20-Year Trends in Reported Work-Related Injury and Illness among Union Carpenters in Washington State

By

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Abstract

Background: The burden of work-related injuries and illnesses in the United States is great and is accompanied by substantial direct and indirect costs. Construction workers are at higher risk of work-related fatality, injury, and illness than most other working populations.

Materials and Methods: By combining administrative data sources, we identified a dynamic cohort of union carpenters who worked in Washington State from 1989 to 2008, hours worked, and their workers' compensation claims; the data were linked on an individual basis using blinded identifiers. We calculated incidence density rates for all claims, claims that were considered Occupational Health and Safety Administration (OSHA)-recordable, and claims that involved paid lost time (PLT); the latter were further stratified by the injury mechanism groupings, "Struck by object," "Fall to a lower level," and "Overexertion with lifting." Poisson regression was used to assess risk by categories of age, sex, union tenure, and calendar time.

Results: The cohort of 26,591 carpenters worked 192 million hours over the 20-year period. Significant declines of *reported* claims occurred in all categories over the observed period with the greatest decline in "Fall to a lower level" claims that involved PLT. For all claim categories, younger workers, female workers, and workers with less union tenure were at increased risk of reporting injury when adjusting for other covariates. Comparisons of incidence rates from the cohort to Bureau of Labor Statistics (BLS) incidence rates for the construction industry revealed large absolute discrepancies (higher rates in the cohort) that converged as time proceeded.

Conclusions: Declines observed in injury incidence rates may reflect the combination effect of improved construction workplace safety and changes in reporting practices, among other factors. Though the absolute differences between the cohort's incidence rates and BLS incidence rates declined significantly overtime, the relative differences between the two remained fairly stable.

Systematic Review: Does the Bureau of Labor Statistics Survey of Occupational Injuries and Illnesses Accurately Capture Work-Related Musculoskeletal Disorders?

Introduction

Musculoskeletal disorders (MSD) may arise from acute injury, overuse, repetitive trauma, or a combination of the three. In their review of the epidemiology of work-related MSDs, Punnett and Wegman describe MSDs as “a wide range of inflammatory and degenerative conditions affecting the muscles, tendons, ligaments, joints, peripheral nerves, and supporting blood vessels” (Punnett and Wegman 2004). Accordingly, work-related MSDs encompass common clinical conditions such as tendon inflammation disorders, nerve compression disorders, and osteoarthritis, as well as less standardized conditions, such as myalgia, lower back pain, and other regional pain syndromes without distinct pathology (Punnett and Wegman 2004). Most commonly involved regions include the lower back, neck, shoulder, forearm, and hand.

The effects of work-related MSDs are vast. Work-related MSDs pose significant social and economic costs to workers and their families (Morse, Dillon et al. 1998; Dembe 2001) across all U.S. industries (US Department of Labor, Bureau of Labor Statistics 2010). In a cross-sectional survey of 3,200 working-aged individuals in Connecticut conducted through random digit dialing, workers identified as having suffered a work-related, upper extremity MSD were more likely to have been divorced in the previous 12 months, to have moved for financial reasons, to have lost a home due to financial reasons, or to have lost health insurance coverage due to financial constraints. Furthermore, individuals identified as having suffered a work-related, upper extremity MSD scored worse on activities of daily living (ADL) scales. Odds ratios ranged from 8.2 to 35.2 for reporting of “a lot of” or “some” difficulty with carrying out ADLs between cases and controls. Participants also reported having increased difficulty with physical tasks such as opening jars, caring for a small child, and completing household chores (Morse, Dillon et al. 1998).

Beyond the physical limitations associated with work-related MSDs, individuals may experience other maladaptive responses to their conditions and the associated stigma, such as drug abuse, sleep disturbances, sexual problems, depression, and lowered self-esteem (Dembe 2001). Such responses are not limited to the individual worker, but may include the worker's family and coworkers (Dembe 2001).

In addition to the effects of work-related MSDs on the individual, work-related MSDs are responsible for a substantial cost burden on the national scale (Leigh, Markowitz et al. 1997). MSDs represent up to a third of the total costs incurred for occupational disorders in the United States (Leigh, Waehrer et al. 2006), and they contribute significantly to loss of productivity in the workplace (Kennedy, Amick et al. 2010). Furthermore, because of cost-shifting , work-related MSDs may pose a significant economic burden to other payers of workers' health care, not just workers' compensation (Lipscomb, Dement et al. 2009).

Characteristics of work-related MSDs create difficulty in establishing an MSD as, in fact, work related (Blessman 1991). These qualities include: (1) long latencies between exposure and disease occurrence, which is particularly complex when workers have multiple employers over time; (2) multiple causes of disease, including those that are not occupational; (3) difficulty in associating occupational exposures with employment experience; and (4) difficulty in quantifying relevant occupational exposures (Blessman 1991). Consequently, work-related MSDs may be less likely to be captured by national surveillance than acute injuries in which there is a clear link between exposure and outcome (Punnett and Wegman 2004).

In the United States, the Bureau of Labor Statistics' (BLS) Survey of Occupational Injuries and Illnesses (SOII) serves as the primary national surveillance system that tracks work-related injuries and illnesses. Numerous reports in the literature question the reliability of BLS data in capturing work-related injuries and illnesses, including work-related MSDs (Azaroff, Levenstein et al. 2002; Punnett and Wegman 2004; Rosenman, Kalush et al. 2006; Friedman and Forst 2007). Without reliable information, policy decisions derived from this BLS data may not be in the best interest of workers, particularly workers whose jobs place them at increased risk of developing a work-related MSD.

The SOII conducted by the BLS consists of a probability sample of employers' Occupational Safety and Health Administration (OSHA) logs. OSHA defines recordable injuries and illnesses as those that result in any of the following: loss of consciousness, time away from work beyond the day of injury, work restrictions or transfer to another job, medical treatment beyond first aid, or diagnosis of a significant injury or illness by a physician or other licensed health care professional (US Department of Labor, Occupational Safety & Health Administration 2001). From these criteria, it is clear that a strain or sprain that does not result in documented work restriction or transfer and is managed with over the counter anti-inflammatory medications may not be considered a recordable injury (Welch and Hunting 2003). However, the compounding effect of multiple sprains or strains to the same body part over the course of one's employment may amount to a disabling, work-related MSD, which still would not be captured by BLS.

