to U.S. retired men of the same age range (60-105). We also statistically adjusted for any differences between the national survey sample and the BMWED survey sample in age, region of the country, and race/ethnicity for the NHIS-OHS and in age and race/ethnicity for the QWL. The numbers and percentages of health measures in these BMWED comparison analyses differ slightly from the prevalence analyses described above because of missing data on gender used to adjust the comparison analyses. We applied survey weights from the NHIS-OHS and the QWL to these national survey data files before analysis to obtain national population prevalence estimates of health measures. We used Poisson regression to compute adjusted prevalence ratios for differences in work exposures or health between the BMWED sample and the national survey sample (proc genmod in SAS 9.4) for these comparisons since in cases where the outcomes being compared are common, odds ratios would tend to overestimate the true prevalence ratios.

3. Comparisons to other studies

Some of our MSD health symptom questions were used in other studies conducted in other countries. To compare BMWED members to workers in those other studies, we included comparisons to all studies that we could locate that involved workers in physically demanding jobs, or samples from the general population. We hypothesized that BMWED members would have a higher prevalence of symptoms and health problems than the general population in other studies, and a similar prevalence of symptoms and health problems as workers in physically demanding jobs.

4. Associations between working conditions and musculoskeletal ill health

a. Health outcomes. We analyzed the survey data to see which working conditions, job titles, equipment or tools were associated with health problems. We looked specifically at 11 different health problems:

1) 4 back health problems: Back pain during the past week (question 41), Back pain lasting more than 1 week at a time (question 43), Back-related injury reported to railroad or railroad medical department (question 46), and Back pain goes down the leg below the knee at least weekly (question 48). All these questions excluded people who reported daily or weekly back problems before they started their present job (question 49).

2) 4 hand health problems: Been told by a doctor that you have carpal tunnel syndrome (question 32), Finger numbness or tingling daily or weekly (question 50), White fingers from cold or white fingers having a clear boundary daily or weekly (question 50), Hand/wrist pain in past week lasting a day or more (question 52).

3) 3 other health problems: Severe joint pain in the past year (question 51), Shoulder pain in past week lasting a day or more (question 52), Knee pain in past week lasting a day or more (question 51).

b. Hypotheses. Our main hypotheses were that the 5 working conditions questions would be associated with the 11 health problems. We also expected to see stronger connections between the health problems and "high" vehicle vibration exposure than with "low" vehicle vibration exposure or "high" tool vibration exposure than with "low" tool vibration exposure. Finally, we considered as exploratory the other associations we examined between health problems and years using specific job titles, specific vehicles and specific tools.

c. Analyses. We used Poisson regression (GENLIN in SPSS v. 24) to assess the adjusted prevalence ratio (PR) of having each of the 11 health problems. (A prevalence ratio is the percent of health problems reported by one group divided by the percent of health problems reported by another group.) The measures of working conditions, job titles, equipment and tools were entered into separate regression models to determine their associations with each of the 11 health outcomes. All regression analyses adjusted for age, region of the country, race/ethnicity, second job, second job potential vehicle vibration exposure and spare time potential vehicle vibration exposure. We restricted the analyses to active male BMWED members, given the very small number of women who completed the survey (19 active female survey respondents).

5. Associations between working conditions and cardiovascular disease and diabetes

a. Health outcomes. We analyzed the survey data to see which working conditions and job titles were related to health problems. We looked specifically at 9 different health problems, taken from question 32 of the survey:

1) 5 measures of heart disease or stroke: Coronary heart disease; angina (also called angina pectoris); heart attack (also called myocardial infarction); any other kind of heart condition or heart disease; and stroke. We also created a composite measure called "any heart disease or stroke" defined as a "yes" if the participant reported any of these 5 measures of heart disease or stroke.

2) 2 questions on diabetes: Diabetes or sugar diabetes; and prediabetes, impaired fasting glucose, impaired glucose tolerance, borderline diabetes, or high blood sugar. The question on diabetes also asked "If yes, how old were you when a doctor or other health professional FIRST told you that you had diabetes or sugar diabetes? We only counted self-reports of diabetes diagnosis which occurred at age 21 or older, as our measure of adult-onset (Type II) diabetes.

3) Intermediate conditions increasing risk for cardiovascular disease: Hypertension, also called high blood pressure; and high cholesterol.

b. Hypotheses. Our main hypotheses were that the one measure of heavy occupational physical demands (repeated lifting, pushing, pulling, or bending), and the 5 stressful working conditions we assessed would be associated with the above 9 health problems, plus the one composite measure (any heart disease or stroke). We considered as exploratory the associations between the 10 health measures and years in specific job titles.

c. Analyses. We used Poisson regression (GENLIN in SPSS v. 24) to assess the adjusted prevalence ratio (PR) of having each of 8 health measures. Analyses were not conducted for angina and stroke, since there were fewer than 10 cases of each of those conditions, and thus very wide and unreliable confidence intervals would be produced. The measures of working conditions and years in job titles were entered into separate regression models to determine their associations with each of the 10 health measures. All regression analyses adjusted for age, region of the country, race/ethnicity, second job, second job car, van or motorcycle use, and spare time car, van or motorcycle use (hours/week). We restricted the analyses to active male BMWED members, given the very small number of women who completed the survey (19 active female survey respondents).

G. Were survey respondents representative of BMWED members and retirees?

The 2016-17 BMWED health and safety survey was at least partly completed by 4,816 members, approximately 12% of members and retirees. It was thus important to determine to what extent the members who answered the survey (survey respondents) were representative of all active or retired members who received the invitation to complete the survey. There were two main methods that we used to examine whether the survey respondents were representative of all members:

1) We compared survey respondents to the national membership of the union on available demographic information (age, years on the job, gender, region of country, and railroad employer).

2) We compared survey respondents to a random sample of non-respondents who later agreed to complete a short (10-question) version of the survey by telephone. This telephone survey of members who had not responded to the on-line survey was done by local union officials.

Results of our analyses are contained in Appendix 4. Briefly, active members and retirees who completed the survey were, on average, younger, and had slightly better working conditions than members who did not complete the survey. Survey respondents also tended to be healthier than non-respondents in their responses on surgeries, cancer, or shortness of breath. However, back pain in the past week was slightly more common in survey respondents.

Therefore, the percent of members who reported injuries and illnesses on the 2016-17 BMWED survey would probably be somewhat less than the percent that would have been reported by all BMWED active members or retirees if all had completed the survey. This implies that the results we report are likely conservative (lower) estimates of the prevalence of ill health (except for back pain). In addition, these findings suggest that associations between working conditions and the health of BMWED members that we report (except for back pain) are likely underestimates of the true associations that would have been seen if all members and retirees had completed the survey.

III. SURVEY RESULTS

A. Working conditions

Questions 11-24 in the BMWED Health and Safety survey asked members and retirees about a variety of working conditions. Results from those questions by BMWED member status (active, out on disability, retired based on age, and retired based on medical condition) are detailed in the Appendix Tables A5a, A5b and A5c ("job exposures").

1. Vehicles

The most common type of vehicle used by survey participants (question 11) was Truck (heavy, road or hi-rail), reported by n=1,984, with an average 10.5 years, and 7.8 hours/day of use, followed by Light Truck/Van (road or hi-rail (n=1,347, average 12.0 years of use, and 7.5 hours/day), Ballast Regulator, (n=1,086, average 6.1 years of use, and 8.4 hours/day), Tamper (n=1.005, average 6.9 years of use, and 8.6 hours/day) and Backhoe (n=913, average 6.2 years of use, and 7.6 hours/day). Survey participants reported an average of 2.8 vehicles operated since starting on the railroad, with a range of 1-14.

2. Tools

BMWED members and retirees reported many different types of tools used at work since working for the railroad (question 16). The most commonly used tools were Sledgehammer (n=3,999, 97.7%), Spike Maul (n=3,841, 94.0%), Claw Bar (n=3,937, 96.5%), Lining Bar (n=3,748, 92.0%), Track Wrench (n=3,574, 87.9%), Spike Puller (n=3,521, 87.9%), Rail Saw (n=3,395, 84.7%), Rail Drill (n=3,344, 83.3%), Impact Wrench (n=3,190, 80.6%), Tamping Gun (n=3,031, 76.5%), Spike Driver (n=3,019, 76.9%), and Impact Tool (n=3,005, 77.2%).

3. Biomechanical and vibration exposures

BMWED members and retirees reported always (8-10 hours/day) or often (4-6 hours/day) standing (n=3,008, 77.4%), sitting (n=1,580, 40.5%), bothered by vehicle/equipment vibration (n=961, 26.7%), bothered by hand tool vibration (n=1,022, 27.8%) and bothered by noise (n=1,480, 39.9%) (question 17).

Nearly ¾ (n=2, 947, 73.6%) reported that their job involves repeated lifting, pushing, pulling or bending often or always (question 18). Most (n=3,461, 86.2%) work a regular daytime schedule (question 20).

4. Work organization

Nearly 1/3 (n=1,211, 30.1%) disagreed with the statement "My job allows me to make a lot of decisions on my own (question 21), and nearly 2/5 (n=1,565, 39.0%) disagreed with "I can count on my supervisor or manager for support when I need it (question 22). Similarly, nearly 2/5 (n=1,595, 39.9%) disagreed with "The health and safety of workers is a high priority with management where I work" (question 23). Most (n=3,534, 87.5%) reported that there are often or sometimes "not enough people or staff to get all the work done" (question 24).

5. Non-work exposures (potential confounders)

a. Second job. Two hundred ninety-three participants (7.3%) reported working a second job for at least 20 hours per month since working for the railroad (question 12). Two hundred sixty-six of them reported the industry of the second job. Half (n=133) reported Services/Administration, about a quarter reported Construction (n=72, 27.1%) and about a sixth reported Farm/Agriculture (n=46, 17.3%). They reported working an average of 9.4 years on the second job with a range of 1-53 years. To assess how much exposure to vibration there was on the second job, the survey asked about type of vehicle used on the second job. This question (#14) was answered by 171 people. About half (n=83) reported a car, 47 reported more than one answer (27.5%) and 15 reported a tractor (8.8%), which typically has higher vibration exposure than a car.

b. Second job car, van or motorcycle use. Of the 171 who answered the question on second job vehicle use, 83 reported car (48.5%), 9 reported van (5.3%) and 1 reported motorcycle (0.6%).

c. Spare time vehicle use. The survey also asked about vehicles used in one's spare time, outside of work or commuting to work (question 15). The most common answers were Car or Van (n=3,669, 12.2 hours/week), mower (n=1,326, 2.4 hours/week), All Terrain Vehicles (n=415, 3.1 hours/week), Tractor (n=389, 4.2 hours/week) and Motorcycle (n=379, 5.4 hours/week).

d. Spare time car, van or motorcycle use. Participants averaged 8.1 hours/week using a car, van or motorcycle during their spare time.

6. Comparisons to U.S. national averages

Active male BMWED members were less likely to work an evening, night or irregular schedule compared to all U.S. male workers (14.2% vs. 28.3%) (adjusted prevalence ratio(PR)=0.51, 95% CI 0.46-0.57, p<.001) (Table 1). Active male BMWED members were much more likely to report that they often or always have a job that involves repeated lifting, pushing, pulling or bending (74.6% vs. 46.9%) (adjusted PR=1.61, 95% CI 1.54-1.70, p<.001). The proportion of BMWED members was slightly lower than that of US "construction and extraction" workers (80.4%) [Shockey, et al., 2018]. Active male BMWED members were more likely to report that often or sometimes there were not enough people or staff to get all the work done (88.1% vs. 65.2%) (adjusted PR=1.34, 95% CI 1.25-1.44, p<.001). Active male BMWED members were also much more likely to *disagree* that "my job allows me to make a lot of decisions on my own" (31.6% vs. 12.3%) (adjusted PR=3.01, 95% CI 2.70-3.35, p<.001) or *disagree* that "I can count on my supervisor or manager for support when I need it" (39.7% vs. 9.2%) (adjusted PR=4.18, 95% CI 3.72-4.68, p<.001) or *disagree* that "the health and safety of workers is a high priority where I work" (40.7% vs. 5.2%) (adjusted PR=7.96, 95% CI 6.91-9.16, p<.001).

B. Musculoskeletal disorders

Questions 32 and 41-52 in the BMWED Health and Safety survey asked members and retirees about a variety of musculoskeletal health problems. Descriptive results of those questions are detailed in Appendix Tables A7a, A7b and A7c.

1. Carpal tunnel syndrome and arthritis (reported diagnoses)

Nearly 1 in 10 members and retirees reported having been diagnosed with carpal tunnel syndrome (n=370, 9.7%). In addition, 473 (12.4%) reported having been diagnosed with arthritis. Sometimes, work-related musculoskeletal conditions are misdiagnosed as arthritis.

a. Comparisons to U.S. national averages. Compared to all U.S. **employed men** age 18-74, active BMWED men were more likely to have ever been told by a doctor or a health professional that they have carpal tunnel syndrome (7.9% vs. 3.6%) (adjusted PR=1.99, 95% CI 1.64-2.43, p<.001) (Table 1). And about the same percent were told that they have arthritis (13.3% vs. 12.7%), a difference that was not statistically significant, that is, a difference likely due to chance.

Compared to U.S. **retired men** age 60-105, retired BMWED men were more likely to have

Table 1: Prevalence of Working Conditions and Reported Carpal Tunnel Syndrome Diagnosis Among Active BMWED Men (n=2,748) Compared to U.S. Employed Men			
Working Conditions questions 18-24	**BMWED %**	**U.S. %**	**Adjusted prevalence ratio[a]**
18. How often does your job involve repeated lifting, pushing, pulling, or bending?			
Often/Always	74.6%	46.9%	1.61***
Sometimes/Seldom/Never	25.4%	53.1%	
20. Which of the following best describes the hours you usually work?			
Evening, Night, Irregular	14.2%	28.3%	0.51***
Daytime	85.8%	71.7%	
21. My job allows me to make a lot of decisions on my own.			
Strongly Disagree/Disagree	31.6%	12.3%	**3.01*****
Strongly Agree/Agree	68.4%	87.7%	
22. I can count on my supervisor or manager for support when I need it.			
Strongly Disagree/Disagree	39.7%	9.2%	**4.18*** **
Strongly Agree/Agree	60.3%	90.8%	
23. The health and safety of workers is a high priority with management where I work.			
Strongly Disagree/Disagree	40.7%	5.2%	**7.96*** **
Strongly Agree/Agree	59.3%	94.8%	
24. How often are there not enough people or staff to get all the work done?			
Often/Sometimes	88.1%	65.2%	1.34***
Rarely/Never	11.9%	34.8%	
Reported Diagnoses question 32			
32. Have you ever been told by a doctor or other health professional that you had carpal tunnel syndrome?			
Yes	7.9%	3.6%	1.99***
No/Don't Know	92.1%	96.4%	

Note: Percents and prevalence ratios (PRs) reflect comparisons between BMWED men aged 18-74 and men of the same age range from the 2015 U.S. National Health Interview Survey (NHIS), except for question 24, which was from the 2014 U.S. Quality of Work Life survey. Women were excluded from this analysis due to their small sample size (only 19 active BMWED women completed the survey).
[a]PRs adjusted for age, race/ethnicity, and region, by Poisson regression. PRs >2 are in boldface.
*p<.05, **p<.01, ***p<.001, which indicates level of statistical significance.

ever been told by a doctor or a health professional that they have carpal tunnel syndrome (15.2% vs. 9.1%) (adjusted PR=1.41, 95% CI 1.05-1.89, p=.023). Retired BMWED men were less likely to report that they had been told that they had arthritis (28.8% vs. 44.9%) (adjusted PR=0.64, 95%

CI 0.55-0.74, p<.001).

2. Back pain (symptoms)

Back pain (questions 41-49) was a very common condition among BMWED members and retirees, either lower back pain more than 3 times/year (n=2,625, 70.6%), lower back pain lasting more than 1 week at a time (n=1,601, 43.4%), back pain during the past week (n=1,866, 50.4%), or always (every day) or often (4-6 days/week) low back pain during the past week (936, 27.0%). Only in a small number of cases (n=257, 7.1%) was there "severe injuries or fractures in the area of current discomfort". Therefore, most cases of low back pain were likely chronic conditions due to day-to-day physical work demands. Only in a small number of cases (194, 5.3%) did members or retirees report having back problems when they started their present job. Therefore, railroad work likely contributes to many of the cases of back pain.

Only in a small percent of cases (307, 10.2%) did active members report a back-related injury to the railroad or the railroad medical department. However, members out on disability (37, 48.1%), or those retired due to age (205, 36.1%) or medical condition (15, 60.0%) were much more likely to have reported their condition.

