

New Electric-Shock Job Exposure Matrix

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Background To evaluate a consistent association between jobs in “electric” occupations and amyotrophic lateral sclerosis (ALS), a comprehensive job exposure matrix (JEM) that includes electric shocks and magnetic fields (MF) is needed.

Methods We used incident electric shocks and electrocutions from two available data sources along with expert judgment to create a JEM that was integrated into an existing MF JEM. The final JEM contained ordinal electric-shock exposure assignments for 501 job titles.

Results Main occupational groups experiencing the electric shocks were precision production, craft, and repair occupations. Specific jobs with the highest proportion of shocks per 100,000 workers were: electrical apprentices (99.7), mechanic and repairer helpers (74.0), hoist and winch operators (63.3), and electrical power installers (52.4). Examples of job titles with low electric-shock exposures were administrative support occupations, data-key entry operators, and waiters and waitresses.

Conclusions Combining publicly available data with an expert panel is a viable method to construct an electric-shock MF JEM. This JEM will allow an evaluation of association between electric shocks and neurodegenerative diseases. *Am. J. Ind. Med.* 55:232–240, 2012. © 2011 Wiley Periodicals, Inc.

KEY WORDS: electric shocks; electrocutions; expert panel assessment; job exposure matrix

INTRODUCTION

A consistent association between jobs in “electric” occupations and amyotrophic lateral sclerosis (ALS) has been reported [Kheifets et al., 2008]. However, it is unclear which physical factor, if any, in the electrical environment of these jobs is important; electric shocks,

electric fields, and magnetic fields (MF) have all been proposed as potential causative agents. Exposures to all three factors are highly correlated in the well-studied electric utilities. Therefore, identification of a relationship between ALS and one or more of these electrical factors will require methodology for separating these exposures for occupations, both inside and outside the electric utility industry. The methodology described in this study produces a measure of occupational electric-shock exposure that is independent of MF exposure, allowing for integration of both exposures into one job exposure matrix (JEM).

Numerous studies on occupational electromagnetic fields (EMF) and neurodegenerative disease, including several for ALS, have been published over the past 20 years. A detailed review is published by Kheifets et al., [2008]. The main epidemiologic limitations of these studies have been twofold: (1) exposure misclassification based on job titles alone and/or limited EMF exposure data and (2) potential confounding due to other exposures, such as electric shocks. Moreover, electric-shock exposures have only been

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examined for occupations within select industries, such as electric utility, railway, and construction.

Two elements affecting capture of workplace shock events are severity and perception. Shock severity depends on voltage level, the current passing through a person's body, the body's resistance, the path through the body, the shock duration, and the source frequency [Capelli-Schellpfeffer and Lee, 1999; El-Sharkawi, 2005]. The physiological effects of shocks are determined by the nature of electric current and electrical properties of the tissue, which may be altered by tissue damage, sweat and personal protective equipment [Conrad, 1939]. Federal data sources will likely capture the most severe, primary shock cases while mild-to-moderate accidents might not get recorded; since it is unlikely a worker would report an event causing pain but not direct physical harm. Alternating current passing through the body at 60 Hz, may be imperceptible at 1 mA, noticeable (>1 mA), produce "not let go" response (16 mA), produce respiratory muscle paralysis (20 mA) or cardiac arrest (2 amps) [NIOSH, 1998]. Conceivably, the lower the perceived physical effects, the less likely a worker would report an event. Presently, only two studies have examined microshocks in workers [Fordyce et al., 2007; Ahmed and Rowland, 2009], in one analysis of 102 linemen, body mass index and painful sensations were inversely related [Ahmed and Rowland, 2009]. Given the ranges in severity and shock perception, captured events would underestimate the full extent of electric shocks in an occupation, but could serve as sentinel events, allowing for relative ranking.