Another limitation is that the SOII does not include workers of federal, state, and local government agencies, household workers, the self-employed, workers of employers with fewer than 11 employees (US Department of Labor, Occupational Safety & Health Administration

2001). These populations that are excluded from the SOII amount to a considerable portion of the US workforce. Consequently, in addition to OSHA's definition as to what is considered a recordable injury or condition, the scope of surveyed populations in the SOII limits BLS's ability to capture work-related MSDs among all workers, particularly those who are contingently employed by small employers.

Previous studies have investigated and/or documented BLS undercounting of work-related injuries and illness in various sub-populations, during various time-periods, using different comparison data sets, and using various methods of statistical analysis. Estimates of under-counting vary. The goal of this systematic review is to identify and review the existing literature that specifically documents the BLS undercount of work-related MSDs. Variation in research methods across the literature will be explored to help us understand the heterogeneity of reported estimates.

Methods

The question of interest, "Does the BLS accurately capture work-related MSDs?" was one that was most appropriately addressed through review of observational studies. In this review, we are not evaluating an intervention, but characterizing the accuracy of national surveillance. We did not follow methods for conducting and reporting systematic reviews of randomized controlled trials of clinical problems or issues. Additionally, methods used in meta-analysis of observational studies were not appropriate for this aim because studies that assess BLS surveillance may not be strictly observational in nature. For this review, we used a combination of sources to establish our approach (Stroup, Berlin et al. 2000; German, Lee et al. 2001; Kennedy, Amick et al. 2010). Our aim was to provide clarity to our process such that others could benefit from the scope of this review.

Outcomes of Interest

In developing the search strategy and criteria for this review, we were interested in the work-related MSDs captured by the BLS compared to the work-related MSDs captured by other sources. We defined work-related MSDs in accordance with Punnett and Wegman's definition as any inflammatory or degenerative conditions affecting the muscles, tendons, ligaments, joints, peripheral nerves, and supporting blood vessels. With this definition, we excluded traumatic fractures and amputations but included acute strains and sprains.

Inclusion/Exclusion Criteria

This systematic review was performed as a complement to ongoing research on workers' compensation claim rates among a cohort of union carpenters in Washington State, who perform a variety of construction industry tasks. Claim rates calculated from the cohort data were approximated to BLS units of exposure time to make comparisons to BLS data so that we might estimate BLS's capture of work-related injuries and illnesses. Because the years of interest in our Washington State carpenters study were 1989-2008, we wanted our systematic review to cover a similar period of interest. Therefore, our search was limited to articles published in the time period of January 1, 1989 to April 8, 2011.

A variety of study designs could be used to answer the question of whether or not BLS accurately captures work-related MSDs. Study designs included for this review were retrospective and prospective cohort studies, cross-sectional studies, and studies using capture-recapture methods. We also considered articles that did not specify a cohort or cross-sectional study design, but utilized existing, surveillance and administrative data sets, such as workers' compensation data, physician reports data, or emergency room data.

The BLS SOII is conducted through a probability sample of mandated employer OSHA logs (US Department of Labor, Occupational Safety & Health Administration 2001). The likelihood of the BLS statistics capturing the *true* burden of work-related MSDs is dependent on the disorders being recorded on OSHA logs. However, assessing the proportion of recorded injuries on OSHA logs for a specific employer does not translate into the accuracy of BLS data because BLS data is compiled from a probability sampling strategy which provides another source of potential error. As such, we excluded studies that used OSHA logs of specific employers as a substitute for BLS data when comparing to alternative surveillance sources.

Search Strategy

We performed a search of MEDLINE and Cochrane databases using the terms presented in **Table 1**. We constructed search categories in two broad areas: work setting terms and health outcome terms. The terms within each category were combined using Boolean “OR” operators. Then the two categories were combined using a Boolean “AND” operator. The search was limited to articles published in the time period of January 1, 1989 to April 8, 2011, the day we conducted our initial search. In addition to the MEDLINE and Cochrane database searches, we conducted hand searches of the references of retrieved articles that were to undergo full text review to identify relevant, non-indexed articles.

Title Review

The primary author conducted a title review to identify potential articles pertaining to measures of work-related MSDs compared to BLS data. In conducting our title review, we erred on the side of inclusion rather than exclusion so that we would be sensitive in detecting articles pertinent to our systematic review question.

The titles retrieved by the search were reviewed by the same single reviewer. As the question for the basis of this systematic review focuses on work-related MSDs, we excluded titles that did not concern work-related injury or illness. To make comparisons to BLS data, the study population must have been within the US. Given that surveillance of occupational injuries and illnesses is predicated on assessing populations rather than individuals, we excluded titles that denoted that the article did not endorse a population perspective. Hence, titles with terms "case series" or "case report" were excluded. We excluded titles that indicated that the article concerned work-related conditions exclusively in professional athletes and performing artists.

W excluded titles that indicated that the article was primarily concerned with etiology or natural history of disease, symptoms, or diagnosis of work-related MSDs. This excluded titles that denoted the article focused primarily on characterization of risk factors for work-related MSDs without measures of the occurrence of work-related MSDs.

Abstract Review

After title review, the reviewer read the remaining abstracts to assess the pertinence of the article to the question addressed in this review. Similar to the title exclusion criteria outlined above, we excluded articles whose abstracts suggested no concern of work-related conditions, a focus on non-US populations, lack of population perspective, a focus on professional athletes and performers as a sub-population, and a focus on the etiology, risk factors, and natural history of a disorder. Abstracts that failed to convey that a comparison was made to national surveillance data through the use of reference terms such as, "Bureau of Labor Statistics," "BLS," "Occupational Health and Safety Administration," "OSHA," "national surveillance," "undercount," or "under-report," were not considered for full text review. A full text review was conducted for the articles that remained after the title and abstract reviews by a single reviewer.