Somewhat less common low back symptoms included "always or often" cramping (221, 7.7%), burning sensation (175, 6.3%), stiffness (1099, 32.9%), swelling (139, 5.1%), "pins and needles" (214, 7.6%), numbness (108, 3.9%) and numbness in back and lower leg (295, 10.1%). Most of these symptoms were more common in retired members and those out on disability than active members.

Daily or weekly symptoms of sciatica (pain from the lower back down the leg below the knees) was experienced by 439 (12.8%). One in 6 members or retirees reported taking medicine for their back problem (579, 16.7%). Only 116 (3.3%) reported missing 3 or more days of railroad work in the past year due to back problems.

a. Comparisons to other studies. Studies of workers in other countries have used the same or similar back pain questions (see Appendix Table A2d). Nearly half (48.9%) of active BMWED members reported back pain in the past week, a higher percent than track maintenance workers in the UK (36%) or the general employed population in Norway (15%) [Riley, 2006].

3. Hands (symptoms related to nerve entrapment or vibration-related damage)

About a quarter of members and retirees reported symptoms consistent with nerve entrapment, such as carpal tunnel syndrome, or nerve damage due to vibration, daily or weekly during the past year (question 50). Such symptoms include numbness or tingling of the fingers (n=937, 26.3%), numbness or tingling of the fingers lasting more than 20 minutes during or after using vibrating tools (n=642, 18.4%), waking up at night with pain, tingling, or numbness in the hand or wrist (n=665, 18.9%) or difficulty picking up very small objects, such as screws or buttons or opening tight jars (n=486, 13.9%). A smaller proportion of workers reported symptoms daily or weekly during the past year consistent with vibration-related disease -- fingers gone white (blanching) when exposed to cold (n=201, 5.8%) or, if having experienced white fingers, the whiteness was clearly demarcated (showed limits or boundaries) (n=109, 3.3%).

a. Comparisons to other studies. A quarter (25.0%) of active BMWED members reported tingling or numbness in their fingers daily or weekly compared to 17.3% of British male workers, who reported the symptom lasting 3 or more minutes in the past week [Palmer, et al., 1999] (Appendix Table A2b). 17.6% of active BMWED members reported pain, tingling or numbness in their hand or wrist disturbing sleep daily or weekly compared to 7.4% of British male workers, who reported the symptom lasting 3 or more minutes in the past week [Palmer, et al., 1999]. 21.6% of active BMWED members reported cold-induced blanching (whitening) attacks of their fingers in the past year compared to 10.6% of British male workers ever [Palmer, et al., 1999]. 12.5% of active BMWED members reported blanching attacks associated with a clear edge in the past year compared to 4.1% of British male workers ever [Palmer, et al., 1999].

4. Other joint pain (symptoms)

Over half of members and retirees reported severe joint pain in the past year (n=1983, 52.1%). If they said "yes" to this question (#51), then additional questions were asked about specific joints.

a. Wrists/hands. 29.1% of active members reported pain in either wrist/hand lasting a day or more in the past year compared to 21.6% of French male workers [Parot-Schinkel, et al., 2012] and similar to 30% of another group of workers facing high physical job demands -- Scandinavian and Russian male mine workers [Burstrom, et al., 2017] (Appendix Table A2a). 23.1% of BMWED members also reported pain in either wrist/hand lasting a day or more in the past week, and 13.9% said they had been prevented from carrying out normal activities (such as job, housework or hobbies) due to wrist/hand pain.

b. Knee pain. 34.2% of active BMWED members reported knee pain lasting a day or more in the past year compared to 28.3% for knee and lower leg of French male workers [Parot-Schinkel, et al., 2012] and 37% for knee and lower leg of Scandinavian and Russian male mine workers [Burstrom, et al., 2017] (Appendix Table A2a). 23.9% of BMWED members also reported knee pain lasting a day or more in the past week, and 13.5% said they had been prevented from carrying out normal activities due to knee pain.

c. Hip pain. 17.7% of active BMWED members reported hip pain lasting a day or more in the past year compared to 16.7% (for hip/thigh) of French male workers [Parot-Schinkel, et al., 2012] and 16% of Scandinavian and Russian male mine workers [Burstrom, et al., 2017] (Appendix Table A2a). 12.5% of BMWED members also reported hip pain in the past week, and 8.3% said they had been prevented from carrying out normal activities due to hip pain.

d. Shoulder pain. 29.3% of active BMWED members reported shoulder pain lasting a day or more in the past year compared to 28% of French male workers reporting shoulder pain at any time [Parot-Schinkel, et al., 2012] and 50% of Scandinavian and Russian male mine workers reporting shoulder pain at any time [Burstrom, et al., 2017] (Appendix Table A2a). 22.1% of BMWED members also reported shoulder pain in the past week, and 15.2% said they had been prevented from carrying out normal activities due to shoulder pain.

e. Neck pain. 24.9% of active BMWED members reported neck pain lasting a day or more in the past year compared to 33.5% of French male workers reporting neck pain at any time [Parot-Schinkel, et al., 2012] and 52% of Scandinavian and Russian male mine workers reporting neck pain at any time [Burstrom, et al., 2017] (Appendix Table A2a). 18.0% of BMWED members reported neck pain lasting a day or more in the past week, and 11.3% said they had been prevented from carrying out normal activities due to neck pain.

f. Elbow pain. 17.4% of active BMWED members reported pain in either elbow lasting a day or more in the past year compared to 17.2% of French male workers reporting elbow or forearm pain at any time [Parot-Schinkel, et al., 2012] and 17% of Scandinavian and Russian male mine workers reporting elbow pain at any time [Burstrom, et al., 2017] (Appendix Table A2a). 13.6% of BMWED members reported elbow pain lasting a day or more in the past week, and 9.4% said they had been prevented from carrying out normal activities due to elbow pain.

C. Cardiovascular disease and diabetes

Question 32 in the BMWED Health and Safety survey asked members and retirees about a variety of cardiovascular health problems and diabetes. Results from those are detailed in Appendix Tables 6a and 6b.

The most common cardiovascular conditions were high blood pressure ("hypertension") (n=887, 23.3%) and high cholesterol (n=711, 18.7%). Few members reported actual heart disease, angina, a heart attack or stroke. 173 reported having been diagnosed with diabetes or borderline diabetes at or after age 21 (4.6%) and 209 with prediabetes (5.5%).

a. Comparisons to national averages. Compared to all U.S. **employed men** age 18-74, active BMWED men were somewhat less likely to have ever been told by a doctor or a health professional that they have high blood pressure (21.3% vs. 24.6%), high cholesterol (16.5% vs. 22.9%), coronary heart disease (0.9% vs. 2.4%), angina (0.3% vs. 0.9%), a heart attack (0.8% vs. 1.4%), other heart disease (1.4% vs. 4.9%) or stroke (0.2% vs. 0.9%). All these differences were statistically significant, that is, real differences not likely due to chance. There was no statistically significant difference between BMWED active men and U.S. employed men on the prevalence of diabetes or borderline diabetes diagnosed at age 21 or older (4.6% vs. 5.6%) or "prediabetes, impaired fasting glucose, impaired glucose tolerance, borderline diabetes, or high blood sugar" (3.9% vs. 3.8%).

Compared to all U.S. **retired men** aged 60-105, BMWED retired men were less likely to have ever been told by a doctor or a health professional that they have high blood pressure (33.2% vs. 61.4%), high cholesterol (30.7% vs. 54.9%), coronary heart disease (5.8% vs. 19.1%), angina (2.3% vs. 7.3%), a heart attack (3.0% vs. 13.2%), other heart disease (6.6% vs. 18.8%), stroke (0.8% vs. 8.5%), or diabetes or borderline diabetes diagnosed at or after age 21 (3.4% vs. 23.4%). All these differences were statistically significant, that is, real differences not likely due to chance. There was no statistically significant difference between BMWED retired men and U.S. retired men on the prevalence of "prediabetes, impaired fasting glucose, impaired glucose tolerance, borderline diabetes, or high blood sugar" (10.4% vs. 9.2%).

D. Associations between working conditions and musculoskeletal ill health

1. Back health

Three of our measures of back pain (questions 41, 43 and 48) were all statistically significantly associated with "vehicle equipment vibration bothers me", "hand tool vibration bothers me", "job involves repeated lifting, pushing, pulling, or bending", and disagree that "health and safety of workers is a high priority with management where I work" (see Table 2 and Appendix Table A10).

Most of these associations showed a "dose-response" trend, that is, increasing risk of pain as the working conditions measure becomes more hazardous. For example, while 28.8% of active male BMWED members reported back pain during the past week if vehicle equipment vibration did not bother them, 47.8% of members reported this symptom if vehicle equipment vibration bothered them sometimes (1-2 hours/day), and 61.8% of members reported this symptom if vehicle equipment vibration bothered them always (8-10 hours/day).

Table 2: Associations of Selected Work Factors with Back Pain in the Past Week among Active BMWED Men (n=2,748)		
Work Factors	**Back pain %**[a]	**Prevalence Ratio**[a]
17. Vehicle/equipment vibration bothers me		
8-10 hours/day	61.8%	**2.15*** **
4-6 hours/day	57.4%	1.99***
1-2 hours/day	47.8%	1.66***
<1 hour/day	38.7%	1.35**
0 hours (ref.)	28.8%	1.00
17. Hand tool vibration bothers me		
8-10 hours/day	61.6%	**2.26*** **
4-6 hours/day	56.2%	**2.06*** **
1-2 hours/day	46.1%	1.69***
<1 hour/day	39.7%	1.45**
0 hours (ref.)	27.3%	1.00
18. Job involves repeated lifting, pushing, pulling or bending		
Often/Always	46.0%	1.72*
Sometimes	38.3%	1.43
Seldom/Never (ref.)	26.8%	1.00
23. Health and safety of workers is a high priority with management where I work		
Strongly Disagree	60.8%	1.92***
Disagree	49.0%	1.55***
Agree	39.8%	1.26*
Strongly Agree (ref.)	31.7%	1.00
24. How often are there not enough people or staff to get all the work done?		
Often/Always	48.6%	1.01
Sometimes	37.2%	0.77
Rarely	32.5%	0.68
Never (ref.)	48.1%	1.00
6. Risk for 10 years of MOW work		1.07
11. Risk for 10 yrs (x fraction of day) exposed to high vibration equipment		1.18
11. Risk for 10 yrs (x fraction of day) exposed to low vibration equipment (trucks)		1.07
16. Risk for 10 yrs (x fraction of day) exposed to power tools (high vibration)		1.55***
16. Risk for 10 yrs (x fraction of day) exposed to hand-tools (low vibration)		1.19**

[a]Prevalence ratio (PR) and back pain % adjusted for age, region, race/ethnicity, second job, second job vehicle vibration, and spare time vehicle vibration using Poisson regression. *p<.05, **p<.01, ***p<.001

PR >2 in boldface. Prevalence ratios are the percent in one group divided by the percent in another group

Question 24 ("not enough people or staff to get all the work done") and years doing MOW work (adjusted for age) were not significantly associated with back pain. Finally, our measures of hazardous working conditions were not consistently related to reporting back-related injury to the railroad or railroad medical department (question 46).

a. Job titles. 7 of 44 associations between years worked in specific job titles and back health (11 job titles x 4 measures of back health) were statistically significant, after taking age into account. Small significantly increased risks were seen for machine operator, equipment operator and electric traction employee for "back pain lasting more than 1 week at a time", for machine operator, equipment operator and truck driver/bus driver for "back-related injury reported to railroad or railroad medical department", and for trackman/laborer for reporting a back-related injury to the railroad.

b. Vehicles. Average years using high vibration vehicles (from ballast regulator to brush cutter) were not significantly associated with back symptoms, in part, due to the relatively small number of people reporting such use. The numbers of active BMWED members reporting use of any individual vehicle ranged from 125 to 1052. Use of *any* such vehicle was reported by 1363 members. As a result of these smaller numbers, some apparently elevated risks for 10 years of use (PR=1.51, p=.06, that is, a 51% increased risk for "back pain lasting more than 1 week at a time" and PR=1.70, p=.10, that is, a 70% increased risk for "back-related injury reported to railroad or railroad medical department") were not statistically significant (Table 2 and Appendix Table A10).

More members reported using lower vibration vehicles, such as trucks (heavy, road or hi-rail) or light trucks/vans, ranging from 1261 for heavy trucks to 1881 for light trucks/vans. As a result, use of either type of vehicle could be computed for 1467 members. Ten years of use of these vehicles was associated with an increased risk of "back pain lasting more than 1 week at a time" (PR=1.21, p=.006) and "back-related injury reported to railroad or railroad medical department") (PR=1.49, p<.001). A PR=1.21 represents an increased risk of back pain of 21% for every 10 years worked on heavy or light trucks.

7 of 52 associations between specific vehicles and back health (13 vehicles x 4 measures of back health) were statistically significant, after adjusting for age, in part, due to the relatively smaller number of people reporting use of specific vehicles. Years worked on a grader, cribber/scarifier, heavy truck and light truck were significantly associated with "back pain lasting more than 1 week at a time". Years worked on a heavy truck and light truck were significantly associated with "back-related injury reported to railroad or railroad medical department". Years worked on a tie crane were significantly associated with "back pain goes down leg below the knee".

c. Tools. Average years using power tools and average years using hand-tools were both statistically significantly associated with increased risk of all 4 back symptom and injury questions, even after taking age into account (Table 2 and Appendix Table A10). (In part, this was due to the larger number of people reporting use of tools than use of vehicles. Use of any tool could be computed for 2,377 members.) Risk of health problems was greater for power tools than for hand-tools. For example, 10 years use of power tools increased risk for "back pain lasting more than 1 week at a time" by 81%. However, 10 years use of hand-tools increased risk for "back pain lasting more than 1 week at a time" by 26%.

Years worked on many different types of tools were statistically significantly associated with back symptoms or injuries, in part, due to the relatively larger number of people reporting use of specific tools (Table 2 and Appendix Table A10). 40 out of the 84 tests of associations for power tools (21 power tools x 4 back health measures) were statistically significant. 22 out of the 28 tests of associations for hand-tools (7 hand-tools x 4 back health measures) were statistically significant. Most significant associations were not large, that is, in the range of 1.15 to 1.4 (an increased risk of back symptoms of 15% to 40% for each 10 years of use of specific tools). The largest associations were for "asphalt tamper", with 72% increased risk of "back-related injury reported to railroad or railroad medical department", and 91% increased risk of "back pain goes down leg below the knee" for every 10 years of use of this tool.

2. Hand health

All four of our measures of hand pain (questions 50a, 50d or e and 52) or carpal tunnel diagnosis (question 32) were statistically significantly associated with vehicle equipment vibration bothers me, hand tool vibration bothers me, job involves repeated lifting, pushing, pulling, or bending, and disagree that health and safety of workers is a high priority with management where I work (see Tables 3 and 4 and Appendix Table A11). (However, we could not compute a prevalence for white finger symptoms for exposure question 23 and because all the cases of daily or weekly white finger symptoms were reported by members reporting "often/always" "job involves repeated lifting, pushing, pulling", and no one reported these symptoms if "sometimes" or "seldom/never" "job involves repeated lifting, pushing, pulling".)

Most of these associations showed a substantial "dose-response" trend, that is, increasing risk of pain or injury as the working conditions measure becomes more hazardous. For example, while 2% of active male BMWED members reported a diagnosis of carpal tunnel syndrome if hand tool equipment vibration did not bother them, 7% of members reported this diagnosis if hand tool equipment vibration bothered them sometimes (1-2 hours/day), and 15% of members reported this diagnosis if vehicle equipment vibration bothered them always (8-10 hours/day).

As another example, while 1% of active male BMWED members reported symptoms of vibration white finger if hand tool equipment vibration did not bother them, 4% of members reported these symptoms if hand tool equipment vibration bothered them sometimes (1-2 hours/day), and 17% of members reported these symptoms if vehicle equipment vibration bothered them always (8-10 hours/day).

Years of MOW work (adjusted for age) was significantly associated with reported diagnosis of carpal tunnel syndrome (Table 3) and with finger numbness and tingling (Appendix Table A11), but not with the other two measures of hand health (Table 4, Appendix Table A11).

Question 24 ("not enough people or staff to get all the work done") was not associated with any of the four measures of hand health.

<u>a. Job titles</u>. 10 of 44 associations between years worked in specific job titles and hand health (11 job titles x 4 measures of hand health) were statistically significant, after taking age into account. Every ten years worked as a machine operator were significantly associated with all 4 measures of hand health, with increased risks ranging from PR=1.11 to PR=1.32.