To date, data on occupational electric shocks remain fragmented; most articles using the U.S. Bureau of Labor Statistics (BLS) electrical injury, illnesses and fatalities data have focused either on industry or solely on occupational fatalities [Taylor, 2002; Cawley, 2003; Cawley and Homce, 2008]. Between 1992 and 1998, nearly 35,000 workers sustained lost work time or died due to electrical shocks or burn injuries [Cawley, 2003]. While these are rare occurrences, their potential to cause severe injury is high. Overall, 44% electrical fatalities occurred in the construction industry; many because of contact with power lines [Cawley, 2003]. Aside from electricians, nearly 25% of construction industry fatalities were among construction laborers, carpenters, and painters [McCann et al., 2003]. More recently, Lombardi et al. [2009] found workers in services, manufacturing, and retail had the largest number of worker compensation electrical injuries over a 1-year period. When Cawley and Homce [2008] examined 1992–2002 Census of Fatal Occupational Injuries data, they noted occupations, such as truck drivers, farmers, and groundskeepers, as sustaining fatal electrical injuries. These data underscore the need for full exploration of occupations outside of utility industries likely to experience electric shocks. As a result, nationally

available fatal and non-fatal data are important to ensure broad coverage of occupations representative of many industries.

Job exposure matrices are tools used to classify exposures for occupations based on "what is generally known about exposures with particular tasks in particular industries" [Armstrong et al., 1992]. The purpose of our JEM is to develop and assign electric-shock exposure categories to job titles in the absence of direct electric shocks measures for individual workers [Goldberg et al., 1993]. To optimize the performance of any JEM used to evaluate the possible role of a factor in the development of neurodegenerative diseases, capturing contrasts in exposure is paramount [Goldberg et al., 1993].

Several factors contribute to the potential for electric-shock exposure. The factors include: types of energy sources, the physical work environment, availability of training, and safeguards [Hintz, 2005]. Injury and fatality data can be used to determine electric-shock exposure potential. If each factor was known for each occupation, then presumably one could assign electric-shock exposure potential based solely on statistical models using a set of outlined assumptions. However, given the number of unquantifiable factors in the work environment, the use of expert panel for exposure categorization of occupations is necessary, and more so because exposure is not directly measurable and no occupational hygiene standard is available. Consequently, we combine expert panel assessment with available U.S. data on occupational electric shocks and electrocutions, to develop probability of electric shocks in different occupations. We then incorporate these into an existing MF JEM [Bowman et al., 2007].

MATERIALS AND METHODS

We used existing data on incident electric shocks and electrocutions from two sources: the BLS Survey of Occupational Injuries and Illnesses (BLS SOII) and the Occupational Safety and Health Administration Integrated Management Information System (OSHA IMIS).

The BLS SOII provides estimates of the number and rates of workplace injuries and illnesses in the U.S. BLS solicits survey data from employers having 11 employees or more in agricultural production, and from all employers in agricultural services, forestry, and fishing; oil and gas extraction; construction; manufacturing; transportation and public utilities; wholesale trade; retail trade; finance, insurance, and real estate; and services (except private households). To assure consistent occupational coding with U.S. mortality data that we plan to use and the most relevant time period following implementation of the OSHA Electrical Standard CFR 1910, Subpart S, we requested from BLS all non-fatal injuries for 1992–1999 with nature of injury code 093x (electrocutions, electric

shocks) by occupation. BLS SOII represented 22,858 workers involved in non-fatal electric shocks among 306 job titles, that is, 3-digit 1990 Bureau of Census (BOC) codes. Where occupations were reported and the number of events not reported for a given year, we assumed the minimum reportable number of four shock incidents per year. Then, we summed number of electric shocks across years to obtain total number of incidents in each detailed occupation (n_{BLS}).

We also accessed OSHA IMIS, an online accident investigation database that is used to manage resources within state agencies. OSHA state offices investigate and complete standardized forms (OSHA-170) for selected events, for example, fatalities, serious injuries, explosions, and those featured in media or newspapers [US DOL, 2009]. These forms are subsequently logged into IMIS. We extracted 2,470 records representing 155 occupations and 367 industries, primarily fatal occupational data, from OSHA IMIS online database using the keyword “electric” for the period of January 1, 1992 to December 31, 1999. For the records extracted from the specified time period, OSHA classified industries using the 1987 Standard Industrial Classification system [US OMB, 1987]. We assumed that electrocutions or fatal electrical events are reasonable indicators of a potential for electric shocks within an occupation. Each record was evaluated to retain electric shock events only, to remove duplicate entries and to assign BOC code the given occupational title. We summed the number of electric shocks and electrocutions reported in OSHA IMIS across years by job titles (n_{OSHA}).