Full Text Review, Abstraction, and Evaluation

Articles that fit our above described inclusion and exclusions criteria underwent abstraction with an in depth consideration of findings, strengths, and limitations. Given the nature and specificity of our question, the reporting/evaluation systems used to explore clinical or etiological questions were not appropriate to the quality evaluation of the articles included in this review. After a review of traditional, randomized controlled trial reporting criteria (Begg, Cho et al. 1996), observational study criteria (von Elm, Altman et al. 2007), and guidelines for the evaluation of public health surveillance systems (German, Lee et al. 2001), we did not feel that the application of a quality evaluation instrument for the purpose of this systematic review would be as useful as an in-depth discussion of the findings, strengths, and limitations of the limited articles we included in our final review.

Results

Search Findings

A flow diagram of our search and identification of articles is presented in **Figure 1**. The literature search of MEDLINE database using the defined terms retrieved 2,584 titles. A review of the titles yielded 262 abstracts for review. Five articles were retrieved for full text review. A hand search of the references of the full-text reviewed articles produced an additional three titles that also underwent full-text review. The search of the Cochrane database using the defined terms retrieved 24 titles (3 Cochrane Reviews, 1 Other Review, 14 Articles, and 6 Economic Evaluations). After a title review, all of the articles from the Cochrane database were excluded. After full-text review of the 8 articles identified through our search of the MEDLINE and Cochrane databases and hand search of references, we excluded 6 articles for reasons outlined below.

Excluded Articles that Underwent Full Text Review (n=6)

In this section, we briefly describe the 6 articles that underwent full-text review and our rationale for excluding them from this review.

In 2001, Morse et al. reported on the use capture-recapture analysis to estimate the true incidence of work-related MSDs of the upper extremity (Morse, Dillon et al. 2001). Their population of interest was all workers in the state of Connecticut in the year 1995. They used Connecticut State workers' compensation insurance data and State of Connecticut Physician Occupational Disease Surveillance System (ODSS) data to carry out their analysis. Though they used two datasets to estimate the true frequency of work-related MSDs of the upper extremity, Morse et al. did not make comparisons to BLS data. As such, we did not include the report in this systematic review.

A cross-sectional survey of 1,598 Michigan workers diagnosed with neck, upper extremity, and low back work-related musculoskeletal disease was conducted from April to June 1996 (Rosenman, Gardiner et al. 2000). These workers were identified from their previous study of occupational disorders among of 30,000 Michigan workers (Biddle, Roberts et al. 1998). The research team identified demographic characteristics of the 1,598 Michigan workers as well as elucidated their reasons for not reporting to workers' compensation through telephone interview. However, no frequency statistics were calculated, nor were comparisons to BLS data made. For these reasons, the article was excluded.

For the year 1999, Leigh et al. created regression models to estimate the undercounting of non-fatal work-related injuries and illnesses by BLS (Leigh, Marcin et al. 2004). They calculated risks from the pooling of previous studies and used the results of the 1999 BLS SOII. Leigh et al. stratified their estimates by category of employer (government vs. private), but did not stratify by type of injury or illness. Overall, they reported that BLS missed a substantial fraction of non-fatal occupational injuries, with estimates that BLS missed 33-69% of all work-related injuries in the US working population. Yet, since this estimate was not stratified by type of injury or illness, we could not extrapolate the degree of under-reporting for work-related MSDs specifically; consequently, this article was excluded from our systematic review.

Work-related MSDs of the wrist and hand were studied in workers in 5 automotive plants from the years 1984 to 1987 (Nelson, Park et al. 1992). Incidence rates of cumulative trauma disorders of the hand and wrist were estimated from the workers' health insurance claims data and were compared to incidence rates of the OSHA logs maintained at each facility during the period of interest. Because health insurance claims were not necessarily work-related, only the first available claims of specified International Statistical Classification of Diseases and Related Health Problems (ICD-9) codes were considered cases to approximate work-relatedness. Prior research has determined the attributable fractions of work-relatedness of private medical insurance claims is reliable for the determination of work-related MSDs of the upper extremities (Park, Nelson et al. 1992). Work-related MSDs of the hand and wrist had incidence rates of 2.8 and 7.2 per 1,000 person years for OSHA logs and health insurance data, respectively. Despite these results, because the comparison was made to company-specific OSHA logs instead of BLS data, this article was excluded from our analysis.

Silverstein et al. examined a combination of pre-existing, administrative, and newly acquired surveillance sources in 8 departments at 4 U.S. automotive plants for the years 1986-1989 to assess prevalence, incidence, and risk factors associated with upper extremity MSDs among the workers (Silverstein, Stetson et al. 1997). They found that from the years 1986-1988, the OSHA log work-related MSD incidence rates were considerably lower than the incidence of work-related MSDs as determined by self-reported medical treatment for work-related injuries. Because comparisons were made against employer-specific OSHA logs, this article has relevance to our question but was excluded from our review.

In a case study of 110 packers at a manufacturing plant that produced a variety of children's products, Pransky et al. compared the number of cases of work-related MSDs they determined among packers to the number recorded on the OSHA log (Pransky, Snyder et al. 1999). They found that the OSHA logs captured only 5% of the cases they detected through a modified version of the musculoskeletal symptoms questionnaire developed by the National Institute of Occupational Safety and Health (NIOSH). However, like the Nelson et al. and Silverstein et al. studies, this study was excluded from the analysis because it made comparisons to company-specific OSHA logs.

Included Articles

The article abstractions of the two articles identified for inclusion in this systematic review are presented in **Table 2**.

In accomplishing their primary objective of analyzing the increasing trends of cumulative trauma disorders of the upper extremities (CTDUE), Brogmus et al. compared data on CTDUEs from Liberty Mutual Group Insurances workers' compensation claims to BLS data for the years 1984-1993 (Brogmus, Sorock et al. 1996). In their article, they asserted that Liberty Mutual Insurance was the largest writer of workers' compensation insurance in the United States since 1936 and insured approximately 10% of the private-carriers workers' compensation insurance business in the United States during the period of observation (Brogmus, Sorock et al. 1996). Cases in the Liberty Mutual Insurances claims data set were defined based on criteria presented in **Table 2**. There was no specification as to how they obtained their BLS data.