<u>b. Vehicles</u>. Ten years of use of high vibration vehicles (from ballast regulator to brush cutter) were significantly associated with vibration white finger symptoms (PR=2.75, p=.01), however, they were not associated with other hand symptoms or diagnoses (Tables 3 and 4 and Appendix Table A11). Average years using lower vibration vehicles, such as trucks (heavy, road or hi-rail) or light trucks/vans, were statistically significantly associated with diagnosis of carpal

Table 3: Associations of Selected Work Factors with Reported Diagnosis of Carpal Tunnel Syndrome (CTS) among Active BMWED Men (n=2,748)		
Work factors	**CTS %**[a]	**Prevalence Ratio**[a]
17. Vehicle/equipment vibration bothers me		
8-10 hours/day	16.0%	**5.62*****
4-6 hours/day	9.0%	**3.25*****
1-2 hours/day	7.0%	**2.59*****
<1 hour/day	5.0%	1.80
0 hours (ref.)	3.0%	1.00
17. Hand tool vibration bothers me		
8-10 hours/day	15.0%	**8.96*****
4-6 hours/day	11.0%	**6.44*****
1-2 hours/day	7.0%	**4.22*****
<1 hour/day	3.0%	2.01
0 hours (ref.)	2.0%	1.00
18. Job involves repeated lifting, pushing, pulling or bending		
Often/Always	7.0%	1.43
Sometimes	5.0%	1.04
Seldom/Never (ref.)	5.0%	1.00
23. Health and safety of workers is a high priority with management where I		
Strongly Disagree	10.0%	1.73*
Disagree	8.0%	1.49
Agree	5.0%	0.86
Strongly Agree (ref.)	6.0%	1.00
24. How often are there not enough people or staff to get all the work done?		
Often/Always	7.0%	0.52
Sometimes	6.0%	0.41*
Rarely	6.0%	0.45
Never (ref.)	14.0%	1.00
6. Risk for 10 yrs of MOW work		1.55***
11. Risk for 10 yrs (x fraction of day) exposed to high vibration equipment		1.85
11. Risk for 10 yrs (x fraction of day exposed to low vibration equipment (trucks)		1.33*
16. Risk for 10 yrs (x fraction of day) exposed to power tools (high vibration)		**2.85*****
16. Risk for 10 yrs (x fraction of day) exposed to hand-tools (low vibration)		1.90***

[a]Prevalence ratio (PR) and CTS % adjusted for age, region, race/ethnicity, second job, second job vehicle vibration, and spare time vehicle vibration using Poisson regression. Significant PR >2 in boldface.
*p<.05, **p<.01, ***p<.001

Table 4: Associations of Selected Work Factors with Vibration White Finger Symptoms among Active BMWED Men (n=2,748)		
Work factors	**Symptom %[a]**	**Prevalence Ratio[a]**
17. Vehicle/equipment vibration bothers me		
8-10 hours/day	15.0%	**11.99**[***]
4-6 hours/day	10.0%	**7.64**[***]
1-2 hours/day	4.0%	**3.42**[**]
<1 hour/day	2.0%	1.85
0 hours (ref.)	1.0%	1.00
17. Hand tool vibration bothers me		
8-10 hours/day	17.0%	**15.25**[***]
4-6 hours/day	10.0%	**8.96**[***]
1-2 hours/day	4.0%	**3.95**[**]
<1 hour/day	2.0%	1.62
0 hours (ref.)	1.0%	1.00
18. Job involves repeated lifting, pushing, pulling or bending		
Often/Always	**-----**[b]	**-----**[b]
Sometimes	**-----**[b]	**-----**[b]
Seldom/Never (ref.)	**-----**[b]	**-----**[b]
23. Health and safety of workers is a high priority with management where I		
Strongly Disagree	12.0%	**4.01**[***]
Disagree	6.0%	1.99
Agree	3.0%	1.08
Strongly Agree (ref.)	3.0%	1.00
24. How often are there not enough people or staff to get all the work done?		
Often/Always	7.0%	2.94
Sometimes	2.0%	1.06
Rarely	4.0%	1.61
Never (ref.)	2.0%	1.00
6. Risk for 10 yrs of MOW work		1.22
11. Risk for 10 yrs (x fraction of day) exposed to high vibration equipment		**2.75**[*]
11. Risk for 10 yrs (x fraction of day exposed to low vibration equipment (trucks)		1.19
16. Risk for 10 yrs (x fraction of day) exposed to power tools (high vibration)		**3.59**[***]
16. Risk for 10 yrs (x fraction of day) exposed to hand-tools (low vibration)		**2.02**[***]

[a]Prevalence ratio (PR) and symptom % adjusted for age, region, race/ethnicity, second job, second job vehicle vibration, spare time vehicle vibration using Poisson regression. Significant PR >2 in boldface. *p<.05, **p<.01, ***p<.001

[b]Adjusted PR and adjusted symptom % could not be computed since no people in the "sometimes" or "seldom/never" categories reported daily or weekly symptoms.

tunnel syndrome (PR=1.33, p=.01), finger numbness or tingling daily or weekly (PR=1.26, p=.002), and hand/wrist pain in past week lasting a day or more (PR=1.24, p=.007). However, years of truck use were not significantly associated with vibration white finger symptoms.

15 of 52 associations between specific vehicles and hand health (13 vehicles x 4 measures of hand health) were statistically significant, after adjusting for age. Years using a front-end loader, tie crane, crane, pettibone, and heavy trucks were significantly associated with at least 2 hand symptoms/diagnoses.

c. Tools. Average years using power tools and average years using hand-tools were both statistically significantly associated with increased risk of hand symptoms or carpal tunnel syndrome, even after taking age into account (Tables 3 and 4 and Appendix Table A11). Risk was greater for power tools than for hand-tools. For example, every 10 years use of power tools increased risk for diagnosis of carpal tunnel syndrome by 2.85 times. However, 10 years use of hand-tools increased risk for diagnosis of carpal tunnel syndrome by 1.90 times. 63 of 84 associations between specific power tools and hand health (21 power tools x 4 measures of hand health) were statistically significant, after adjusting for age. 27 of 28 associations between specific hand-tools and hand health (7 hand-tools x 4 measures of hand health) were statistically significant, after adjusting for age. Significant associations between 10 years use of power tools and hand symptoms/diagnoses ranged from PR=~~1.22~~2.31 to PR=3.59~~1.98~~. Significant associations between 10 years use of hand-tools and hand symptoms/diagnoses ranged from PR=1.33~~18~~ to PR=2.02~~1.74~~.

3. Other musculoskeletal outcomes

Our other measures of musculoskeletal symptoms (joint pain, shoulder pain, knee pain) (questions 51and 52) were all statistically significantly associated with vehicle equipment vibration bothers me, hand tool vibration bothers me, job involves repeated lifting, pushing, pulling, or bending, and disagree that health and safety of workers is a high priority with management where I work (see Table 5 for knee pain and Appendix Table A12 for all other musculoskeletal outcomes).

Most of these associations showed a “dose-response” trend, that is, increasing risk of pain as the working conditions measure becomes more hazardous. For example, while 10.9% of active male BMWED members reported knee pain during the past week if vehicle equipment vibration did not bother them, 24.6% of members reported this symptom if vehicle equipment vibration bothered them sometimes (1-2 hours/day), and 42.3% of members reported this symptom if vehicle equipment vibration bothered them always (8-10 hours/day).

Neither question 24 (“not enough people or staff to get all the work done”) nor years of MOW work (adjusted for age) were associated with joint pain, shoulder pain, or knee pain (Table 5, Appendix Table A12).

a. Job titles. 3 of 33 associations between years worked in specific job titles and other musculoskeletal health problems (11 job titles x 3 measures of musculoskeletal health) were statistically significant, after taking age into account. Years worked as trackman/laborer, machine operator and foreman were significantly associated with a small increased risk of “knee pain in past week lasting a day or more”, after taking age into account. However, years worked in various job titles were not significantly associated with severe joint pain, or shoulder pain.

Table 5: Associations of Selected Work Factors with Knee Pain in the Past Week Lasting a Day or More for Active BMWED Men (n=2,748)		
Work factors	**Knee pain %**[a]	**Prevalence Ratio**[a]
17. Vehicle/equipment vibration bothers me		
8-10 hours/day	42.3%	**3.98*****
4-6 hours/day	35.2%	**3.24*****
1-2 hours/day	24.6%	**2.26*****
<1 hour/day	17.4%	1.59**
0 hours (ref.)	10.9%	1.00
17. Hand tool vibration bothers me		
8-10 hours/day	50.0%	**6.32*****
4-6 hours/day	34.0%	**4.30*****
1-2 hours/day	24.5%	**3.10*****
<1 hour/day	17.1%	**2.17*****
0 hours (ref.)	7.9%	1.00
18. Job involves repeated lifting, pushing, pulling or bending		
Often/Always	25.5%	**3.11****
Sometimes	16.8%	2.05
Seldom/Never (ref.)	8.2%	1.00
23. Health and safety of workers is a high priority with management where I work		
Strongly Disagree	33.7%	**2.41*****
Disagree	28.7%	**2.05*****
Agree	19.6%	1.40*
Strongly Agree (ref.)	14.0%	1.00
24. How often are there not enough people or staff to get all the work done?		
Often/Always	26.3%	1.03
Sometimes	17.5%	0.69
Rarely	20.0%	0.78
Never (ref.)	25.5%	1.00
6. Risk for 10 yrs of MOW work		1.09
11. Risk for 10 yrs (x fraction of day) exposed to high vibration equipment		1.26
11. Risk for 10 yrs (x fraction of day exposed to low vibration equipment (trucks)		1.27**
16. Risk for 10 yrs (x fraction of day) exposed to power tools (high vibration)		**2.16*****
16. Risk for 10 yrs (x fraction of day) exposed to hand-tools (low vibration)		1.42***

[p]revalence ratio (PR) adjusted for age, region, race/ethnicity, second job, second job vehicle vibration, and spare time vehicle vibration using Poisson regression. Significant PR >2 in boldface. *p<.05, **p<.01, ***p<.001

b. Vehicles. Average years using high vibration vehicles (from ballast regulator to brush cutter) were not significantly associated with other musculoskeletal symptoms, in part, due to the relatively small number of people reporting such use. Because of these smaller numbers, an apparently elevated risk for 10 years of use (PR=1.49, p=.15, for "Shoulder pain in past week lasting a day or more" was not statistically significant (Appendix Table A12). Ten years of use of lower vibration vehicles, such as trucks (heavy, road or hi-rail) or light trucks/vans, were statistically significantly associated with "severe joint pain in the past year" (PR=1.12, p=.048) and with "knee pain in past week lasting a day or more" (PR=1.27, p=.002).

4 of 39 associations between specific vehicles and hand health (13 vehicles x 3 measures of hand health) were statistically significant, after adjusting for age. Therefore, at least 2 of those significant associations may have been observed due to chance (at the p<.05 significance level).

c. Tools. Average years using power tools and average years using hand-tools were both statistically significantly associated with increased risk of other musculoskeletal symptoms (joint pain, shoulder pain, or knee pain), even after taking age into account (Table 5 for knee pain and Appendix Table A12 for other musculoskeletal outcomes). Risk was greater for power tools than for hand-tools. For example, 10 years use of power tools increased risk for "knee pain in past week lasting a day or more" by 116% (2.16 times). However, 10 years use of hand-tools increased risk for "knee pain in past week lasting a day or more" by 42%.

43 of 63 associations between specific power tools and other musculoskeletal health (21 power tools x 3 measures of musculoskeletal health) were statistically significant, after adjusting for age. All 21 associations between specific hand-tools and musculoskeletal health (7 hand-tools x 3 measures of musculoskeletal health) were statistically significant, after adjusting for age. Significant associations between 10 years use of power tools and musculoskeletal symptoms ranged from PR=1.16 to PR=1.68. Significant associations between 10 years use of specific hand-tools and musculoskeletal symptoms ranged from PR=1.13 to PR=1.47.

E. Associations between working conditions and cardiovascular disease and diabetes

Results of these analyses are shown in Tables 6-8 and Appendix Tables A13-A15.

1. Cardiovascular risk factors

Self-report of a diagnosis of hypertension (high blood pressure) or high cholesterol were not significantly associated with individual working conditions assessed in the survey, nor with years of MOW work or with years in a specific jobtitle, with one exception. High cholesterol was associated with the respondent's disagreeing that "Health and safety of workers is a high priority with management where I work", PR=1.41 (95% CI 1.01, 1.95, p=0.04).

2. Heart disease and stroke

Self-report of a diagnosis of coronary heart disease, angina, heart attack, heart disease or stroke was not significantly associated with individual working conditions assessed in the survey, nor with years of MOW work or with years in a specific jobtitle, also with one exception: the risk of stroke was *lower* among members reporting often or always "not enough people or staff to get all the work done", PR=0.09 (95% CI 0.01, 0.97, p=0.047).

Self-report on the composite measure of any heart disease or stroke appeared to be roughly twice as likely among members reporting that they strongly disagreed that "My job allows me to make a lot of decisions on my own", or who strongly disagreed that "Health and safety of workers is a high priority with management where I work". However, in part due to the overall low prevalence of heart disease or stroke, neither of these associations were statistically significant.

There were no cases of "any heart disease or stroke" among members who reported that the "job involves repeated lifting, pushing, pulling or bending seldom or never" (the reference group). In such a situation, a prevalence ratio (PR), 95% confidence intervals and a p-value cannot be computed since the PR would involve division by zero. Similarly, there were no cases of angina among members who reported that they strongly agreed with the statement "I can count on my supervisor or manager for support when I need it", or "Health and safety of workers is a high priority with management where I work" (reference groups), or who, when asked, "How often are there not enough people or staff to get all the work done" reported 'often' or 'always' (reference group). Similarly, there were no cases of stroke in the group that "strongly agreed" that the "Health and safety of workers is a high priority with management where I work". Similarly, there were no cases of heart attack or heart disease among members who reported that there were "never" (reference group) "not enough people or staff to get all the work done". These findings need to be interpreted with caution given the low prevalence (proportion) of cardiovascular conditions reported by active BMWED members.

3. Diabetes

Self-report of a diagnosis of diabetes or prediabetes were not significantly associated with any individual working conditions question, nor with years of MOW work nor with years in a specific job title.

Table 6: Associations of selected work factors with response to the question: "Have you ever been told by a doctor or other health professional that you have hypertension", Active BMWED Men (n=2,748)

Work Factors	Hypertension %[a]	Prevalence Ratio[a]
18. Job involves repeated lifting, pushing, pulling or bending		
Often/Always	18.9%	1.02
Sometimes	19.4%	1.05
Seldom/Never (ref.)	18.5%	1.00
20. Which of the following best describes the hours you usually work?		
Non-daytime shift	19.1%	1.00
Daytime shift (ref.)	19.1%	1.00
21. My job allows me to make a lot of decisions on my own		
Strongly Disagree	26.7%	1.41
Disagree	19.2%	1.01
Agree	18.2%	0.96
Strongly Agree (ref.)	19.1%	1.00
22. I can count on my supervisor or manager for support when I need it		
Strongly Disagree	24.2%	1.37
Disagree	19.7%	1.10
Agree	17.7%	0.99
Strongly Agree (ref.)	17.8%	1.00
23. Health and safety of workers is a high priority with management where I work		
Strongly Disagree	23.0%	1.36
Disagree	20.5%	1.21
Agree	17.6%	1.04
Strongly Agree (ref.)	16.9%	1.00
24. How often are there not enough people or staff to get all the work done?		
Often/Always	19.8%	1.08
Sometimes	18.6%	1.02
Rarely	15.3%	0.84
Never (ref.)	18.4%	1.00
6. Risk for 10 years of MOW work		1.00

[a]Prevalence ratio (PR) and hypertension % adjusted for age, region, race/ethnicity, smoking, second job, second job car, van or motorcycle use, spare time car, van or motorcycle use, using Poisson regression.

Prevalence ratios represent the adjusted proportion in one group divided by the proportion in the reference group.