To assess the proportion of workers affected, we used both the Current Population Survey (CPS) and the 1990 Decennial Census (DC) for the number of workers. CPS is a monthly survey of households conducted by the BOC for the BLS [US Census Bureau, 2009] and it provides a comprehensive body of data on the labor force, employment, unemployment, and persons not in the labor force. Persons captured in the labor force include all non-institutional civilian people age 16 years and older. We obtained the number of workers for each 3-digit 1990 BOC code in 1992–1999 CPS using the online data mining and extraction software, DataFerrett, N_{CPS} [US Census Bureau, 2009]. We used sample-based occupation data from the 1990 Equal Employment Opportunity (EEO) File [US Census Bureau, 1990], which was tabulated from civilian labor force data collected in the 1990 DC. The 1990 DC EEO file contained cross-tabulations for 512 job titles by sex, race, and Hispanic origin for the U.S. We extracted estimates by sex, summing female and male workers for each 3-digit 1990 BOC code to create N_{DC} .

While we have data on the incident cases of electrocution and electric shocks, we have imprecise information on the occupational population at risk. That is why we have defined the estimates as proportions, constructed for

the purpose of evaluating occupational groups at risk of electric shock for the specified time period. To create number of shocked or electrocuted, we assumed the BLS non-fatal electric shock (n_{BLS}) and OSHA IMIS electrocution data (n_{OSHA}) were independent sources and summed by occupation. Using two different worker population estimates, we created two proportions of injury by each occupation which are, $p_{CPS} = (n_{BLS} + n_{OSHA})/N_{CPS}$ and $p_{DC} = [(n_{BLS} + n_{OSHA})/8]N_{DC}$ (injury data were averaged to represent 1 year for the DC proportion).

Proportion distributions (p_{CPS} and p_{DC}) were positively skewed (mean > median). We assigned three interim exposure categories based on tertile cutoff points. Results using different population estimates (CPS and DC proportions) were compared.

For final exposure assignment, we assembled an expert panel with diverse backgrounds and with direct relevant and practical experience consisting of an industrial hygienist, a physicist with research experience with electric shocks and an electrical engineer with electric utility experience and research into MF and shocks. The expert panelists defined electric shock and devised a method for assignment of high exposure, to retain specificity. Clearly, the general population experiences electric shocks, as there about 1,000 deaths due to electric shocks occur each year [Spies and Trohman, 2006]. However, in some occupations electric shocks will occur at a higher rate than those experienced by the general population. Panelists agreed painful events may occur at low currents, but that at levels or exceeding 3 mA an electric shock could likely result in a reportable injury [OSHA, 1991]. As a group, the experts assessed 322 job titles for the electric-shock exposure, based on a proportion exposed along with consideration for potential electrical hazards and knowledge about jobs, according to the following three definitions: (1) low exposure (L) being very unlikely that exposure occurred among workers with this job title; (2) medium exposure (M) being a possibility that some of the workers with this job title had electric-shock exposure (but the probability is fairly low); and (3) high exposure (H) with at least a proportion of the workers with this job title experienced electric shocks. Expert panelists considered workplace factors such as those affecting skin impedance, engineered protection, and personal protection (Table I). In addition, expert panelists independently reviewed exposure assignments for 179 occupations not captured by the data sources. The final assignment of these jobs was based on the exposure agreement of at least two experts. For summary descriptive analysis, occupations were categorized into 13 major occupational groups defined in the 1990 BOC (Table II).