Using workers' compensation data alone it is not possible to identify the population at risk. As work-hour data were not available for all companies insured by Liberty Mutual Insurance, Brogmus et al. were unable to calculate incidence rates to make comparisons to BLS incidence rates. Instead, they assessed CTDUEs as a proportion of all claims submitted to Liberty Mutual Insurance and made comparisons to Disorders Associated with Repeated Trauma (DART) as a proportion of all injury and illness cases reported to BLS. For the years, 1984-1993, they found that DARTs as percentage of all injury and illness cases reported to the BLS were consistently higher than CTDUEs as a proportion of all claims submitted to Liberty Mutual Insurance. For both datasets, the proportion of work-related injuries of all claims/cases increased substantially over the period of interest. BLS's DARTs as percentage of all injuries and illness rose from approximately 0.6% in 1984 to 4.5% in 1993; Liberty Mutual Insurance's CTDUEs as a proportion of all claims rose from approximately 0.45% in 1984 to 3.4% in 1993.

There are important issues to consider in evaluating the results of this study. Despite the fact that the Brogmus et al. study was not limited to a geographic region within the US, their failure to define their population at risk limits the application of their results. Because the population at risk was not defined, we cannot evaluate if the companies insured by Liberty Mutual Insurance over the observed time period were representative of US industry overall. One would expect that workers' compensation insurers are incentivized to seek contracts from companies whose workers are at the lowest risk of occupational injury and illness. Because Liberty Mutual Insurance has remained profitable over a long duration, we might assume that workers insured by Liberty Mutual Insurance were at lower risk of work-related injury and illness than the general workforce. As a result, the calculated proportion of claims due to

CTDUEs by Liberty Mutual may be lower than proportion of all work-related injuries and illness due to CTDUEs for the general workforce.

Since the Liberty Mutual claims dataset was based on workers' compensation claims, it was subject to the same forces, such as burden of clinical findings required for a claim to be filed and workers' concern of reprisal for reporting, that characterize the accuracy of workers' compensation claims in determining the frequency of work-related injury and illness. It has been widely demonstrated that workers' compensation claims are not an accurate characterization of work-related injury and illness (Rosenman, Gardiner et al. 2000; Shannon and Lowe 2002).

Another consideration in evaluating the results of this study is that the Liberty Mutual Insurance claims dataset only captured work-related MSDs of the upper extremity, while the BLS repeated trauma disorder data captured work-related MSDs of the upper extremity and other areas of the body, including the back. Because the Liberty Mutual Insurance claims dataset had a narrower definition than the BLS dataset, naturally, fewer claims would be counted, and CTDUEs as a percentage of all claims filed would be smaller than DARTs as a percentage of all illnesses and injuries for BLS. We might expect the higher proportions in BLS may partially reflect the narrower definition of work-related MSDs by Liberty Mutual Insurance.

In the second abstracted manuscript, Morse et al. estimated annual *true* counts of work-related upper extremity MSDs using capture-recapture methods (Morse, Dillon et al. 2005). They used the electronic data records of the Connecticut Workers' Compensation (WC) First Report of Injury system and physicians' reports to the Connecticut Departments of Labor and Public Health Occupational Disease Surveillance System (ODSS) as the source surveillance systems to derive estimates for the counts of work-related upper extremity MSDs. They then used the capture-recapture estimates to make comparisons to BLS data over the years 1995 to

2001. Their results are summarized in **Figure 2**, where we present a graph of work-related upper extremity MSD counts obtained from WC, ODSS, and BLS as well as the estimates of the true number of work-related MSDs derived from capture-recapture analysis. From this figure, it is evident that the BLS substantially undercounted the number of upper extremity work-related MSDs in the state of Connecticut.

Capture-recapture analysis is predicated on the assumptions that the population of interest is closed and homogenous and that the likelihood of a case being captured by one surveillance system is unaffected by its likelihood of being captured in another surveillance system (Hook and Regal 1995). Morse et al. confirmed that the population of Connecticut workers was closed and homogenous. However, they could not ascertain the correlation between the WC and ODSS surveillance systems. A positive correlation between the two surveillance systems would overestimate the number of cases, while a negative correlation between the two surveillance systems would underestimate the number of cases. Morse et al. conducted a sensitivity analysis to make comparisons to BLS data. They used the lower bound of 95% confidence intervals of the total number of upper extremity work-related MSDs in Connecticut workers as estimated by capture-recapture analysis. Even when comparing to conservative estimates derived from the sensitivity analysis, BLS data still undercounted the number of upper extremity work-related MSDs among Connecticut workers during the period of observation.

Because of the different reporting requirements of the WC, ODSS, and BLS surveillance systems, we must consider the differential legal requirements of the respective surveillance systems as a confounder in the interpretation of this study's results (Oleinick and Zaidman 2010). Differences in the legal reporting requirements between the ODSS and WC surveillance systems may inadvertently generate a positive or negative correlation between the systems, which reduces the validity of capture-recapture analysis. Furthermore, differences in legal reporting requirements between ODSS and BLS and WC and BLS limit the reliability of comparisons between the capture-recapture results and BLS data. If reporting requirements cause one surveillance system to define an event as reportable while the other surveillance system defines the same event as non-reportable, then it is difficult to compare the number of events captured by each system given the inherent differences in the definition of events.

The Morse et al. study demonstrated that not only BLS, but ODSS and WC as well, considerably undercounted the number of upper extremity work-related MSDs that occurred in Connecticut workers of the period of interest. These results were in agreement with our hypothesis that BLS undercounts work-related MSDs. Despite that the defined population of interest geographically limited to all workers within Connecticut, cases of work-related MSDs captured came from a variety workers. Though both datasets used for the capture-recapture analysis had the inherent vulnerabilities associated with workers' compensation data (Rosenman, Gardiner et al. 2000) and physician reporting data (Baker, Melius et al. 1988), the use of both datasets and the rigor of the statistical methods provided good internal validity to the study. Overall, the Morse et al. study was a strong study that demonstrated that WC, ODSS, and BLS data all undercounted the true counts of upper-extremity work-related MSDs.