Table 7: Associations of selected work factors with being told by a doctor or other health professional that they had any heart disease or stroke#, Active BMWED Men (n=2,748)		
Work Factors	**CVD %[a]**	**Prevalence Ratio[a]**
18. Job involves repeated lifting, pushing, pulling or bending		
Often/Always	1.1%	b
Sometimes	1.2%	b
Seldom/Never (ref.)	0.0%	1.00
20. Which of the following best describes the hours you usually work?		
Non-daytime shift	1.5%	1.68
Daytime shift (ref.)	0.9%	1.00
21. My job allows me to make a lot of decisions on my own		
Strongly Disagree	1.7%	1.91
Disagree	0.8%	0.95
Agree	1.0%	1.09
Strongly Agree (ref.)	0.9%	1.00
22. I can count on my supervisor or manager for support when I need it		
Strongly Disagree	1.7%	1.51
Disagree	0.7%	0.67
Agree	0.9%	0.81
Strongly Agree (ref.)	1.1%	1.00
23. Health and safety of workers is a high priority with management where I work		
Strongly Disagree	2.2%	2.16
Disagree	0.6%	0.60
Agree	0.8%	0.82
Strongly Agree (ref.)	1.0%	1.00
24. How often are there not enough people or staff to get all the work done?		
Often/Always	1.0%	1.33
Sometimes	0.7%	0.91
Rarely	1.3%	1.67
Never (ref.)	0.8%	1.00
6. Risk for 10 years of MOW work		1.15

[a]Prevalence ratio (PR) and heart disease or stroke % adjusted for age, region, race/ethnicity, smoking, second job, second job car, van or motorcycle use, spare time car, van or motorcycle use, using Poisson regression. PRs represent the adjusted proportion in one group divided by the proportion in the reference group.. *p<.05, **p<.01, ***p<.001

[b]Prevalence ratio could not be computed because there were no cases in the reference group

#Any heart disease or stroke defined as either coronary heart disease, angina, heart attack, heart disease, or stroke.

Table 8: Associations of selected work factors with response to the question: "Have you ever been told by a doctor or other health professional that you have diabetes or sugar diabetes#", Active BMWED Men (n=2,748)		
Work Factors	**Diabetes %[a]**	**Prevalence Ratio[a]**
18. Job involves repeated lifting, pushing, pulling or bending		
Often/Always	3.2%	1.36
Sometimes	3.3%	1.40
Seldom/Never (ref.)	2.4%	1.00
20. Which of the following best describes the hours you usually work?		
Non-daytime shift	3.2%	1.01
Daytime shift (ref.)	3.2%	1.00
21. My job allows me to make a lot of decisions on my own		
Strongly Disagree	3.9%	1.25
Disagree	3.0%	0.96
Agree	3.3%	1.04
Strongly Agree (ref.)	3.1%	1.00
22. I can count on my supervisor or manager for support when I need it		
Strongly Disagree	2.7%	1.13
Disagree	4.4%	1.88
Agree	2.8%	1.19
Strongly Agree (ref.)	2.4%	1.00
23. Health and safety of workers is a high priority with management where I work		
Strongly Disagree	3.2%	1.45
Disagree	3.9%	1.74
Agree	3.1%	1.38
Strongly Agree (ref.)	2.2%	1.00
24. How often are there not enough people or staff to get all the work done?		
Often/Always	3.3%	1.21
Sometimes	3.1%	1.14
Rarely	2.8%	1.01
Never (ref.)	2.8%	1.00
6. Risk for 10 years of MOW work		1.06

[a]Prevalence ratio (PR) and diabetes % adjusted for age, region, race/ethnicity, smoking, second job, second job car, van or motorcycle use, spare time car, van or motorcycle use, using Poisson regression. *p<.05, **p<.01, ***p<.001

#includes only cases with age of onset at least 21 years old.

PR >2 in boldface. Prevalence ratios represent the adjusted proportion in one group divided by the proportion in the reference group..

IV. DISCUSSION OF SURVEY RESULTS

A. Musculoskeletal ill health

1. Summary

The results suggest that the physical demands of BMWED work (repeated lifting, pushing, pulling, or bending), vibration exposure from vehicles and tools, and a perceived lack of a priority for health and safety by management may contribute to the musculoskeletal injuries and illnesses experienced by active BMWED members. A "dose-response" trend seen for the connection between most of our measures of ill health and many of our working conditions questions is an additional piece of evidence to support the conclusion that working conditions may be causing injuries and illnesses among BMWED members.

2. Vehicles

Average years using high vibration vehicles (from ballast regulator to brush cutter) were significantly associated with 1 of 11 of our measures of ill health (vibration white finger), after taking age into account. This result may be due, in part, to the relatively small number of people reporting such vehicle use. However, average years using lower vibration vehicles, such as trucks (heavy, road or hi-rail) or light trucks/vans, were associated with 7 of 11 of our measures of ill health (back pain lasting more than a week, back-related injury reported, carpal tunnel syndrome, finger numbness or tingling, hand/wrist pain in past week lasting a day or more, severe joint pain in the past year, and knee pain in past week lasting a day or more). While the increased risk was lower for the lower (vs higher) vibration vehicles, as expected from research on vibration-related health effects, the larger number of members reporting use of trucks led to more associations between the lower vibration vehicles (trucks) being statistically significant. Therefore, efforts are needed to prevent the health risks associated with vehicle vibration as shown in other research studies, and as shown in the BMWED Health and Safety survey. Such efforts are detailed in section V. 26 of 143 associations between specific vehicles and ill health (13 vehicles x 11 measures of ill health) were statistically significant, after adjusting for age, in part, due to the relatively smaller number of people reporting use of specific vehicles. At the .05 significance level, 7 of those associations could have been observed due to chance. In addition, associations seen for certain vehicles could be confounded by risk due to other vehicles. Therefore, the analyses of risk of ill health due to specific vehicles reported here should be considered exploratory.

3. Tools

Average years using power tools and average years using hand-tools were both statistically significantly associated with increased risk of all 11 health problems we examined, after taking age into account. As we hypothesized, and consistent with past research on vibration-related health effects, the increase in risk tended to be greater for power tools than for hand-tools. Increased risk for 10 years of tool use ranged from PR=1.55 to PR=3.59 for power tools and PR=1.19 to PR=2.02 for hand-tools. Therefore, efforts are needed to prevent the health risks associated with vibration from power tools, as shown in other research studies, and as shown in the BMWED Health and Safety survey. Such efforts are detailed in section V.

146 out of the 231 tests of associations for specific power tools (21 power tools x 11 health measures) were statistically significant, after adjusting for age. 70 out of the 77 tests of associations for hand-tools (7 hand-tools x 11 health measures) were statistically significant, after adjusting for

age. Associations between specific power tools and ill health tended to be larger than associations between specific hand-tools and ill health.

4. Job titles

20 of 121 associations between years worked in specific job titles and ill health (11 job titles x 11 measures of ill health) were statistically significant, after taking age into account. Most associations were relatively small. Years worked as a machine operator was significantly associated with increases in risk of 7 of 11 measures of ill health, the most consistent set of associations of any job title. We did not expect large associations between reported job titles and health outcomes since members may work a variety of job titles even during the same time period. We expected larger associations between musculoskeletal symptoms and the specific hazards of the job (such as vehicles and tools) than with more general job titles.

B. Cardiovascular disease and diabetes

1. Survey results vs. risk of dying from cardiovascular disease (CVD)

The lower risk of self-reported cardiovascular diagnoses among male BMWED members and retirees compared to all U.S. employed and retired men differs from the results of analyses of causes of death for ages 18 to 64 among BMWED members, 1979 to 2014, conducted by the AOEC research group, led by Dr. David Goldsmith. They found increased risks of death, based on death certificate data, for BMWED members for CVD (Standardized Mortality Ratio (SMR)=1.62, 95% CI 1.56-1.68), cerebrovascular disease, that is, stroke (SMR=1.45, 95% CI 1.29-1.61), atherosclerosis, that is, fatty deposits that can clog arteries (SMR=2.11, 95% CI 1.25-2.97), hypertension (SMR=2.11, 95% CI 1.50-2.71) and diabetes (SMR=1.57, 95% CI 1.39-1.76).

a. Healthy worker effect**.** One possible explanation for the lower cardiovascular risk among BMWED members in the survey is the "healthy worker effect", the fact that employed people tend to be healthier than all people of the same age since the total population includes people too sick to work, or not healthy enough to handle physically demanding jobs. Unhealthy people are less likely to become employed and workers who become sick while they are working are more likely to leave the workforce [Brown, et al., 2017, Buckley, et al., 2015]. The mortality study determined who had died and cause of death among anyone who had been a BMWED member.

We did compare active BMWED male members to all U.S. *employed* men and adjusted for age, which should reduce the impact of the "healthy worker effect". However, since most MoW work is highly physically demanding work, it is likely that some employed U.S. men (including some with early stages of CVD) would not be able to tolerate the physical demands of MoW work, and thus would not be able to be employed in MoW work. If such a selection process occurred, that could explain some of the lower CVD risk seen in BMWED members compared to employed U.S. men.

2. Associations between working conditions and cardiovascular disease and diabetes

Despite some suggestions of increased risk of heart disease or stroke among workers in more stressful or more physically demanding job situations (including no cases of heart disease and stroke in the low occupational physical activity group), none of these associations were statistically significant. This was due, in part, to the low prevalence of heart disease and stroke among active BMWED members. The low prevalence may have resulted from the healthy worker effect (described above), from the fact that survey respondents tended to be younger and healthier than non-respondents, or other reasons.

3. Prevention of cardiovascular disease

a. Does physical activity at work protect against CVD? Does the physical activity of BMWED work protect BMWED members from heart disease and stroke? The BMWED survey results suggests that it might, however, the CVD mortality study of BMWED members suggests that it does not. While aerobic exercise during non-work hours can *reduce* a person's risk of heart disease or stroke, recent research studies indicate that high *occupational* physical activity (OPA) can *increase* a person's risk of CVD [Coenen, et al., 2018, Holtermann, 2015, Holtermann, et al., 2018, Holtermann, et al., 2016, Krause, et al., 2017, Krause, et al., 2015]. Earlier studies that had suggested that OPA might protect workers from CVD or earlier death. However, many of these earlier studies had various limitations in their methods, such as not very precise measures of work exposures, and lack of adjustment for important "confounders" (other factors which could play a role in predicting CVD) such as leisure time physical activity (LTPA) or psychosocial job stressors [Krause, 2010]. Researchers have suggested several reasons why there is this apparent contradiction between the benefits of LTPA, and the increased risk due to OPA.

First, occupational physical activity (OPA) "is of too low intensity or too long duration for maintaining or improving cardiorespiratory fitness and cardiovascular health". Second, OPA increases 24-hour heart rate, which is not beneficial for cardiovascular health. Third, OPA "including heavy lifting or static [stationary] postures elevate 24-hour blood pressure". Fourth, OPA "increases levels of inflammation", which contributes to atherosclerosis (fatty deposits that can clog arteries). Fifth, OPA "is often performed without sufficient recovery time". Long work hours without adequate rest can cause fatigue and exhaustion and may increase CVD risk. Sixth, OPA "is often performed with low worker control… Limited control over work tasks, speed, schedule, protective clothing, psychosocial stressors and the surrounding environment may contribute to the detrimental effects of OPA" [Holtermann, et al., 2018, p. 1].

b. The role of work organization. In the survey, active male BMWED members were more likely to report that there were not enough people or staff to get all the work done compared to U.S. male workers, which may contribute to longer hours or lack of adequate rest. In addition, in the survey, active male BMWED members were much more likely to report low control or have a say on how the job gets done, compared to U.S. male workers. Other studies have suggested that workers with high levels of OPA may need shorter weekly work hours, and longer breaks and recovery periods [Krause, et al., 2009, Wang, et al., 2015, Wang, et al., 2016]. Therefore, assuring adequate rest breaks and reducing very long work hours may help to reduce the CVD risk that may result from very physically demanding work.

Low job control and low social support also appear to increase the risk of CVD in studies of other workers [Schnall, et al., 2016]. In the BMWED survey, members reported much lower levels of job control and supervisor support than U.S. male employees. Therefore, increasing levels of job control and supervisor support may be considered as part of efforts to reduce MoW workers' risk of CVD.

[Clays, et al., 2016, Holtermann, et al., 2018]c. Does leisure time physical activity protect against cardiovascular disease in workers with high occupational physical activity? It is also unclear whether increased exercise off the job (leisure time physical activity) will benefit workers with high occupational physical demands [Holtermann, 2015]. In one study from Israel, among men with moderate to high physical work demands, those men having high levels of leisure time physical activity did not have a significantly reduced risk of dying from heart disease (or dying for any other reason) compared to men with low levels of leisure time physical activity [Harari, et al., 2015]. Other studies have shown mixed results (both reduced and increased risks of heart disease) due to exercise off the job among workers with high occupational physical activity [Holtermann, 2015]. Therefore, it is too early to make any recommendations about the possible benefits of exercise off the job in reducing the risk of heart disease and stroke among BMWED members. In addition, even if future research demonstrates a benefit of leisure-time exercise for workers with high physical work demands, the high rate of musculoskeletal pain reported by BMWED members in this survey could be an important obstacle to their efforts to exercise more off the job.

C. Strengths of study

We used validated and widely used measures of working conditions and musculoskeletal symptoms and diagnoses that allowed us to compare the prevalence of symptoms and working conditions to US national and other studies of workers. We made comparisons to other groups of workers so as to reduce any bias in the results of the study due to the "healthy worker effect" – the general tendency for employed people to be healthier than the population as a whole.

A review article in 2005 found that self-reports of questions on the level of physical effort at work and vibration exposure have shown good-to-excellent reliability, although validity studies comparing self-reports with reference methods (structured interview, observation, or direct measurement) have been mixed [Stock, et al., 2005]. A 2010 study found that job-title based exposure estimates from O*NET, self-reported and observer-rated exposures had "moderate to good levels of agreement for some upper extremity exposures, including lifting, forceful grip, use of vibrating tools and wrist bending" [Gardner, et al., 2010, p. 538].

Several studies have examined whether workers with musculoskeletal symptoms or disorders accurately report their physical work demands. "Two studies that found a differential misclassification of exposure in association with the presence of musculoskeletal complaints concluded that the misclassification was not significant because the difference was too small to have an effect on the risk estimate" [Stock, et al., 2005, p. 430]. A third study found that "persons with carpal tunnel syndrome, when compared with controls, had higher correlations between ergonomist's observations and their self-reported bending of the trunk, bending and twisting of the hands or wrists, and twisting of the forearm" [Stock, et al., 2005, p. 430-431]. Thus, there is not strong evidence from past research that work physical exposures are exaggerated by workers who are experiencing musculoskeletal symptoms.

In addition, our study only used three questions on general physical demands and vibration exposures (questions 17 and 18). Most of our analyses of predictors of musculoskeletal symptoms or diagnoses utilized questions about specific tools and vehicles used, and specific jobtitles of MOW workers.

Finally, the associations seen between work and musculoskeletal symptoms or diagnoses in this survey were not likely due to other factors ("confounding"), since we adjusted in the statistical analysis for the other main factors that might explain the connections between work and musculoskeletal symptoms or diagnoses – age, region of the country worked, race/ethnicity, second job, second job vibration exposure, and spare time vibration exposure. Similarly, any tendencies towards associations between work and cardiovascular conditions or diabetes in this survey were not likely due to other factors ("confounding"), since we adjusted in the statistical analysis for the other main factors that might explain the connections between work and cardiovascular conditions or diabetes – age, region of the country worked, race/ethnicity, second job, second job car, van or motorcycle use, and spare time hours/week of car, van or motorcycle use. The associations are also not due to differences between men and women, since we restricted this analysis to men.

D. Limitations of study

In cross-sectional surveys, we are limited in drawing conclusions about working conditions "causing" the symptoms or diagnoses because exposures and health outcomes are assessed at the same time. A prospective study that follows workers with a range of exposures over time to see which groups of workers develop symptoms, injuries or illnesses is needed to be able to draw stronger conclusions.

In addition, both symptoms and work exposures were collected in the survey by self-report. However, we have no evidence to suggest that self-reporting increased the size of the associations seen between working conditions and musculoskeletal symptoms and diagnoses. It has been suggested that some BMWED members may have underreported illnesses on the survey due to fear of job loss or other disciplinary actions. However, it is unknown to what extent such underreporting may have occurred. In addition, it is unknown whether such illness underreporting was associated with reporting of work exposures. Thus, we cannot be sure whether any such underreporting affected associations between work exposures and health outcomes. Additional analyses of anonymous medical claim or disability data would be beneficial to see if the current results would be replicated with such medical or disability information. Of course, such health data (using standard diagnostic codes) may be affected by other reporting biases.

Also, in some cases, questions were worded somewhat differently than in national surveys making it more difficult to make direct comparisons.