We used the geometric mean of MF time-weighted averages (TWA) in the MF JEM by converting 1980 BOC codes (Appendix D) to 1990 BOC codes. We grouped

TABLE I. Workplace Conditions Contributing to Electric Shocks

Types of energy sources
60 Hz power
Batteries
Environment
Dry and wet or damp conditions
Hot environments affecting perspiration
Un-insulated conductors present
Safeguards
Resistors, capacitors
Insulation
Grounding
Electrical training
None, some or skilled
Work practices
Lock out/tag out procedure
Safety watchers or observers
Availability of protective measures
Fiberglass live line tools
Overshoe footwear
Non-conductive head protection, insulating blankets or covers, gloves

occupations into three MF exposure categories using the following cut-points L ($\leq 0.1 \mu\text{T}$), M (0.1–0.3 μT), and H ($\geq 0.3 \mu\text{T}$) [Bowman et al., 2007].

RESULTS

Exposure Incidents

By occupational group

Main occupational groups with the highest number of electric shocks and electrocutions were precision

production, craft, and repair occupations, followed by service occupations and machine operators, assemblers, and inspectors.

By job title

Electric shock and electrocution data were available for 322 job titles. Most occupations (83%) were exposed to on average less than 10 shocks per year, 16% of occupations had greater than 10 and less than 100 shocks per year, and 1% of occupations were exposed to at least 100 shocks per year. Occupations with the most frequent number of electric shocks and electrocutions were: electricians, cooks, janitors and cleaners, construction laborers, and non-construction laborers.

Exposure Proportions

By occupational group

Occupational groups such as sales occupations, professional specialty occupations, and executive, administrative, and managerial occupations had consistently low electric-shock exposure, while other groups had more variability in electric-shock exposure.

By job title

The highest proportion of electric shocks and electrocutions per 100,000 workers per year included: electrician apprentices (99.7), mechanic and repairer helpers (74.0), hoist and winch operators (63.3), and electrical power installers (52.4). We obtained high agreement between proportion tertiles using CPS and BOC (Kappa statistic = 0.86, $P < 0.0001$). Of 30 occupations not in

TABLE II. Distribution of Job Titles Within Occupational Groups by Electric-Shock Exposure Based on Data and Expert Panel

Occupational group	Job titles			
	No.	H (%)	M (%)	L (%)
Administrative Support Occupations, Including Clerical	55	3 (5.4)	8 (14.5)	44 (80)
Executive, Administrative, and Managerial Occupations	28	1 (3.6)	3 (10.7)	24 (85.7)
Farming, Forestry, and Fishing Occupations	19	3 (15.8)	5 (26.3)	11 (57.9)
Handlers, Equipment Cleaners, Helpers, and Laborers	16	8 (50)	4 (25)	4 (25)
Machine Operators, Assemblers, and Inspectors	61	28 (45.9)	27 (44.3)	6 (9.8)
Precision Production, Craft, and Repair Occupations	102	41 (40.2)	32 (31.4)	29 (28.4)
Private Household Occupations	5	0 (0.0)	0 (0.0)	5 (100)
Professional Specialty Occupations	106	0 (0.0)	8 (7.5)	98 (92.5)
Protective Service Occupations	11	1 (9.1)	0 (0.0)	10 (90.9)
Sales Occupations	23	0 (0.0)	2 (8.7)	21 (91.3)
Service Occupations, Except Protective, and Household	29	6 (20.7)	8 (27.6)	15 (51.7)
Technicians and Related Support Occupations	22	2 (9.1)	6 (27.3)	14 (63.6)
Transportation and Material Moving Occupations	24	10 (41.7)	7 (29.2)	7 (29.2)

agreement, 9 were in the machine operators, assemblers, and inspectors group, 6 were in precision production, craft, and repair occupations group, and 3 were in administrative support occupations, including clerical group. The expert panelist reviewed and assigned these 30 occupations an electric-shock exposure.

By expert panel

Of the possible 501 classifiable BOC occupational titles, 179 occupations were not represented in BLS SOII and OSHA IMIS data. Of those without electric-shocks information, over 40% (78/179) were in professional specialty occupations, followed by 10.6% (19/179) in administrative support occupations, including clerical, 9.0% (16/179) in precision production, craft, and repair occupations and 7.8% (14/179) in executive, administrative, and managerial occupations.