Discussion

This systematic review sought to answer the question: "Does the BLS accurately capture work-related MSDs?" We expected evidence that BLS would undercount work-related MSDs. This expectation was based on the qualities of work-related MSDs that make it difficult to establish them as, in fact, work related (Blessman 1991) as well as prior reports that document that BLS undercounts all work-related injuries and illnesses (Lipscomb, Kalat et al. 1996;

Azaroff, Levenstein et al. 2002; Azaroff, Lax et al. 2004; Leigh, Marcin et al. 2004; Rosenman, Kalush et al. 2006; Welch, Dong et al. 2007; Boden and Ozonoff 2008; Dong, Fujimoto et al. 2011). In addition to establishing the occupational nature of work-related MSDs, in some workplaces, workers are disincentivized from reporting even overt cases by stigmatization and other filters, which contributes to the phenomenon of under-reporting (Pransky, Snyder et al. 1999; Dembe 2001; Azaroff, Levenstein et al. 2002).

We must consider if the results of these studies merit equal weight in drawing conclusions. The two manuscripts we reviewed presented somewhat different conclusions. The characterization of the comparison datasets and statistical methods in the Morse et al. study was superior to the characterization of the Liberty Mutual Insurance workers' compensation claims dataset by Brogmus et al. Though count data typically is not as informative as rate data, for the purpose of capture-recapture analysis, as conducted by Morse et al., count data is a robust measure (Papoz, Balkau et al. 1996) that can be used to compare datasets. On the other hand, proportion data without a defined population of interest, like those used for comparisons to BLS by Brogmus et al., is less reliable and influenced by changes in other claims.

Limitations

This review was subject to a number of limitations. First, it was limited by human resources. In identifying the articles for this systematic review, we would have preferred to read through every abstract that was retrieved in our initial search, rather than perform a title review. However, we did not have adequate human resources available to accomplish this task. We realize that not all occupational health literature is indexed in MEDLINE and Cochrane databases. We chose not to attempt to perform searches of non-indexed, individual journals, whose content is available on the internet. Additionally due to time constraints we did not conduct a search of relevant gray literature, which may have contained studies relevant to our question.

Our search criteria were very specific; we did not include articles that could have been used to infer deficiencies in BLS reporting if they did not specifically seek to make such a comparison. Since we limited our health outcome terms to the MeSH terms defined in **Table 1**, we failed to identify titles for review that assessed work-related MSDs that did not explicitly use our specified terms. For example we did not include a study that assessed incidence of overexertion back injuries in a cohort of Washington State carpenters and concluded the BLS underestimated the risks of construction workers (Lipscomb, Cameron et al. 2008). Additionally, we excluded abstracts that did not contain the terms, “national surveillance,” “undercount,” or “under-report,” and failed to identify relevant articles that may have included other terms describing BLS’s surveillance efforts, such as “underestimation.” As we excluded studies that made comparisons to employer-specific OSHA logs, articles such as the Nelson et al. and Silverstein et al., whose meaningful results would likely contribute to our understanding BLS’s undercount of work-related MSDs were not used in the formulation of our conclusions.

Conclusions and Implications for Future Research

The results of the two included studies are limited and cannot fully characterize the actuality of BLS reporting of MSDs. There are numerous reports that describe that work-related injury and illness rates higher than BLS reports (Azaroff, Levenstein et al. 2002; Azaroff, Lax et al. 2004; Leigh, Marcin et al. 2004; Rosenman, Kalush et al. 2006; Welch, Dong et al. 2007; Boden and Ozonoff 2008) but there is a limited literature that specifically seeks to quantify underreporting of work-related musculoskeletal disorders. This leaves a void in our understanding of true risk of these disorders.

From this review, we did not identify variations in BLS undercounting of work-related MSDs by occupation, race, ethnicity, gender, and other demographics. Evidence suggests that the risk of occupational injury and illness among workers is related to these demographic factors (Loomis and Richardson 1998; Lipscomb, Li et al. 2003; Dong, Ringen et al. 2007; Menéndez and Havea 2010). Furthermore, work-related injuries and illnesses may contribute to health disparities, such as access to health care and life lost years, in our society (Lipscomb, Loomis et al. 2006). Given the inherent difficulty of attributing work-related MSDs as occupational in nature and the differential risks of work-related injury and illness among workers, work-related MSDs may compound the effect of work on health disparities. Thus, future research may entail better characterizing the burden of work-related MSDs among minority populations through sub-group analyses and comparisons to sub-group stratified BLS data.

As policy decisions for the treatment and prevention of work-related MSDs rely on epidemiologic evidence, such as that compiled by the BLS, the accuracy of BLS data has far reaching implications. Continued assessments of the accuracy of BLS may better characterize its shortcomings. Addressing these identified deficiencies might possibly lead to the improved quantification of the burden of work-related MSDs and the differential risk it poses to subpopulations of workers so that informed policy decisions can be made.

Tables and Figures

Table 1: MEDLINE and Cochrane Search Terms

Work Setting Terms	Work Site, Workplace, Work Environment, Occupational Injury, Occupational Disorder, Work-Related
Health Outcome MeSH Terms*	Sprains and Strains, Nerve Compression Syndromes, Hand Arm Vibration Syndrome, Tendinopathy, Tennis Elbow, Bursitis, Sciatica, Osteoarthritis

*For the Cochrane search terms, MeSH terms were not utilized.