Another limitation was that our analyses of specific vehicles in relation to ill health involved multiple comparisons and thus some of the associations observed were likely due to chance. In addition, associations observed between ill health and specific vehicles and specific tools may have been confounded by use of other specific vehicles and specific tools, which were not controlled for in these analyses. Therefore, the analyses of ill health in relation to specific vehicles and specific tools should be considered exploratory.

Finally, the response rate to the survey (≈12%) raises the possibility of "selection bias", that is, the possibility that people who answered the survey were not representative of all BMWED members. We examined such potential bias in two ways. First, by comparing the people who answered the survey to all BMWED active members or retirees on available demographic measures (region of country, railroad employer, age, gender, and years on the job). Second, we conducted a phone survey of a random sample of survey non-participants and asked them 10 questions from the large survey. Both methods revealed that survey participants were younger. The phone survey of non-respondents revealed that the large survey participants were in better health (with the exception of back pain) and had slightly better working conditions than members or retirees who did not fill out the large survey. This means that any associations between working conditions and ill health reported here may be underestimates of the true associations (with the exception of associations with back pain). In other words, the true connections between working conditions and ill health among BMWED members, in many cases, may be even stronger that what we are describing in this report.

E. Additional possible analyses of the survey data

Additional possible analyses of the survey data include:

1) Examine associations between working conditions, job titles, vehicles and tools and musculoskeletal outcomes in retirees.

2) Examine associations between hours per day of standing and both musculoskeletal disorders and cardiovascular disease.

3) Examine time periods of exposure to job titles, vehicles or tools (more recent or more distant past), to see which may have stronger associations with ill health and examine possible confounding of these associations by other vehicles or tools.

4) Measure vibration under field conditions, and examine other working conditions, health problems, and their associations that may be suggested by other research teams or by the BMWED leadership.

V. MAINTENANCE-OF-WAY ERGONOMICS, VIBRATION EXPOSURE AND PREVENTION

A. Review of Hand-Arm Vibration (HAV) Emission Data

As our study has shown, maintenance-of-way workers characteristically use various heavy hand-tools, hand-held vibrating powered tools and machines that contributes to mechanical stress of the joints, muscles and tissues of the upper extremities and other body parts. Vibration exposure at work has been recognized as a physical risk factor in many countries and tool manufacturers and employers have been advised to provide tool design and work strategies that would lower worker exposure and prevent or reduce adverse outcomes. In several European countries injuries from vibration exposure are recognized as compensable occupational diseases. Governmental agencies and regulators do provide guidance to employers and unions about the safe use and the importance of proper maintenance of these tools. Although the collection of field data from BMWED workers and their tools would have been preferable to obtain exposure information in the US railroad industry, nevertheless, such exposure risk estimates can be derived and obtained from other industry studies (i.e., construction) and based on emission information from manufacturers and laboratory studies.

Mechanical vibration from powered tools is directly transmitted through the hands and fingers and can, depending on the vibration levels and duration, cause a condition called hand-arm vibration syndrome (HAV), typically characterized with “white finger syndrome”, pain and sensory deficits. It is recognized in several European countries as a compensable occupational disease if certain criteria are met. Criteria for the recognition, evaluation and prevention of mechanical vibration leading to HAV have been described [Bovenzi, 2007].

A Medline search for vibration emission and exposure information of hand-tools typical for the rail industry and MOW work resulted in zero returns. Expert interviews of health and safety specialists and listings in trade/marketing publications identified the following typical MOW trade tools powered by hydraulic, pneumatic or gas/diesel sources and emitting single shocks or vibrations:

Hammers, breakers, wrenches, grinders, impact tools, tamping guns, spiking guns, rock and rail drills, spike pullers and drivers, tampers and saws. In the North American market, tools and equipment for the railroad industry are manufactured and sold by companies such as: Airrex, American Pneumatic Tools (APT), Atlas Copco (AC)/Chicago Pneumatic (CP), Bance, Bosch, Cembre, Geismar, Hilti, Ingersoll Rand (IR), Makita, Matweld, Railtech, Robel, Stanley/DeWalt, Stihl, Sullair and Wacker-Neuson (WN). Some of these corporations do not sell all of their products in the EU market and these companies are not required to list any vibration emission information in the US market. Nevertheless, the larger and international corporations (i.e., AC/CP) tend to report in the US product information on HAV exposures that the EU requires, but not consistently, while smaller US corporations generally do not report such HAV information (Table 9). Examples of vibration emissions with “high” (greater than 5 m/s^2) and “low” (vibration emission levels of at or below 2.5 m/s^2) vibration emissions are listed below (Tables 10-11).

According to the EU directive (2002) and ANSI D2.70 (2006), if the tool vibration transmitted to each hand in its actual operation is below the action limit (2.5 m/s^2), the tool may be continuously used for 8 hours on every working day. If the vibration measured on a tool handle is greater than this action limit, the tool operation time by each worker should be controlled within a certain time less than 8 hours, depending on the actual vibration magnitude. The standard methods required the direct measurements of powered hand-tools in the field or at workplaces (ISO 5349, 2001; ANSI S2.70, 2006), because they can provide a more realistic risk assessment of the actual tool vibration emissions and workers' vibration exposure. Without such information, the tool vibration emission measured in a laboratory based on a standard test method may be used as a reference for a preliminary selection of the tools or initial evaluation of the vibration exposure. The review of the available manufacturer, supplier and distributor information about ergonomic vibration hazards to the buyer and user showed that only a few of the large international manufacturers tend to report both in the EU and the US market vibration emission data, but these vibration levels tend to be typically lower than those reported by non-commercial investigators that investigate tools in field applications [Christ, 2010, NIOSH, 2018]. In addition, lack of proper maintenance and repair of power-tools likely contribute to higher vibration emissions than reported manufacturer data under laboratory conditions. Some of the international corporations report only the mandated vibration information in the EU market but not in the US market, whereas most of the smaller manufacturers or suppliers in the US often do not report such data. This indicates a need for further vibration exposure studies and field testing of tools and equipment. The release of available commercial information and proper labeling of tool emissions can facilitate good work practices and assist in the prevention of musculoskeletal and HAV disorders among MOW workers. The implementation of the EU Directive is likely an example for workplace improvements and prevention strategies in the US [Donati, et al., 2008, Griffin, 2004, Griffin, 2006].

Table 9: Examples and comparison of vibration emission information provided in the US and EU markets of powered hand-tools (m/s^2)

No	Tool	Manufacturer & Model	Power	Vibration data listed US	Vibration data listed EU	Independent emission listing range (m/s^2) ***
1	Breaker	CP 1920	Air	-/+ (6-18)	+ (6-18)	15-30
		AC P90 (90S EU)	Air	+ (15)	No EU sale (15.3)	
		Airrex T117	Air	-	-	
		Wacker Neuson	Air	-	+ (8.3)	
		APT	Air	-	-	
		Sullair	Air	-	-	
2	Chipping hammer	CP 4125	Air	+ (15)	+ (15)	
		APT	Air	-	-	
		Airrex	Air	-	-	
2	Rock Drills	AC 658	Air	+ (21)	+ (21)	15-32
		Airrex	Air	-	-	
3	Concrete vibrator	Wacker	El/gas	-	+	

		CP 2190	Air	+ (1.6)	+ (1.6)	
4	Hammer Drill	Hilti TE70	Electric	-	+ (9)	13-31
		CP 1816	Electric	+ (<2.5)	+ (<2.5)	7-17
		Wacker	Electric	-	+	
Sources: Manufacturer websites, manuals and sales catalogs, NetworkRail [NetworkRail, 2017] , IFA*** [Christ, 2010], NIOSH Power Tools Database (PTD) [NIOSH, 2018].						

Tables 10 and 11 list examples of powered hand-tools with generally" high" (>5 m/s^2**)** and "low" (<2.5 m/s^2) vibration levels. Most of the data below are from manufacturer information and equipment manuals available in the EU market primarily for the reason that such information is mandated in the EU markets. Actual field emissions may vary and be considerable higher depending on tool usage, maintenance, applications and other factors [Christ, 2010, Kaulbars, 2016].

Table 10: Examples of powered hand-tools with vibration emission levels of greater than 5 m/s^2

No	**Tool**	**Manufacturer & Model** Reference generic (***)	**Power**	**Emission m/s$^{2*/**/***}$**
1	Tamper/Breaker	Atlas-Copco TEX 23HE	pneumatic	4.2-5.3
2	Tamper/Breaker	Bosch GSH 27 VC	electric	8.5
3	Tamper/Breaker	Wacker Neuson	gasoline	8.3 - 12.8
4	Breaker	Makita HM1214 C	electric	8
5	Breaker/Hammer	Chicago P 0125 SVR	pneumatic	30.1
6	Breakers/Hammers	IFA generic range	pneumatic	15-30 ***
7	Impact wrench	Stanley IW16	hydraulic	37** (49 Mfg)
8	Impact wrench	Bance GT350GE	gasoline	19
9	Impact wrench	Hilti SIW 22T-A	battery	14.5
10	Impact wrench	Makita 6905B	electric	16.5
11	Impact wrench	Maxin Master 35	gasoline	19
12	Impact wrench	Cembre NR13E-110	electric	7
13	Impact wrenches	IFA generic range	electric	4-16***
14	Impact wrenches	NIOSH Power Tools Database (PTD)	electric	11-17.4***
15	Impact wrenches	NIOSH PTD	pneumatic	27 – 32.7***
16	Rotary hammer drill	Bosch GBH 2-26	electric	17.5

17	Rotary hammer drill	Hilti TE2	electric	13.5
18	Rotary hammer drill	Hitachi DH24DVC	battery	13.2
19	Rotary hammers	IFA generic range	15-32	12-31***
20	Hammer drill	Makita BHR262T	battery	15
21	Hammer drills	IFA generic	electric	7-16***
22	Leaf blower	Husqvarna	gasoline	11.1
23	Drill cordless	DeWalt DC925	battery	25.3
24	Drill cordless	DeWalt DCD996P2	battery	15
25	Drill cordless	Hilti TE-A22	battery	15
26	Drill cordless	Metabo SB18LTX	battery	18
27	Drill cordless	Milwaukee M28 HD38HX	battery	21
28	Tamper (vertical)	Robel 62.05	gasoline	5.7
29	Rail head scrubber	Geismar DER 674	gasoline	7.1
30	Rail mounted sleeper drill	Geismar PTXL	gasoline	9
31	Grinder	Geismar PHG 2 / MP12	gasoline	7.5 / 9
32	Rail saw	Husqvarna K1250	gasoline	6.3
33	Chain saw	Husqvarna 395XP	gasoline	10.2
34	Blower	Husqvarna 125 BVK	gasoline	11.1
35	Angle grinder	Makita	electric	13.5
36	Angle grinders	IFA generic range	Air/electric	4-11***
37	Rail head scrubber	Rotamag RS200H	gasoline	8.4
38	Hedge trimmer	Stihl HS45	gasoline	10
39	Pole saw	Stihl HT75	gasoline	8.3
40	Chain saws	IFA generic range	electric	2-19
41	Jack hammer	Chicago P. 0069 series	air	29
42	Jack hammer	Atlas Copco TEX P90S	air	15.3
43	Rock Drill	Atlas Copco RH 658LS	air	21.2
*Tool vibration data (above >5 m/s^2 =high); Sources: Mfr., NetworkRail [NetworkRail, 2017] , IFA*** [Christ, 2010], NIOSH Power Tools Database (PTD) [NIOSH, 2018], own data (**); actual field emissions may vary and be considerably higher depending on tool maintenance and applications and other factors.				

Table 11: Examples of powered hand-tools with vibration emission levels of at or below 2.5 m/s²				
No	**Tool**	**Manufacturer & Model** Reference generic (***)	**Power**	**Emission m/s^{2*}**
1	Drill	Abtus 3462 HD	gasoline	<2.5
2	Drill/driver	Bosch GSR14 Prof.	battery	2.5
3	Drill	Cembre LD16BE		1.6
4	Drill	Robel 10.20	battery	1.18
5	Compacting	Altrad-Belle PCLX400	gasoline	2.48
6	Fastening	Cembre PCM-2P-FC	gasoline	2.27
7	Jigsaw	DeWalt DW 321	electric	2.5
8	Grinding (auto)	Geismar MLC	gasoline	1.3
9	Drill hammer	Hilti SFH22A	battery	2
10	Disc cutter	Husqvarna K760	gasoline	2.4
11	Circular saw	Hilti	battery	1.2
12	Trimmer	Husqvarna 555RXT	gasoline	1.6
13	Blower, leaf	Husqvarna 536LiB	battery	0.5
14	Grinder, frog	Matweld 09200A	hydraulic	2.5
15	Blower	Stihl BR380	gasoline	1.3
16	Clipper machine	Robel 34.01	gasoline	
17	Concrete vibrators	IFA generic	electric	<5***
18	Cutting saw (automatic)	Cembre Robokatta RDS14P-AA	Gasoline	0
Tool vibration data (above <2.5 m/s^2 = low); Sources: Mfr., NetworkRail [NetworkRail, 2017] , IFA* [Christ, 2010], NIOSH Power Tools Database (PTD) [NIOSH, 2018], own data (**); actual field emissions may vary and be considerably higher depending on tool usage, maintenance and applications and other factors .				

B. Review of Whole-Body Vibration (WBV) Emission Data

Manufacturers and suppliers of rail industry vehicles in the US typically do not provide any WBV information and the vibration exposure levels depend in great part on the cab and seat design, which may vary among different railroads. Only one study has been published in the peer-reviewed literature and the results are listed below for educational and illustrative purpose among some other data gathered by this author from similar studies and expert exchanges [Johanning, 2011, Wilder, 2009]. Examples of whole-body vibration exposure measurements of railroad maintenance-of-way vehicles from earlier studies are listed in Table 12.

Table 12. Results of rail maintenance-of-way vehicle vibration measurements

No	Measurement	Sampling t	Basic evaluation method a_w (m/s^2)			Vector sum a_v* (m/s^2)	SEAT		
		h:min:sec	**x**	**y**	**z**		**x**	**y**	**z**
1	Ballast regulator	1:09:05	0.18	0.14	0.19	0.37	1.22	1.64	0.83
2	Tamper	0:53:01	0.44	0.15	0.5	0.82	1.08	1.22	0.91
3	Wheel loader	2:25:51	0.29	0.3	0.34	0.68	1.44	1.1	1.37
4	Tie crane	2:22:16	0.23	0.17	0.2	0.45	1.25	1.26	0.94
5	Backhoe	3:16:35	0.26	0.25	0.32	0.60	1.39	1.28	1.12
6	Grader	3:05:03	0.24	0.22	0.39	0.60	1.23	1.32	1.19
7	Bulldozer	2:37:31	0.4	0.34	0.67	0.99	1.12	1.1	0.46
8	Speedswing 181	2:04:00	0.2-1.09	0.26-1.02	0.28-1.08	0.67-2.4	-	-	0.82-1.9
9	Ballast regulator	00:22:00	0.19	0.32	0.4	0.48	-	-	0.8
10	Utility light truck	2:07	0.21	0.37	0.43	0.74	-	-	0.78
11	Crane	-	1.85	1.76	2.63	4.4	-	-	-
12	Tamper	-	0.42	0.12	0.45	0.77	-	-	-
13	Wheel loaders	-	0.2-2.2	0.1- 2.0	0.2-1.7	-	-	-	-
14	Bulldozer	-	0.3-1.8	0.25-1.9	0.3-1.4				
15	Tamper	-	0.2-0.8	0.1-0.25	0.1-0.55	-	-	-	-
16	Dumper/truck	-	0.2-1.8	0.2-2.2	0.25-1.6				

(Table 12 continued)									
No	Crest Factor			MTVV/a_{weq}			VDV/a_w*$T^{1/4}$		
	x	**y**	**z**	**x**	**y**	**z**	**x**	**y**	**z**
1	13.6	14.4	28.9	9.85	5.9	8.25	2.22	1.88	2.33
2	6.9	8.7	7.6	3.68	4.26	2.93	1.65	1.67	1.64
3	16.4	17	23.8	9.47	10.8	9.49	2.09	2.16	2.21
4	9	12.6	13.1	5.22	7.22	6.11	1.65	1.73	1.68
5	21.3	18.9	30.1	12.76	10.54	8.42	2.2	2.3	2.32
6	14.2	11.7	23.3	7.6	6.04	8.07	1.87	1.62	1.88
7	11.7	10.4	8.1	5.72	4.31	2.89	1.78	1.54	1.38
8	-	-	10-42.6	-	-	-	5.27-16.67	4.1-17.2	11.2-50.7
9	7.4	8.9	16.7	4.1	4.4	4.4	1.7	1.85	1.8
10	8.9	8.4	8.6	3.9	3.9	3	1.94	2.06	1.58
11	4.5	17	9	-	-	-	-	-	-
12	3.9	5.4	5.7	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	=	=	=	=

T total measurement time, a_w , vector sum a_v*, *SEAT*, *CF*, *MTVV* and *VDV* ratios according to ISO 2631-1; * The factor $k_{(x,y,z)}$ is included: x-axis: k=1.4; y-axis: k=1.4; z-axis: k=1; Axis: x=fore and aft; y=lateral; z=vertical. Sources: 1-7 [Johanning, 2011]; 8-10 Dr. Johanning's database; 11-12 [Wilder, 2009]; 13-16 [Christ, 2010] (- no data)

C. Prevention

Railroad employers are responsible for providing a safe workplace for their workers in accordance with FRA and OSHA general regulations and mandates. The number and severity of MSDs resulting from physical overexertion or vibration can be substantially reduced by applying ergonomic principles and through proper medical care. Implementing an ergonomic program is effective in reducing the risk of developing musculoskeletal disorders (MSDs) and injuries in high-risk industries, such as the railroad industry. The following are key elements of an ergonomic program:

1. Provide management support

It is well understood, that a strong commitment by management is critical to the overall success of an ergonomic program. Management should define clear goals and objectives for the ergonomic program in collaboration with the Union, discuss these with their workers, assign responsibilities to designated staff members, and communicate clearly with the workforce.