The overall distribution for the 501 occupations assigned probability electric-shock exposure was: 57% L, 22% M, and 21% H. High electric-shock exposure assignments were assigned mainly in four summary occupational groups: (1) handlers, equipment cleaners, helpers, and laborers; (2) machine operators, assemblers, and inspectors; (3) transportation and material moving occupations; and (4) precision production, craft, and repair occupations (Table II). High electric-shock exposure included occupations, such as electrical and electronic technicians, cooks, and construction laborers. Occupations assigned to the medium electric-shock exposure included: groundskeepers and gardeners, production inspectors, printing press operators, bus, truck, and engine mechanics. As expected, low electric-shock exposures were among the broadly defined occupational groups: professional specialty, sales, and protective service occupations. Examples of job titles with low electric-shock exposures were automobile mechanics,

registered nurses, administrative support occupations, data-key entry operators, and waiters and waitresses.

Comparison of electric-shock to magnetic-field exposure

Most frequent occupations highly exposed to both electric shocks and MF were from the precision, craft, and repair occupations. Occupations such as dressmakers and textile sewing machine operators were not exposed to electric shocks but were exposed to MF (Table III). With the expert assignment, shocks-MF exposure contrast resulted in 66 occupations with high exposure to electric shocks and not to MF (Table IV), including construction laborers, parking lot attendants, elevator installers and repairers, and roofers. Occupations having high MF exposure and low or medium electric-shock exposure included dressmakers, tailors, and electrical and electronic equipment assemblers. With expert panel judgment, dental hygienists, camera, watch, and musical instrument repairers, and metal patternmakers and model makers were assessed to have low electric-shock exposure.

DISCUSSION

Our electric-shock classification is the first to capture these relatively low prevalence, but potentially important etiologically, workplace exposures in a systematic manner. This electric-shock JEM covers a wide range of occupations reflecting those held by many workers in the general population. Using data alone would have resulted in fewer jobs with electric-shock exposure assignments, but with the best available technique, that is, data combined with expert judgment, we added 179 jobs to the matrix. A combination of injury data and expert panel assignment for 501 occupations resulted in several jobs not typically

TABLE III. Electric-Shock and Magnetic-Field Exposure Assignments for Selected Job Titles

1990 BOC code	Job title	Electric-shock exposure	Magnetic-field exposure
575	Electricians	H	H
783	Welders and cutters	H	H
676	Pattern makers, layout workers, and cutters	M	H
538	Office machine repairers	M	H
869	Construction laborers	H	L
436	Cooks	H	M
804	Truck drivers	M	M
449	Maids and housemen	M	M
666	Dressmakers	L	H
744	Textile sewing machine operators	L	H
313	Secretaries	L	M
095	Registered nurses	L	L
447	Nursing aides, orderlies, and attendants	L	L

TABLE IV. Exposure Contrast Frequencies for All Job Titles

Electric shock	Magnetic field	
	Yes ($\geq 0.3 \mu\text{T}$)	No ($< 0.3 \mu\text{T}$)
High (yes)	18	66
Medium/Low (no)	26	313

Totals do not equal to 501 as there was no MF exposure available for 78 1990 BOC job titles.

considered as highly exposed to electric shocks, for example, janitors and cleaners and cooks, more likely to be found in services industries rather than utility or construction industries.