Table 2: Article Extraction

Author(s)	Year	Journal	Population of Interest	Time Period	Health Outcome(s)	Comparison Data Set	Measure of Interest	Methodology
Brogmus et al.	1996	Journal of Occupational & Environmental Medicine	All US workers covered by Liberty Mutual Workers' Compensation Insurance	1984-1993	• Using hand, power tools--no sudden injury • Prolonged motion of fingers, wrist, or arms • Repetitive work trauma • Cumulative trauma disorder from the use of a video display terminal • Cumulative trauma/repeated trauma • Exposure to work-environment vibration • Multiple complaints • Video display terminals • Disorder due to repeated trauma • Carpal tunnel syndrome/tenosynovitis/white fingers disease • Repetitive motion • Strains and sprains, soreness	• Liberty Mutual Workers' Compensation Insurance claims records (represents 10% of all private carriers workers' compensation insurance business in the US)	• Liberty Mutual Insurance's Cumulative Trauma Disorders of the Upper Extremity (CTDUE) as percentage of all claims filed • BLS's Disorders Associated with Repeated Trauma (DART) as percentage of total illness and injury cases	Comparison of work-related MSDs of the upper extremity as a proportion of all Liberty Mutual Insurance claims to of work-related MSDs as a proportion of all cases reported to BLS
Morse et al.	2005	American Journal of Industrial Medicine	All Connecticut workers in the sampling population of Connecticut Workers' Compensation	1995-2001	• Peripheral Neuropathies • Tendonitis • Epicondylitis • Hand-Arm Vibration Syndrome • Bursitis • Rotator Cuff Injuries • Thoracic Outlet Syndrome • Chronic Joint Strains • Muscle Pain/Inflammation	• Electronic data records of the Connecticut Workers' Compensation First Report of Injury system (WC) • Physician Reports to the Connecticut Departments of Labor and Public Health	Upper Extremity Work-Related MSD Counts	Capture-Recapture Analysis using WC and ODSS data to determine counts with comparison to BLS counts data

						Occupational Disease Surveillance System (ODSS)		

Figure 1: Systematic Review Flow Chart

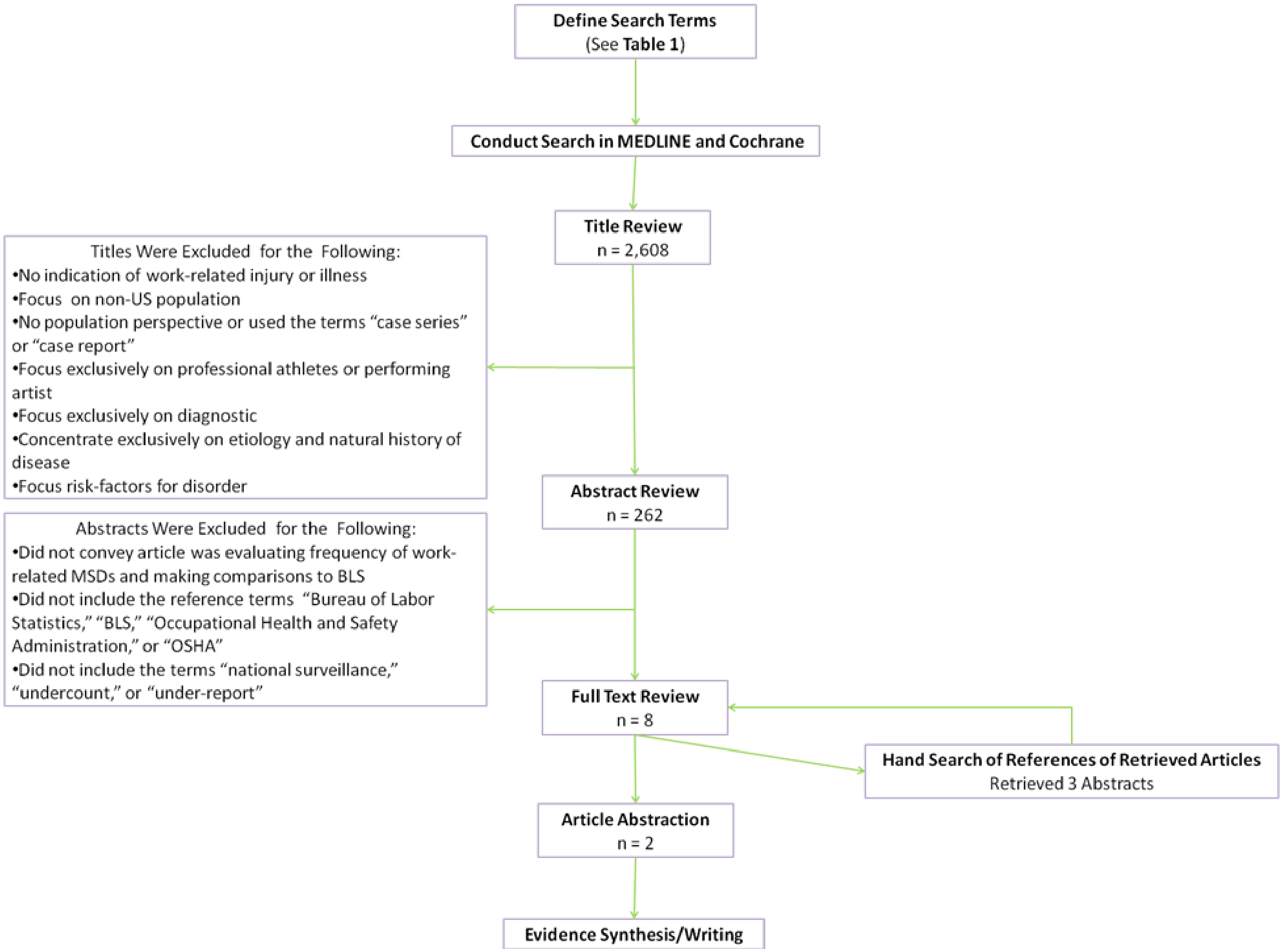
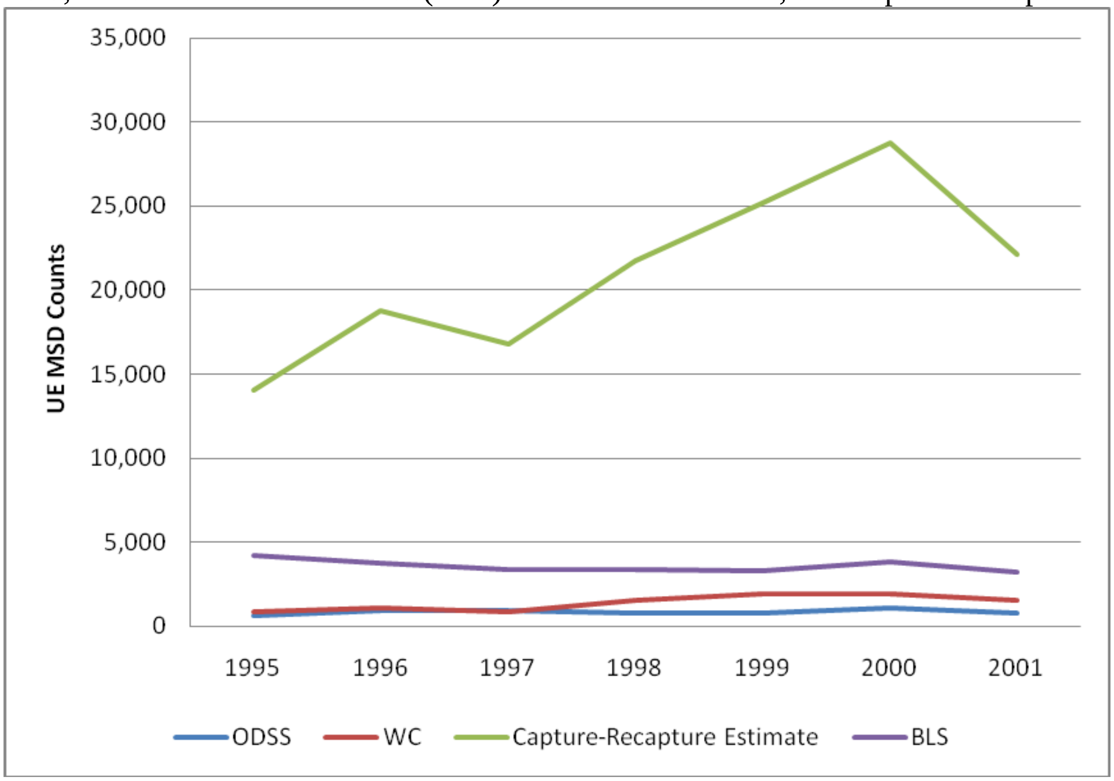