2. Worker and union involvement

A participatory ergonomic approach, where workers and their unions are directly involved in worksite assessments, solution development and implementation, is the essence of a successful ergonomic program. Workers and their unions can:

- Identify and provide important information about hazards in their workplaces.
- Assist in the ergonomic process by voicing their concerns and suggestions for reducing exposure to risk factors and by evaluating the changes made as a result of an ergonomic assessment.
- Receive training. Training is an important element of an ergonomic program. It ensures that workers are aware of ergonomics, vibration hazards, and become informed about ergonomics-related concerns in the workplace and understand the importance of reporting early symptoms of MSDs and timely tool/equipment maintenance/repair.
- Work practices may include:
  - Let the power tool do the work;
  - Hold the power tool with the lightest grip possible consistent with safe work practices;
  - Keep hands and body warm and dry!
- Taking periodic rest breaks or job rotation if possible
  - For example, for every one to two hours of continuous seated WBV exposure take a 5-10 minute break, stand-up and stretch
  - No lifting of objects immediately after prolonged WBV exposure
  - Walking around for a few minutes, before attempting any heavy lifting tasks.
- Stop smoking (Nicotine is hindering good blood circulation)

3. Job analysis

An important step in the ergonomic process is to identify and assess ergonomic problems in the workplace before they result in MSDs. Models of joint management-labor approaches exist and their application should be studied.

4. Medical detection and prevention program

- Obtain anonymous disease/injury data with ICD-9 or ICD-10 coded diagnoses from health insurance companies contracted by the railroad to provide coverage for their employees to permit an analysis of trends in types of health conditions, conditions that are common, or may be unusual and unexpected. Analyses can examine possible connections between health conditions, job title, job tenure and demographics (such as age or employer).
- Obtain from the Railroad Retirement Board (RRB) health and claims data with ICD-codes for similar analysis of trends, common health problems, and possible connections to working conditions. However, the current administrative handling of such claims does not include any ICD-9 or ICD-10 coded diagnoses. The BMWED leadership should support and encourage (if not already done) the RRB to have the RRB claim files updated with appropriate ICD coding.
- Encourage early reporting of MSD symptoms by workers to their health care providers. Early reporting can accelerate the job assessment and improvement process and help to prevent or reduce the progression of symptoms, the development of serious injuries, and subsequent lost-time claims.

5. Medical evaluation and treatment

- Experts in occupational medicine can help obtain a proper work history to determine if the member's symptoms, illness or injury is related to work and to exposure to specific hazards.
- Identify appropriate diagnostic medical tests and additional specialty evaluations
- Work with other primary care or specialty providers to optimize care
- Help develop a specialized treatment plan and recommend work site interventions (administrative and technical controls)
- Provide a disability assessment and assist in rehabilitation services
    - Members should be encouraged to utilize besides their personal health care providers also the independent occupational medicine network clinics and providers from the Association of Occupational and Environmental Clinics (AOEC), with more than 60 clinics and more than 250 occupational health specialist members
    - In New York State, members should be encouraged besides their personal health care providers to also utilize the independent New York State occupational medicine network clinics (see: https://www.health.ny.gov/environmental/workplace/clinic.htm or https://www.health.ny.gov/publications/2722.pdf)
- A specific medical program to detect early symptoms of HAV, carpal tunnel syndrome or other MSDs from vibration and biomechanical exposures should be instituted (see discussion above) utilizing www.aoec.org and NY State network clinic providers and resources.

6. Control Hazards

There are many opportunities and solutions that can be implemented to reduce, control or eliminate workplace MSDs.

- Measure hand-vibration and whole-body vibration emissions from track maintenance vehicles/equipment in the field and identify high risk exposures
- Report and remove from service defective and poorly maintained tools
- Involve workers and the Union in the evaluation, selection and purchasing process of tools with improved ergonomic design and modern vibration attenuation technology
- Employer should only purchase tools/equipment from manufacturers and suppliers that provide vibration reduction technology and publish emissions data following international standards so that the purchaser and user can make appropriated choices and label equipment accordingly (see also [Geiger, 2017])
- Utilize vehicles with suspension systems that minimize vibration and properly maintain such suspension systems
- Utilize modern "air-ride seats" or seats with other appropriate suspension systems
- It is usually more efficient to reduce machine vibration through readily available engineering controls and designs. Some tools available on the market are equipped with anti-vibration devices, which can maintain a high production efficiency without increasing the vibration emission on their handles.
- It should be recognized that personal protective equipment is the last resort for protection against hazards at work and should be used only after all other options have been explored**.** ‘Anti-vibration’ gloves do not provide significant risk reduction at frequencies below 150 Hz (equal to 9 000 r/min). This means that for most powered hand tools the reduction is negligible. Therefor gloves should not be relied upon to provide protection from hand-arm-vibration [European Committee for Standardization, 2016]**.** Workers should be educated about the limitation of anti-vibration gloves.
- On the other hand, the use of gloves in a tool operation is generally recommended, especially for field workers working in a cold climate. This is primarily because the gloves can keep the hands warm, dry, reduce the skin contact pressure, and protect the hands from mechanical cuts and chemical exposures. It is not necessary to use vibration-reducing (VR) gloves or certified anti-vibration (AV) gloves to achieve these gloving purposes. Gloves and clothing should the assessed for a good fit and keeping the hands and body warm and dry. However, some VR gloves or “taping” of tool handles or “tool wraps” may be considered in some special cases, depending on the specific tools [Dong, et al., 2014]. The AV gloves can usually reduce the vibrations at more than 200 Hz, especially at more than 500 Hz. Hence, they may reduce sharp peaks from impulsive tools [Xu, et al., 2011]. It should also be noted that some of the VR gloves may substantially increase grip effort [Wimer, et al., 2010]. If a large grip force is required to control a tool, the selected gloves should not further substantially increase the grip effort, as this may increase hand fatigue and the risk of carpal tunnel syndrome. The selected gloves should also be comfortable and have a large coefficient of friction, which may reduce the grip force required to control the tool.

7. Evaluate Progress

Periodically assess the effectiveness of the ergonomic program and ensure its continuous improvement and long-term success. As an ergonomic program is first developing, assessments should include determining whether goals set for the ergonomic program have been met and determining the success of the implemented ergonomic solutions.

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B. Funding

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C. Trade names, commercial products and vibration data

Mentioning of trade names, commercial products, organizations or listed vibration values does not imply endorsement or guarantee of performances and accuracy and are only shown or listed as examples and illustrations. The authors have no commercial interests or connection with any of the listed manufacturer or supplier. The authors are not responsible for accuracy of the listed commercial information and data. Any risk assessment and activities are solely the responsibility of the reader or users of the tools/equipment. It is highly advisable to hire a professional consultant with proper qualification and certification to conduct any ergonomic and vibration risk assessment.

D. Author's contributions

Drs. Johanning and Landsbergis were responsible for the design of the musculoskeletal disorder and cardiovascular disease portion of the BMWED Health and Safety study, for selection of survey questions relevant to this portion of the study, for analysis of resulting data and for writing this report. Study investigators have periodically and appropriately reviewed with BMWED, and with other researchers conducting other portions of the Health and Safety study, study designs as they are developed, the collection of data, the analysis of data, the preliminary summarization of findings, the proposed peer reviews of study materials and the proposed publication of study findings. Drs. Johanning and Landsbergis have the discretion to independently publish or not publish the results of this study. Mr. Stillo, Mr. Jain and Ms. Davis conducted data cleaning, data analysis and helped to prepare report tables.

E. Disclosure

The authors declare no conflicts of interest. Dr. Johanning has represented BMWED workers in FELA claims as a medical expert and treating physician. He follows the Ethical Guidelines of ICOH. ACOEM and AOEC. Dr. Landsbergis is a consultant to the Center for Social Epidemiology, Marina Del Rey, CA, on issues related to work organization and CVD.

F. IRB approval

This portion of the BMWED Health and Safety study was approved by the SUNY Downstate Medical Center Institutional Review Board.

VII. REFERENCES

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VIII. APPENDICES

APPENDIX 1. Musculoskeletal symptom questions in the BMWED Health and Safety survey

Table A1. Musculoskeletal symptom questions in the BMWED Health and Safety survey				
#	Question	Adapted from:	Validity	References
41	Have you had back pain during the past week? Y/N	NMQ; MRC National Survey of Health and Vibration	NMQ is repeatable, sensitive and useful as a screening and surveillance tool, with a clinical exam as the reference.	[Crawford, 2007, Descatha, et al., 2007, Kuorinka, et al., 1987]; [Palmer, et al., 1998]
42	Do you have lower back pain more than 3 times per year? Y/N			[Johanning, 1991, Johanning, et al., 2004, Johanning, et al., 1996]
43	Do you have lower back pain lasting more than 1 week at a time? Y/N			[Johanning, 1991, Johanning, et al., 2004, Johanning, et al., 1996]
44	Did you have any severe injuries or fractures in the area of current discomfort? Y/N	VIBRISKS		[Griffin and Bovenzi, 2007]
45	Did your doctor or chiropractor tell you that you had a back problem and/or is treating you for a back problem? Y/N			[Johanning, 1991, Johanning, et al., 2004, Johanning, et al., 1996]
46	Have you ever reported a back-related injury to the railroad or railroad medical department? Y/N			[Johanning, 1991, Johanning, et al., 2004, Johanning, et al., 1996]
47	Within the last week, how often did you have any of the following in your lower back? (Daily, 4-6 days/wk, 1-2 days/wk, up to 1 day/wk, Never)			[Johanning, 1991, Johanning, et al., 2004, Johanning, et al., 1996]
	Pain			
	Cramping			
	Burning sensation			
	Stiffness			

	Swelling			
	“Pins and Needles”			
	Numbness in back only			
	Numbness in back and			
48	During the past year, how often have you had the following experiences? (Daily, 1-2x/wk, 1-2x/month, 1-2x/yr, Never)			
	Your back pain goes from the lower back down the leg below the knee(s)	VIBRISKS MRC National Survey of Health and Vibration	Questions on low back pain validated in MRC community surveys.	[Griffin and Bovenzi, 2007, Palmer, et al., 1998]
	You take any pain medicine for your back problem			
	While working for the railroad, have you missed/did you miss 3 or more days of work due to back problems			
49	When you started your present job, did you have back problems? (Daily, 1-2x/wk, 1-2x/month, 1-2x/yr, Never)			
50	How often have you had the following symptoms during the past year? (Daily, 1-2x/wk, 1-2x/month, 1-2x/yr, Never)	VIBRISKS		[Griffin and Bovenzi, 2007, Palmer, et al., 1998]
	Do you have numbness or tingling of the fingers at any time?			[Health and Safety Executive, 2018]
	Do you have any numbness or tingling of the fingers lasting more than 20 minutes during or after using vibrating tools?			[Health and Safety Executive, 2018]

	Do you wake up at night with pain, tingling, or numbness in your hand or wrist?	MRC National Survey of Health and Vibration	Good repeatability, sensitivity and specificity (for Sx lasting 3+ minutes).	[Palmer, et al., 1998]
	Have any of your fingers gone white (blanching) on cold exposure?	MRC National Survey of Health and Vibration	Questions on finger blanching validated in MRC community surveys.	[Palmer, et al., 1998]
	If you have experienced white fingers, was the whiteness clearly demarcated (showed limits or boundaries)?	MRC National Survey of Health and Vibration	Questions on finger blanching validated in MRC community surveys.	[Palmer, et al., 1998]
	Do you have difficulty picking up very small objects, i.e., screws or buttons or opening tight jars?			
51	Have you had pain lasting a day or more in your …. during the past week; during the past 12 months; During the past 12 months have you been prevented from carrying out normal activities (e.g. job, housework, hobbies) because of pain in your:	NMQ; MRC National Survey of Health and Vibration	NMQ is repeatable, sensitive and useful as a screening and surveillance tool, with a clinical exam as the reference.	[Crawford, 2007, Descatha, et al., 2007, Kuorinka, et al., 1987]; [Palmer, et al., 1998]
	Knees			
	Hips			
52	Shoulders			
	Neck			
	Wrists/Hands			
	Elbows			
Abbreviations: NMQ, Nordic Musculoskeletal Questionnaire; MRC, Medical Research Council, UK				

APPENDIX 2. Comparison of musculoskeletal symptom prevalence among BMWED members and other studies

Table A2a. Comparison of BMWED active members to other male workers on prevalence of musculoskeletal symptoms in the past 12 months (Nordic Musculoskeletal Questionnaire)

		General population studies		**Physically demanding jobs**
Symptom area	BMWED active members, 2016-17 (of 3,073)	French male workers, 2002-5 [Parot-Schinkel, et al., 2012]	French male workers, 2002-5 [Bodin, et al., 2012]	Male mine workers: Finland, Norway, Sweden, Russia, 2012-3 [Burstrom, et al., 2017]
	"Severe joint pain" lasting 1+ days			
Neck	24.9%	33.5%		52%
Shoulder	29.3%		28%	50%
Shoulder/upper arm		34.0%		
Elbow	17.4%			17%
Elbow/forearm		17.2%		
Wrist/hand	29.1%	21.6%		30%
Upper back		20.9%		27%
Low back		59.3%		60%
Hips	17.7%			
Hip/thigh		16.7%		16%
Knees	34.2%			
Knee/lower leg		28.3%		37%
Ankle/foot		15.7%		18%

Table A2b. Comparison of BMWED active members to studies of other male workers on prevalence of vibration-related symptoms

		General population studies
Symptom	BMWED active members, 2016-17	British male workers, 1997-8 [Palmer, et al., 1999]
	Past year	Ever
Blanching attacks		13.0%
Cold-induced blanching attacks	21.6%	10.6%
Blanching attacks associated w/	12.5%	4.1%
	Past week	Past week (lasting 3+ minutes)
Tingling/numbness in hand	25.0%	17.3%
Tingling/numbness in hand	17.6% (incl. pain)	7.4%

Table A2c. Musculoskeletal symptoms comparative annual prevalence [Riley, 2006]

	Track maintenance workers	Railway Workers Brulin et al 1995, (n=660)	Nordic reference data: all industry 1986/87. (n=7569)	Nordic: Lumberjack (n=40)	Nordic: Engineering Mechanic (n=56)	Nordic: Construction Worker (n=104)	HSE reference data: all industry (n=663)	HSE reference data 1999: Ground workers (n=41)	HSE reference data 1999: General Labourers (n=88)	Brick packers (Pinder 2001, n=127)
1. Neck	14%	16.0	24%	25%	29%	31%	30%	19.5	15.9	32%
2. Shoulders	24%	22.0	24%	28%	40%	48%	26%	34.1	27.3	36%
3. Elbows	4%	10.0	10%	12%	14%	26%	9%	9.8	17.0	32%
4. Wrists/ hands	16%	14.0	13%	2%	16%	34%	25%	31.7	31.8	49%
5. Upper back	4%	38.0	10%	8%	11%	11%	12%	9.8	5.7	14%
6. Lower back (small of back)	64%	7.0	41%	49%	46%	50%	44%	46.3	50.0	61%
7. Hips/ thighs/ buttocks	8%	11.0	11%	15%	16%	17%	12%	12.2	15.9	13%
8. Knees	20%	40.0	25%	23%	23%	35%	27%	26.8	37.5	28%
9. Ankles/ feet	24%	26.0	13%	13%	20%	17%	14%	19.5	15.9	17%

Note: 3-month prevalence data for 25 track maintenance workers in South Wales, and for the 663 HSE reference sample workers. 12-month prevalence data for 7,569 Nordic workers.