Occupational Rates of Electric Shocks and Electrocutions

Previous literature and regulations have included information about electric-shock rates by industry [US DOL, 1990; Cawley and Homce, 2008], but literature on occupational electric-shock rates is scarce [US DOL, 1990; Taylor et al., 2002; Bracken et al., 2009]. A feasibility assessment of the 1990 OSHA Electrical Safety-related Work Practices Standard for General Industry [US DOL, 1990], injury incidence rates (per 100,000 workers), derived from previously unpublished data, aided OSHA to determine which workers were at risk of injury and most in need of electrical training, based on actual and potential electric-shock risks. OSHA determined a high-level training was required for electrical and machine assemblers (93.3) and stationary engineers (42.6). For non-routine work on live electrical parts, OSHA determined an average level training was required for home appliance and power tool repairers (10.1), and gas and petroleum operators (4.60). Finally, OSHA determined workers that needed minimal level training included welders and cutters (10.1), painters and paperhangers, and electrical engineers (1.0). In an analysis of 1992–1999 U.S. Census of Fatal Occupational Injuries, Taylor et al. found occupational electrocution rates ranged from 0.71 to 15.91 per 100,000 worker years [Taylor, 2002]. The highest electrical fatality rates were among electrical power installers (15.9), earth drillers (8.75), and electrician apprentices (8.25). Within the electric utility industry, Bracken et al. [2009] published electrical injury probabilities (per 100,000 workers) for a few grouped occupations, such as electrical power installers (302), welders and cutters (355), and supervisors (12.8). The highest proportions calculated for the electric-shock JEM seemed comparable to rates captured in the literature; however, we found several “helper” occupations with high proportions of electric shocks.

Limitations of Occupational Data

Due to the nature of the collected information, only the most severe accidents are likely to be captured. For example, OSHA tends to investigate incidents that include fatalities and events where three or more employees are hospitalized [Froines et al., 1989]. Upon examination of 1999 data, BLS non-fatal injury and illness undercounting was estimated between 33% and 69% by Leigh et al. [2004]. Thus, the number of accidents captured is likely to be an underestimate, but this will not have a major impact on our JEM. Capturing the full spectrum of electric-shock injuries is a well-recognized challenge in occupational health and remains as an important caveat of the developed electric-shock JEM.

More problematic is that these data may not be entirely representative of workforce electrical accidents: data may be skewed towards certain occupations and industries, excluding self-employed, private households, and federal governments and agencies [Ruser, 2008]. BLS data are from a two-stage design survey; first, randomly selecting from private sector establishments, and, second, selecting cases involving lost work time [US BLS, 2010], which would exclude small employers.

To capture expansive indicators of electric shocks, we combined both BLS SOII and OSHA IMIS data, despite their distinctly different methodology, that is, survey estimates and actual count data, respectively. We could have included an indication for injury severity by weighting fatalities, using days away from work or considering lifetime risk [Fosbroke et al., 1997]. However, we created the electric-shock JEM for application in neurodegenerative diseases study, for which non-fatal electric shocks may be equally, if not more relevant. While some researchers have observed progressive ALS occurring more among those electrical injuries of < 300 V [Abhinav et al., 2006], there are several case reports which describe onset of ALS following severe electrical injury [Zoccolella et al., 2008; Huynh et al., 2010]. The temporality between injury and onset of disease makes electric shocks a plausible risk factor [Panse, 1975], but which type of electric shocks is less clear. Both data sources reflect electric shocks that result in lost time, and, as expected, certain occupations are not captured by these data sources.

Determination of appropriate worker population denominators has continued to be problematic for construction of national occupational rates [Ruser, 1998; Richardson et al., 2004] and we were faced with the same challenge. To address this we used to distinct data sources, which resulted in similar assignments for most occupations. Further, few differences due to population denominators were resolved by expert panel.

Regardless, the injury and illness data for each occupation were solely one factor in assessment of exposure,

which also included consideration of the workplace environment. Limitations aside, national occupational injury, and illness data shed light on occupations outside the well-studied electric utility, construction and railway industries, experiencing electric shocks and electrocutions.