Figure 2: Morse et al. Work-Related Musculoskeletal Diseases of the Upper Extremity Counts by Year in Connecticut Workers as Determined by Connecticut Occupational Disease Surveillance System (ODSS) Data, Workers' Compensation First Report of Injury System (WC) Data, Bureau of Labor Statistics (BLS) Data for Connecticut, and Capture-Recapture Analysis



Morse et al. 2005. *Am J Ind Med*. 48(1): 40-9

20-Year Trends in Reported Work-Related Injury and Illness among Union Carpenters in Washington State

Introduction

The burden of work-related injury and illness in the United States is great (Leigh, Markowitz et al. 1997). In 1992, the direct and indirect costs associated with occupational injury and illness were estimated to rival those of circulatory diseases, cancer, and musculoskeletal conditions (Leigh, Markowitz et al. 1997). Along with the societal costs, the individual costs of work-related injury and illness are considerable (Morse, Dillon et al. 1998; Dembe 2001; Lipscomb, Dement et al. 2009). Because construction workers are at higher risk of work-related fatality, injury, and illness than other working populations, they bear a disproportionate burden of work-related injury and illness (US Department of Labor, Bureau of Labor Statistics 2010).

Bureau of Labor Statistics (BLS) data and workers' compensation (WC) records are the primary sources of information on work-related injury and illness in the United States. BLS data on non-fatal injuries and illnesses are based on a probability sample of employers' Occupational Safety and Health Administration (OSHA) logs. National estimates generated from these sampled data are presented each year in the BLS Annual Survey of Occupational Injury and Illness (SOII). The SOII does not include workers of federal, state, and local government agencies, household workers, the self-employed, and workers of employers with fewer than 11 employees (US Department of Labor, Occupational Safety & Health Administration 2001). These exclusions translate to BLS's failure to survey approximately 25% of the construction labor force (Dong, Fujimoto et al. 2011).

OSHA does not require employers to record cases that only involve "minor" injuries or illnesses; recordable injuries and illnesses are limited to those that result in loss of consciousness, time away from work beyond the day of injury, work restrictions or transfer to another job, or medical treatment beyond first aid (US Department of Labor, Occupational Safety & Health Administration 2001). Though some champion that the declines in work-related injury and illness reflected in the SOII demonstrate the positive effects of surveillance, targeted enforcement, and prevention methods, others challenge that these achievements have been over-emphasized (Azaroff, Levenstein et al. 2002; Azaroff, Lax et al. 2004; Leigh, Marcin et al. 2004; Rosenman, Kalush et al. 2006). There is growing evidence that BLS data significantly underestimates risks to workers in the US (Azaroff, Levenstein et al. 2002; Leigh, Marcin et al. 2004; Rosenman, Kalush et al. 2006; Boden and Ozonoff 2008). Given the design, even a perfectly conducted SOII with complete compliance of workers and employers in reporting injuries would fail to capture a substantial number of work-related injuries and illnesses in the US population.

Leigh et al. estimated that the BLS Annual Survey missed between 33% and 69% of all nonfatal work-related injuries occurring in 1999 (Leigh, Marcin et al. 2004). Furthermore, there are concerns about whether the reported declines in non-fatal work-related injury rates are in fact indicative of improved safety, rather than a decline in the efficacy of documentation (Welch, Dong et al. 2007). Under-reporting to BLS is attributed to a combination of factors: willful neglect on the part of employers, as well as recent economic, legal, and political changes that hinder the documentation of work-related injury and illness to US surveillance entities (Pollack and Keimig 1987; Azaroff, Lax et al. 2004; Friedman and Forst 2007). The failure of BLS to accurately capture occupational injuries and illnesses is a particular problem among construction workers (Glazner, Borgerding et al. 1998; Welch and Hunting 2003; Welch, Dong et al. 2007; Dong, Fujimoto et al. 2011), that has likely resulted in the under-recognition of the magnitude of their occupational injuries and illnesses and makes assessment of the effectiveness of prevention efforts difficult to establish.