Table A2d. Musculoskeletal symptoms comparative weekly prevalence [Riley, 2006]

	Track maintenance workers	Nordic reference data: all industry (1985)
1. Neck	12%	11%
2. Shoulders	4%	11%
3. Elbows	4%	4%
4. Wrists/ hands	8%	6%
5. Upper back	4%	4%
6. Lower back (small of back)	36%	15%
7. Hips/ thighs/ buttocks	4%	5%
8. Knees	16%	10%
9. Ankles/ feet	16%	6%

Note: Data for 25 track maintenance workers in South Wales, 7,569 Nordic workers

APPENDIX 3. BMWED Health and Safety Survey

THE BMWED HEALTH AND SAFETY SURVEY

Thank you for responding to this important survey. Over the years, concerns have grown about the potential risks of maintenance of way work (MOW) to your health and safety. In response, the Brotherhood of Maintenance of Way Employes Division (BMWED) is embarking on a major research study, the BMWED Health and Safety Study, to document any such risks and their impact on members and retirees. One part of this research is a survey of the membership. We need your help.

Your survey answers are entirely CONFIDENTIAL, so please be completely candid. **NEITHER THE UNION NOR THE RAILROAD WILL SEE YOUR SURVEY RESPONSES.** Your survey answers will be separated from any personal identifying information to protect your privacy, and then all the anonymous survey responses will be combined together and coded as an additional layer of protection. This procedure will be in place whether you answer by mail, phone, or on the internet. All research work is being done by independent professional researchers from Ruth Ruttenberg & Associates, the State University of New York (SUNY), and the Association of Occupational & Environmental Clinics (AOEC) who will destroy these surveys once the data have been entered into a general data base. Your name and other personal identifiers will not be attached to your survey responses. To help further protect your privacy, we have received a Certificate of Confidentiality from the National Institutes of Health.[1]

We ask that you answer all the questions, but you are free to leave blank any questions with which you are uncomfortable. If you have any additional concerns, issues or ideas that you would like to share, please add them in the "Additional Comments" section at the end of the survey." It should take about 30-45 minutes to complete the survey.

The survey asks for some general information about you and your family. It asks about your current and past health as well as your work history. We will also ask about the impact of any work-related illnesses or injuries on you and your family.

You are encouraged to take the survey on-line; however, you can also submit a paper copy or request a telephone interview in which your responses will be noted for you. If you answer on-line, we have developed a secure, private website to tabulate your answers. If you answer by mail or phone, anything possibly identifying you with your answers will be destroyed. We have taken

[1] The researchers can use this Certificate of Confidentiality to legally refuse to disclose information that may identify you in any federal, state, local, civil, criminal, administrative, legislative, or other proceeding; for example, if there is a court subpoena, the BMWED researchers will use the Certificate to refuse any demands for information that might in any way identify you. You should understand that a Certificate of Confidentiality does not prevent you or a member of your family from voluntarily releasing information about yourself or your involvement in this research or from asking researchers in writing to release information to others such as your doctor.

these steps to minimize any risk that personal information could be disclosed. Your privacy is our highest priority as we move forward with this important research.

Your participation in this survey is very important. BMWED will use the findings to help rail workers live longer and healthier lives, and reduce conditions impacting BMWED members' health and safety through a combination of regulatory improvements and labor/management engagement. However, your participation is completely voluntary. As a way of thanking you, we will enter your name into a raffle drawing, if you wish. There will be ten BMWED hoodies to be won in the raffle (handled by an independent contractor). Please see the end of the survey for details.

We need your permission in order to begin.

I consent to fill out this questionnaire as a participant in the BMWED Health and Safety Survey.

Yes ☐ **No** ☐

To answer on-line, go to: www.bmwesurvey.com.

To answer in writing, send your survey to:

Ruth Ruttenberg, 1830 Hallstrom Road, Northfield, Vermont 05663

To answer in a telephone interview, call Ruth Ruttenberg at 802-485-4554

If you have any questions about this survey, please contact Rick Inclima, BMWED Director of Education and Safety at *202-508-6449 or ricki@bmwe.org*.

I. BACKGROUND INFORMATION

1. Do you currently work for a railroad?

   ☐ Yes
   ☐ No, I'm out on disability
   ☐ No, I retired based upon age
   ☐ No, I retired based upon a medical condition

2. Which railroad company do you now work for, or, if you no longer work, which was the last railroad you worked for?

   ☐ Alaska Railroad
   ☐ Amtrak
   ☐ BNSF
   ☐ Commuter Railroad ________(name)
   ☐ CSX
   ☐ Canadian Pacific
   ☐ Canadian National
   ☐ Kansas City Southern
   ☐ Norfolk Southern
   ☐ Soo Line
   ☐ Tex-Mex
   ☐ Union Pacific
   ☐ Other, please list ___________________

3. In what Region of the country did you perform the majority of your railroad work?

   ☐ **NORTHEAST** (CT, ME, MA, NH, NJ, NY, RI, VT, DE, DC, MD, OH, PA, VA, WV)
   ☐ **SOUTHEAST** (AL, FL, GA, KY, MS, NC, SC, TN, AR, LA)
   ☐ **CENTRAL** (IL, IN, MI, MN, WI, IA, CO, KS, MO, NE, OK, TX)
   ☐ **WESTERN** (AZ, CA, NV, UT, ID, MT, NM, ND, OR, SD, WA, WY)

4. What year did you retire? ________

5. If you've been granted a disability annuity by the Railroad Retirement Board, what year did you leave work? _________

6. How many years have you worked for the railroad as a maintenance of way employee? _____

7. At what age did you begin work for a railroad? _______

8. What year were you born? _______

9. Below are broad categories of railroad jobs. Please indicate which jobs you worked and provide your best estimate regarding the years you worked them:

Job description	Check here if you worked this job	Start Year	Estimated total years you worked this job	Check if you wore a dust mask when working this job			Was there visible airborne dust when working this job?		
				Always	Some times	Never	Always	Some times	Never
Trackman/Laborer									
Machine Operator (hand-held power tools and small walk behind/beside machines)									
Equipment Operator (medium/large, self-propelled on-track/off-track equipment)									
Surfacing Gang Equipment Operators (ballast regulators, tamper, mechanical boom)									
Welder/welder helper									
Foreman (foreman, assistant foreman, section foreman, B&B foreman)									
Track inspector									
Bridge and Building employee (painter, carpenter, ironworker, structural welder, plumber)									
Electric Traction employee (catenary power and 3rd rail)									
Truck driver/bus driver (CDL driver, boom truck, material truck, gang bus, lowboy truck)									
Roadway equipment mechanic/repairman									
Other (explain ______)									

10. In the past 2 years, approximately how many nights a month did you spend away from home for work?

1-5 nights ☐ 6-10 ☐ 11-15 ☐ 16-20 ☐ more than 21 nights/month ☐

II. WORK HISTORY (Vehicle and Tools)

11. Please tell us if and what vehicles you have operated or been riding on since you started working for the railroad. Please be as specific as possible, but report only if you have done it for more than one year.

Vehicle type	Yes	IF YES, What year did you begin?	About how many years did you do this work?	About how many hours per day?
Ballast Regulator				
Tamper				
Front end loader				
Tie crane				
Crane (American, Ohio, or other:25-80				
Backhoe				
Grader				
Bulldozer				
Cribber/ Scarifier (tie renewal gang)				
Pettibone				
Brushcutter				
Truck(s) (heavy; road or hi-rail)				
Light truck/van (i.e., F150-350) (road				
Other, please list _____________				

Other Jobs and Activities

12. Did you work at any other job more than 20 hours per month since you went to work for the railroad? Yes ☐ No ☐

If you are holding a second job (or held one since you began working for the railroad), please complete the following questions. If yes, please answer questions 13 and 14. If no, please go to question 15.

13. If yes, what was the other job?

a. Occupation:________________________
b. Industry : Construction ☐ Farm/agriculture ☐ Factory work ☐ Services ☐
c. Year began _________

d. Estimated total number of years you worked the 2nd job

____

14. For this second job, in the past year, which did you use on a daily basis?

	Yes
a. Car (other than going to and from work)	
b. Van (other than going to and from work)	
c. Bus or Coach (other than going to and from work)	
d. Train (other than going to and from work)	
e. Motorcycle (other than going to and from work)	
f. Rock crusher	
g. Concrete production machinery	
h. Tractor	
i. Loader	
j. Excavator	
k. Bulldozer	
l. Grader	
m. Scraper	
n. Dumper	
o. Other earth-moving machinery	
p. Road roller	
q. Mower (seated)	
r. Off road forestry vehicle	

15. In your spare time (i.e. outside work and going to and from work), please give your best estimate of the total number of hours (or minutes) per week you spend driving or riding in the vehicles listed below.

	Hours Per Week
Car or Van	
Bus or Coach	
Commuter Train	
Motorcycle	
Snowmobiles	
ATVs	
Horseback Riding	
Mountain Biking	
Mower	

Tractor	

16. Please tell us what tool(s) you have operated, at work, since you started working for the railroad. Please be as specific as possible, but report only if you have done/handled this for more than one year. Please mark all that apply.

Tool Type	Yes	About how many years have you used these tools?	About how often do you use this (these)				
			Always	Often	Some times	Rarely	Never
POWER TOOLS							
Jack hammer							
Rock drill							
Concrete vibrator							
Hammer drill							
Nail gun							
Reciprocating saw							
Rivet buster							
Scabbler							
Air hammer							
Impact wrench							
Nut splitter							
Tamping gun (hand							
Profile grinder							
Spike puller							
Spiker gun							
Spike driver							
Rail saw							
Impact tool							
Grinder							
Asphalt tamper							
Rail drill							
Other, list_______							
HAND-TOOLS							
Sledge hammer							
Spike maul							
Claw bar							
Anchor wrench							
Track wrench							
Lining bar							
Clip applicator							
Other, list ______							

III. WORKING CONDITIONS

17. Please describe how many hours during your work day you face each of the following conditions:

AT WORK:	Always (8-10 hours)	Often (4-6 hours)	Sometimes (1-2 hours)	Seldom (less than 1 hour)	Never (0 hours)
I sit					
I stand					
Vehicle/equipment vibration bothers me					
Hand tool vibrations bother me					
Noise bothers me					

18. How often does your job involve repeated lifting, pushing, pulling, or bending?

Often/Always ☐ Sometimes ☐ Seldom/Never ☐

19. How would you estimate your exposure during your railroad career to …?

	Light	Moderate	Heavy	Extreme
Ballast dust				
Creosote				
Diesel Fumes				
Herbicides/Pesticides				
Solvents/Chemical				

20. Which of the following best describes the hours you usually work?

☐ A regular daytime schedule (most of your shift is between the hours of 6 AM and 6 PM)

☐ A regular evening shift (most of your shift is between the hours of 2 PM and midnight)

☐ A regular night shift (most of your shift is between the hours of 9 PM and 8 AM)

☐ An irregular schedule such as rotating shifts, split shifts, or some other schedule where hours change from day to day or week to week

Rate the Following Statements About Your Feelings on the Job/About Your Job/Work Environment	Strongly Agree	Agree	Disagree	Strongly Disagree
21. My job allows me to make a lot of decisions on my own				
22. I can count on my supervisor or manager for support				
23. The health and safety of workers is a high priority with				

24. How often are there not enough people or staff to get all the work done?

Often ☐ Sometimes ☐ Rarely ☐ Never ☐

IV. GENERAL HEALTH STATUS

25. Please list any and all health problems that you think could *possibly* be related to your railroad work, and when the symptoms first emerged. (You can add more at the end of the survey under "Other Comments.") Examples might include: lung cancer, chronic bronchitis, skin cancers, neurological conditions, joint pain, rotator cuff, crushed finger –but these are just examples.

Health Problem	Year the Symptoms First Emerged
1.	
2.	
3.	
4.	
5.	
6.	

26. Have you had surgeries since you began working for the railroad? Yes ☐ No ☐

If yes, which ones and at what age?

Type of Surgery	Any Additional Detail About the Type of Surgery	Your Age at Time of Surgery
Back		
Colon		
Elbow		
Eye		
Hip		
Kidney		
Knee		
Neck		
Shoulder		
Skin (melanoma)		
Stomach		
Other (Please describe) ________________________________		
Other (Please describe) ________________________________		

	Yes	No	Inconclusive
27. Have any of your illnesses or symptoms been recognized by a doctor as being work-related? If yes, which ones? ___________________________________			
28. Has the railroad disputed your doctor's diagnosis of work relatedness?			

	Yes	No
29. Have you smoked at least 100 cigarettes in your ENTIRE LIFE?		
30. Do you NOW smoke cigarettes: Every day ☐ Some days ☐ Not at all ☐		
31. If yes, how many cigarettes do you smoke per day? ___________ If you no longer smoke, how many cigarettes, at most, did you smoke per day? ___________		

	Yes	**If yes, how many years have you had this condition?**
32. Have you EVER been told by a doctor or other health professional that you had……		
Chronic obstructive pulmonary disease, also called COPD?		
Asthma		
A lung disease called silicosis or silico-tuberculosis?		
Hypertension, also called high blood pressure?		
High cholesterol?		
Coronary heart disease?		
Angina, also called angina pectoris?		
A heart attack (also called myocardial infarction)?		
Any other kind of heart condition or heart disease?		
A stroke?		
Arthritis?		
Rheumatoid Arthritis?		
Gout?		
Lupus?		
Fibromyalgia?		

A condition affecting the wrist and hand called carpal tunnel syndrome?		
Diabetes or sugar diabetes?		
Prediabetes, impaired fasting glucose, impaired glucose tolerance, borderline diabetes, or high blood sugar? <u>If yes</u>, how old were you when a doctor or other health professional FIRST told you that you had diabetes or sugar diabetes? __________		
33. During the past 12 months, have you been told by a doctor or other health professional that you had weak or failing kidneys? Do not include kidney stones, bladder infections or incontinence.		

	Yes	**<u>IF YES,</u>**		
		What year diagnosed?	**Did a doctor tell you it was work related?**	**Do you think it was work related?**
34. Has a doctor ever told you that you have a central nervous system condition such as ....?				
Memory issues, Forgetfulness				
Dementia				
Parkinson's disease				
Tremor in your hands or legs				
Tingling or numbness in your hands or legs				
Multiple Sclerosis (MS)				
Lead poisoning				
Mercury poisoning				
35. Has a doctor told you that you have cancer? If so, what kind?				
Bladder cancer				
Brain cancer				
Kidney cancer				
Leukemia				
Lung cancer				
Lymphoma				

Melanoma or other skin cancers				
Pancreatic cancer				
Prostate cancer				
Stomach cancer				
Other cancer (please describe________________)				
36. Have you suffered a severe traumatic work injury resulting in missing work for more than 3 days, such as ...?				
Crushed hand, wrist, or fingers				
Injury to back				
Injury to neck				
Injury to head				
Injury to knees				
Injury to foot/ankle				
Injury to hips				
Injury to shoulders				
Injury to trunk				
Other traumatic injury (please describe ______________________)				

	Usually	**Sometimes**
37. Do you have shortness of breath when you walk on level ground?		
38. Do you wheeze when you walk on level ground?		
39. Do you have a productive cough when you wake up, more than 3 days per weeks?		
40. Do you have phlegm production, when you wake up, more than 3 days per weeks?		

BACK HEALTH

Back Health	**Yes**	**No**
41. Have you had back pain during the past week?		
42. Do you have lower back pain more than 3 times per year?		
43. Do you have lower back pain lasting more than 1 week at a time?		