Performance of the Electric-Shock JEM

JEMs are best suited to capture exposure prevalence greater than 10%, with dichotomous categories non-differential biases will be introduced as the specificity decreases [Bouyer, 1993]. In 1998, the injury rate for non-fatal electric shocks treated in emergency departments was 0.006 incidents per 100 full-time equivalent worker, representing 0.2% of total estimates [CDC, 2009]. Overall the expected shock prevalence is low; consequently the positive predictive value will be low measured with imperfect specificity. Despite this, the electric-shock JEM may have sufficiently high specificity, decrease false positives, and, thus, lead to less misclassification in future epidemiologic studies [Greenland and Lash, 2008]. Since data presented and opinion of experts resulted in previously unobserved findings, repetition of the JEM methodology with new objective data, such as worker's compensation may be advisable. However, these data may be limited given the scarcity of U.S. data sources and rarity of the exposure, for example, 1.2% due to electric shocks in an analysis of 11,410 electrical worker compensation claims received by state of Washington between 1998 and 2001 [Connon et al., 2003]. In addition, international comparisons can further enhance this JEM.

Unfortunately, there is no "gold standard" to quantify the specificity, nor is the exposure directly measurable, therefore electric-shock exposure assignments are the best determination, given the data.

Lack of industry or additional job task information within the JEM may limit its specificity. Using the MF JEM, authors from a recent study evaluated inclusion of detailed information about jobs, such as tasks and time spent working near electrical sources, affected MF categories; they noted a 3% increase in the number of jobs exposed to 0.3 μT or greater as compared to a JEM [Coble et al., 2009]. Future work incorporating industry or job task information may improve specificity of the MF exposure assessment component, in absence of source information and direct measurements. Though including industry will have a problem of its own, as it could result in unreliable estimates and consequently a need for stronger assumptions.

Due to sparse data and lack of solid estimates of numbers employed in specific occupations, our electric-shock exposure categorization is somewhat uncertain, especially for specific occupations, such as office machine repairers, vehicle washers and equipment cleaners, and non-nursing

health-aides. We attempted to reduce this uncertainty, by using expert assessment, which incorporated employment data and workplace factors. Potential exposure to electric shocks in a workplace involves a number of variables, of which injury data are one factor [Hintz, 2005]. Expert assessment, used in many fields including engineering and occupational hygiene, is the best manner to create informed exposure assignments. Errors in occupational coding of injury data could lead to exposure misclassification. For example, relying on data alone chief executive officers would be highly exposed to electric shocks, but with expert panel assessment are reassigned to medium exposed. Hence, examination by expert panelists would minimize these problems, assigning an appropriate exposure.

Strengths of the Electric-Shock JEM

The main strength of this work is the categorization of electric-shock exposures among non-utility occupations, previously not evaluated. These data have never been systematically compiled into a usable tool for population studies. Furthermore, we report occupations not classically recognized as exposed to electrical hazards. The present work illuminates the importance of tracking actual frequency of occupational injuries and combining expert panel opinion for exposure probability. Our approach may be reproduced for other workplace exposures that are not directly measured, where no data are available and for which occupational exposure limits do not exist.

The degree of certainty about the proportion of electric shocks within each occupation or relative rates within each occupation could be elicited to create a more quantified JEM. Actual quantification of each evaluator's degree of certainty has been done in a limited number of health-based studies. The field of occupational hygiene has only recently started incorporating Bayesian methods into the expert judgment arena [Ramachandran et al., 2003]. The use of expert subject matter knowledge to assign electric-shock exposure offsets data limitations and allows for quantification of certainty during the creation of the JEM. In the future, the electric-shocks MF JEM can be enhanced by including the experts' degree of certainty to the assigned exposures and further incorporating this information in epidemiologic analyses.

CONCLUSION

Despite the numerous limitations of using publicly available data, construction of an electric-shock JEM is feasible. Combining such data with expert panel judgment results in an approach aimed at incorporating factors not reflected in injury data. The effort yielded a number of occupations with exposure only to electric shocks or only to MF needed for epidemiologic analyses capable of

disentanglement of the potential associations between shocks, MF, and neurodegenerative disease.

The largest number of electric shocks occurred among precision production, craft, and repair occupations. Occupations having the highest number of electric shocks not previously identified by the literature included: cooks, janitors and cleaners, and miscellaneous laborers. Prevention efforts could be directed towards these worker groups including hazard education and training and/or workplace safety improvements. Future work should also account for uncertainties in the data sources and exposure assessment.

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