44.	Did you have any severe injuries or fractures in the area of current discomfort? Please describe: ____		
45.	Did your doctor or chiropractor tell you that you had a back problem and/or is treating you for a back problem? If yes, what was the diagnosis? ______________________		
46.	Have you ever reported a back-related injury to the railroad or railroad medical department? If yes, please describe the injury: ____________________________________		

47. Within the last week, how often did you have any of the following in your lower back?

	Always (every day)	**Often (4-6 days/wk)**	**Sometimes (1-2 days/wk)**	**Seldom (up to 1 day/wk)**	**Never**
Pain					
Cramping					
Burning sensation					
Stiffness					
Swelling					
"Pins and Needles"					
Numbness in back only					
Numbness in back **and** lower leg					

48. During the past year, how often have you had the following experiences? (Please check the best answers)

	Daily	**1-2 times a week**	**1-2 times a month**	**1-2 times in a year**	**Never**
Your back pain goes from the lower back down the leg below the knee(s)					
You take any pain medicine for your back problem					
While working for the railroad, have					

you missed/did you miss 3 or more days of work due to back problems					

49. When you started your present job, did you have back problems?

- ☐ Daily
- ☐ 1-2 times a week
- ☐ 1-2 times in a month
- ☐ 1-2 times in a year
- ☐ Never

HAND HEALTH

50. How often have you had the following symptoms during the past year? (Please check the best answers.)

	YES				**NO, Never**
	Daily	**1-2 times a week**	**1-2 times in a month**	**1-2 times in a year**	
Do you have numbness or tingling of the fingers at any time?					
Do you have any numbness or tingling of the fingers lasting more than 20 minutes during or after using vibrating tools?					
Do you wake up at night with pain, tingling, or numbness in your hand or wrist?					
Have any of your fingers gone white (blanching) on cold exposure?					
If you have experienced white fingers, was the whiteness clearly demarcated (showed limits or boundaries)?					
Do you have difficulty picking up very small objects, i.e., screws or buttons or opening tight jars?					

OTHER JOINT PAIN PROBLEMS

51. If you have had severe joint pain in the past week or the past year, please answer the questions below in the boxes.

	During the past week have you had pain lasting a day or more in your …	**During the past 12 months have you had pain lasting a day or more in your …**	**During the past 12 months have you been prevented from carrying out normal activities (e.g. job, housework, hobbies) because of pain in your …**
KNEES	Yes ☐	Yes ☐	Yes ☐
HIPS	Yes ☐	Yes ☐	Yes ☐

52. What about severe pain in your upper body parts?

	During the past week have you had pain lasting a day or more in your …	**During the past 12 months have you had pain lasting a day or more in your …**	**During the past 12 months have you been prevented from carrying out normal activities (e.g. job, housework, hobbies) because of pain in your …**
SHOULDERS	Yes ☐	Yes ☐	Yes ☐
NECK	Yes ☐	Yes ☐	Yes ☐
WRISTS/ HANDS	Yes ☐ IF YES: Right ☐ Left ☐ Both ☐	Yes ☐ IF YES: Right ☐ Left ☐ Both ☐	Yes ☐ IF YES: Right ☐ Left ☐ Both ☐
ELBOWS	Yes ☐ IF YES: Right ☐ Left ☐ Both ☐	Yes ☐ IF YES: Right ☐ Left ☐ Both ☐	Yes ☐ IF YES: Right ☐ Left ☐ Both ☐

V. IMPACT OF YOUR HEALTH STATUS ON YOU, YOUR FAMILY, AND YOUR COMMUNITY

53. Have you had out-of-pocket expenses associated with work-related illnesses, symptoms, or injuries while working for the railroad? Yes ☐ No ☐

If yes, please answer the questions below about types of expenses and amount.

Type of Out-of-Pocket Expense	Check here if you had this expense	Approximate amount you spent or lost	What illness or injury required this expense?
Medical devices			
Travel to doctors			
Parking			
Over the counter medications			
Prescription medications			
Medical appointment co-pay/co-insurance			
Caretaker/health aide			
Unpaid caretaker's lost wages			
Child care/Elder care			
Other, describe _______________ _______________________________			
Other, describe _______________ _______________________________			

54. If you have missed work as a result of illnesses or symptoms that might be work related, please answer the questions below.

Type of work related illness or injury for which you missed work	How many days did you miss work since you began BMWE work	Approximate number of total days that family members missed school to care for you	Approximate number of total days that family members missed work to care for you
Example: kidney disease	40 days	0 days	8 days
1.			
2.			
3.			
4.			
5.			
6.			

55. Have any illnesses or symptoms, that you think are railroad work-related, caused significant financial or other family burden, such as

	Yes	**<u>If yes</u>, due to what illness or symptom**
Serious financial hardship		
Cancelled vacation		
Put off buying a car ☐ or house ☐ or major appliance ☐		
Had a car ☐ or house ☐ or major appliance repossessed ☐		
Personal bankruptcy		
Mounting credit card debt		
Threatening bill collectors		
You had to take on a second job		
Someone in your household/family had to take on another job to pay bills. If so, who? ______________________		
Someone in your household/family had to cut back on work or school to take care of you. If so, who? _______________________________		
Needed to purchase home care, day care, or elder care		
Other (Please explain _____________________ ______________________________		

56. Have any illnesses or symptoms caused changes in your <u>social interactions</u>?

	Yes	**<u>If yes</u>, due to what illness or symptom**
Can't volunteer or volunteer less, no energy (explain – church, scouts, sports coaching….) _____________________________________		
Don't have the energy to go out		
Have given up hobbies		

Have to hire people to do chores around the house or do errands		
Church members or others have to come and help me and/or family		
City, county or state social services are needed to help with family issues		
Don't have as much fun as I used to		
Other (Please explain ___________________ ______________________________________		

57. Have any illnesses or symptoms caused/contributed to stress in <u>family interactions</u>? (Please explain.)

	Yes	**<u>If yes</u>, due to what illness or symptom**
Marital stress (relationship damaged, separation, divorce)		
Children moving back in to help out		
Children moving out		
A parent or in-law needing to move in to help out		
Partner having to take on a new job to help with expenses		
Partner having to quit a job to take care of you		
Child having to postpone/ drop out of school for caretaking and/or income earning related to illness		
Child with lower grades in school		
Not being able to go to children's activities		
Mental health issues (Circle relationship: self, spouse, child, other)		
Substance abuse (Circle relationship: self, spouse, child, other)		
Other (Please describe) ___________________ ______________________________________		

DEMOGRAPHIC QUESTIONS

58. What is your gender? Male ☐ Female ☐

59. Which of the following best describes your racial/ethnic background?

☐ African-American
☐ Asian
☐ Caucasian
☐ Hispanic
☐ Native American
☐ Other _______________

60. What is your BMWED Local number? ____________

61. Other comments related to your health status or elaboration of comments already written.

____
____
____
____
____
____
____
____
____
____
____
____
____
____

(Feel free to write more if you wish.)

Please Note: If you have any pictures of hand-tools that bother you in particular, please send us a picture. Please send to: Ruth Ruttenberg, 1830 Hallstrom Road, Northfield, VT 05663 or rruttenberg@tds.net.

APPENDIX 4. Comparing BMWED survey respondents to non-respondents

The 2016-17 BMWED health and safety survey was at least partly completed by 4816 (approximately 12% of) members. Therefore, it is important to determine whether the members who answered the survey (survey respondents) were representative of all members. There are two main ways that we can judge whether the survey respondents were representative:

1) To compare survey respondents to the national membership of the union on available demographic information (age, years on the job, gender, region of country, and railroad).

2) To compare survey respondents to a random sample of non-respondents who later agreed to complete a short version of the survey by telephone.

Comparing survey respondents to the national membership of the union

The average number of years worked by active survey respondents was about 2 years less than active members who did not fill out the survey. The average age of active survey respondents was about 3 years less than active members who did not fill out the survey (see Table A4a). The average age of retired members who answered the survey was about 4 ½ years less than all retired members (see Table A4b).

The percent of active survey respondents who lived or worked in each region of the country, who worked for a particular railroad, or who were male were similar (though not exactly the same) to active members who did not fill out the survey (Table A4a). Likewise, the percent of retired survey respondents who lived or worked in each region of the country, who had worked for a particular railroad, or who were male were similar (though not exactly the same) to all retired members (Table A4b).

Comparing survey respondents to a random sample of non-respondents

BMWED health and safety staff selected a random sample of 395 survey non-respondents and asked BMWED local union representatives to telephone those members and ask them 10 questions from the larger survey. Representatives were asked to call at least half of the survey non-respondents on their lists. Therefore, between 198 and 395 non-respondents received a phone call, and 135 non-respondents completed the 10-question telephone survey. Thus, the response rate for the telephone survey was between 34.2% (135/395) and 68.2% (135/198),

Of the 10 questions selected from the larger survey, 4 were health questions (had surgeries, had cancer, have shortness of breath, had back pain), 3 were working conditions questions (hand tool vibrations bother me, exposure to ballast dust, worked with a spiking gun), 1 question asked about cigarette smoking and 2 were about the demographics of the people answering the survey (age and region of country where one works).

Age. Survey respondents were substantially younger (by an average of about 3 years) than non-respondents surveyed by phone (Table A4c). This is consistent with the comparison to the national membership of the union.

Region. The percent of active survey respondents who worked in each region of the country was similar to (though not exactly the same as) non-respondents surveyed by phone (Table A4c). There were non-respondents who were surveyed by phone from all regions of the country, however, there was a somewhat higher percent from the Western region, and a somewhat lower percent from Central/Midwest region compared to respondents to the large survey. This is consistent with the comparison of survey respondents to the national membership.

Health. The percent of active survey respondents who reported surgeries, cancer, or usual shortness of breath was lower than non-respondents who completed the short phone survey (Table A4c). However, the percent of active survey respondents who reported back pain in the past week was higher than non-respondents who completed the short phone survey

Working conditions. The percent of active survey respondents who reported using a spiking gun, or were bothered always or often by hand tool vibrations, was lower than non-respondents who completed the short phone survey (Table A4c). On the other hand, the percent of active survey respondents who reported extreme or heavy exposure to ballast dust was similar to the percent of non-respondents who completed the short phone survey.

Smoking. The percent of smokers among active members who completed the large survey was similar to non-respondents who completed the short phone survey (Table A4c).

Conclusions

In summary, active members and retirees who completed the survey were younger than those that did not (from the union's total membership), but were fairly similar on region of the country, railroad employer and gender. Because survey respondents were younger, the percent who reported injuries and illnesses on the survey would probably be a little less than the percent that would have been reported by the BMWED active membership or BMWED retirees as a whole.

In addition, active members who completed the large survey were younger and healthier than the random sample of non-respondents who completed the short phone survey – with the exception of "back pain in the past week", which was more common among active members who completed the large survey. Therefore, the percent of active members who reported injuries and illnesses on the large survey would probably be somewhat less than the percent that would have been reported by the BMWED active membership as a whole – with the exception of back pain. Such difference in health cannot be explained by cigarette smoking, since smoking rates were similar between large survey respondents and non-respondents who completed the short phone survey.

Finally, the active members who completed the large survey had slightly better working conditions (based on 3 questions) than the random sample of non-respondents who completed the short phone survey. That result, combined with the fact that the large survey respondents were younger and healthier (with the exception of back pain), means that any connections (associations) seen in future analyses between working conditions and the health of BMWED members would likely underestimate the true connections (with the exception of back pain).

Table A4a. Active BMWED Members

	Survey Respondents		Non-Respondents	
	Number	**%**	**Number**	**%**
Region*	3982	100%	30387	100%
Northeast	1025	25.66	7168	23.59
Southeast	546	13.67	5236	17.23
Central / Midwest	1700	42.69	12038	39.62
Western	711	17.86	5945	19.56
Gender	2810	100%	30387	100%
Male	2791	99.32	30361	99.91
Female	19	0.68	26	0.09
Railroad	3995	100%	30387	100%
Amtrak	361	9.04	2422	7.97
BNSF	1115	27.91	7068	23.26
CSX	637	15.94	4396	14.47
Canadian Pacific	68	1.70	-	-
Canadian National	169	4.23	1	0.00
Kansas City Southern	32	0.80	406	1.34
Norfolk Southern	564	14.12	3701	12.18
Union Pacific	824	20.63	7995	26.31
Other	225	5.64	4398	14.47

	Survey Respondents			Non-Respondents		
	Number	**Averag**	**SD**	**Number**	**Avera**	**SD**
Years on the Job	3969	12.72	10.73	30386	14.90	13.03
Age	3925	42.70	10.56	29934	44.52	12.10

Notes: In analysis of age, 70 Survey respondents and 40 non-respondents were excluded from the comparisons for reporting that they were over the age of 75. Age values for active members >75 were assumed to be typographical errors.

All comparisons between survey respondents and non-respondents were statistically significant, that is, real differences, not due to chance.

SD=standard deviation, a measure of the distribution of answers to questions about age and years on the job. About 95% of all the answers are within +/- 2 standard deviations.

* “Region of the country where you work” for survey respondents; region of the country where one lives for non-respondents.

Table A4b. Retired BMWED Members

	Survey Respondents		All Retired Members	
	Number	**%**	**Number**	**%**
Region*	695	100%	2431	100%
Northeast	170	24.46	530	21.80
Southeast	46	6.62	275	11.31
Central/Midwest	343	49.35	1079	44.39
Western	136	19.57	547	22.50
Gender	632	100%	2431	100%
Male	629	99.53	2431	100
Female	3	0.47	0	0
Railroad	703	100%	2415	100%
Amtrak	26	3.70	52	2.14
BNSF	216	30.73	625	25.71
CSX	86	12.23	209	8.60
Canadian Pacific	26	3.70	-	-
Canadian National	29	4.13	-	-
Kansas City Southern	5	0.71	9	0.37
Norfolk Southern	87	12.38	336	13.82
Union Pacific	158	22.48	465	19.13
Other	70	9.94	719	30.23

	Survey Respondents			All Retired Members		
	Number	**Average**	**SD**	**Number**	**Average**	**SD**
Age	673	67.27	7.27	2294	70.96	10.45

Note: 30 Survey respondents and 113 Retired Members were excluded from these comparisons for age reporting that they were younger than 60 or older than 105 years old. Age values <60 or >105 were assumed to be typographical errors.
All comparisons between survey respondents and all retirees were statistically significant, that is, real differences, not due to chance.
SD=standard deviation, a measure of the distribution of answers to the question about age. About 95% of all the answers are within +/- 2 standard deviations.
* "Region of the country where you worked" for survey respondents; region of the country where one lives for all retirees.

Table A4c. Comparing survey respondents to random sample of non-respondents on 10 questions							
Active Members						**Analysis**	
	Survey Respondents (maximum n=3995)			Phone survey of random sample of non-respondents (n=135)		Difference between groups	
Variable	**N**	**total N respondents**	**%**	**N**	**%**	**Chi-square**	**p**
26. Have you had surgeries since you began working for the railroad?							
Yes	860	3073	27.5%	57	42.2%	12.839	<0.001
35. Has a doctor ever told you that you have cancer? (no "no" option on survey)							
Yes	107	3073	3.5%	11	8.1%	2298.626	<0.001
37. Do you have shortness of							
Usually	42	3073	1.4%	8	5.9%	33.235	<0.001
Sometimes	664	3073	21.2%	28	20.7%		
Never	2028	3073	65.2%	99	73.3%		
41. Have you had back pain during the past week?							
Yes	1477	3073	47.3%	55	40.7%	2.78	0.095
17. Hand tool vibrations bother me							
Always	206	3308	6.1%	19	14.1%	23.661	<0.001
Often	609	3308	18.0%	21	15.6%		
Sometimes	1049	3308	31.2%	41	30.4%		
Seldom	737	3308	22.0%	15	11.1%		
Never	552	3308	16.5%	39	28.9%		
19. How would you estimate your exposure during your railroad career to ballast dust?							
Extreme	554			25	18.5%		
Heavy	1054			33	24.4%		
Moderate	1233			50	37.0%		
Light	450			26	19.3%		

16. Have you ever operated a spiker gun since you started working for the railroad?							
Yes	2229	3416	64.1%	126	93.3%	45.848	<0.001
29. Have you smoked at least 100 cigarettes in your entire life?							
Yes	1354	3073	43.3%	63	46.7%	0.356	0.551
Region*				127	100%		
Northeast	1025			31	24.4%		
Southeast	546			15	11.8%		
Central / Midwest	1700			44	34.6%		
Western	711			37	29.1%		

	Survey Respondents			Non-Respondents				
	N	**Mean**	**SD**	**N**	Mean	SD	**t-test**	**p**
Age	3925	42.7	10.6	135	45.5	11.6	3.008	0.003

Notes: 70 Survey respondents were excluded from the comparisons for age for reporting that they were over the age of 75. Age values for active members >75 were assumed to be typographical errors.

Total N respondents = total number of survey respondents answering any question on that page of survey

SD=standard deviation, a measure of the distribution of answers to questions about age and years on the job. About 95% of all the answers are within +/- 2 standard deviations.

* “Region of the country where you work” for survey respondents; region of the country where one lives for non-respondents.