We evaluated temporal trends in injury and illness incidence rates among a large, retrospective cohort of union carpenters in Washington State over a 20-year period using work-related injury data provided by the State of Washington Department of Labor and Industries (L&I) and employment records maintained by the Carpenters' Trust of Western Washington (CTWW). Previous reports (Lipscomb, Kalat et al. 1996; Lipscomb, Cameron et al. 2008) have documented that these carpenters have higher injury rates than those reported by BLS for the construction industry. Our objective was to describe trends in reported work-related injuries and illnesses among this cohort, to identify high risk groups within the cohort, and to compare the absolute and relative measures of risk among carpenters in the cohort to those reported through BLS overtime.

Materials and Methods

Data Sources

Using data from the Carpenters Trusts of Western Washington (CTWW) and the Washington State Department of Labor and Industries (L&I), the state agency that administers the state-wide workers' compensation program, we identified a cohort of union carpenters who worked in the State of Washington between the years 1989 and 2008 and their reported workers' compensation (WC) claims. Data were provided with a blinded, unique carpenter identification number, such that we were able to merge records on an individual basis; these methods have been previously described in detail (Lipscomb, Dement et al. 1997; Lipscomb, Dement et al. 2000; Lipscomb, Li et al. 2003). For each carpenter in the dataset provided by CTWW, we were given the unique carpenter identification number, date of birth, gender, earliest date of union activity, and hours of union work recorded for each month. We limited our cohort to include individuals who worked at least 3 months of union hours during this 20-year period.

The WC data included the unique carpenter identification number, date of injury, cost of medical care received, if the injury involved paid lost time (PLT) (which occurs after the 3rd lost day in Washington), and codes describing the nature of injury, the body part affected by injury, the source of injury (brick, drywall, etc.), and the event or exposure causing the injury. American National Standards Institute (ANSI) codes were used to code claims prior to 2003 and Occupational Injury and Illness Classification System (OIICS) codes were used in later years. Employers that self-insure for WC in the state of Washington are only required to report claims to L&I if those claims result in PLT from work. Privately insured employers are not required to report claims that do not involve PLT to L&I. Otherwise, we received all reported WC claims for the period of interest. The data received from L&I and CTWW did not indicate the size of the employer of if the employer was self-insured.

These union carpenters perform a wide variety of construction industry tasks, including drywall installation, residential building, roadway and bridge construction, pile-driving, and light and heavy commercial building, including high-rise construction. Because of the varied nature of work performed by the union carpenters, we compared injury rates of the cohort to those of the overall construction industry. We were provided BLS incidence rates of all recorded injuries and illnesses and all time lost cases (cases in which time off extends beyond the day of injury) for the construction industry for the years 1992-2008 by The Center for Construction Research and Training, formerly known as The Center to Protect Workers' Rights (CPWR). CPWR also provided BLS incidence rates of injuries involving lost time for the more common construction industry injury mechanism groupings: “Struck by object, “Fall to a lower level,” and “Overexertion with lifting.”

Definition of Time at Risk

For this analysis, hours worked each month were the measure of time at risk. Each carpenter was considered to be at risk of a work-related event in any month in which they worked union hours. One full-time equivalent (FTE) was defined as an individual working full time for one year; this assumes a 40-hour work week and 2 weeks of vacation per year, which amounts to 2,000 hours.

Definition of Events

We only counted WC claims that occurred during months in which the individual worked union hours to define events and time at risk on the same basis. Injury events were then limited to those that approximated the OSHA reporting criteria. For the purpose of our analysis, we considered claims that had medical costs or resulted in PLT to be OSHA-recordable. As we did not have data available that documented associated loss of consciousness, work restriction, or transfer to another job, we were unable to use these definitions as qualifiers in identifying OSHA-recordable events.

Classification of Injury Mechanisms

After identifying the OSHA-recordable claims, we further stratified the claims involving PLT into the injury mechanism groupings of “Struck by object,” “Fall to a lower level,” and “Overexertion with lifting” for comparison to the BLS estimates for the construction industry provided by CPWR. The associated ANSI and OIIICS codes for these injury mechanism groupings are provided in **Table 1**.

Statistical Analysis

We calculated the age of each carpenter upon first entry into the cohort and the mean/median age of the cohort by year to allow comparisons to age distribution of the US construction industry (The Center for Construction Research and Training 2007). Duration of time observed in the cohort was calculated for each carpenter and was used to derive average time observed in the cohort overall, by year, and by gender.

To assess the risk of sub-populations within the cohort, we conducted Poisson regression analysis. We treated age and time in the union as time-varying variables. Poisson regression was used to calculate crude incidence rates, crude rate ratios, and adjusted rate ratios for all claims, OSHA-recordable claims, claims involving PLT, and claims involving PLT stratified by injury mechanism groupings using the following variables: age (categorical), gender, time in union (categorical), year (categorical), and indicator variable for injury classification system. This regression technique is particularly useful in the analysis of longitudinal data for a dynamic cohort, such as this one, by allowing maximal use of all data available for each individual regardless of their observation time. The incidence rates for all claims and OSHA-recordable claims were expressed per 200,000 hours worked, equivalent to the BLS metric of 100 full time equivalents (FTE). For the claims involving PLT, the incidence rates were per 20,000,000 hours worked (10,000 FTEs), the metric used by BLS to report incidence rates for work-related injuries and illnesses involving lost time.

We assessed temporal trends of incidence rates for the cohort data and BLS data by comparing absolute and relative risk measures over time. All statistical analyses were generated using SAS® software, Version 9.1.3 (SAS Institute, Inc. 2003).

Institutional Review Board Approval

This research was approved by the Institutional Review Boards of Duke University Medical Center, the University of North Carolina at Chapel Hill Gillings School of Public Health, and the Washington State Department of Health and Human Services.

Results

The Cohort

A total of 26,591 carpenters who worked at least 3 months (consecutive or non-consecutive) of union hours in the State of Washington between 1989 and 2008 were identified. Overall, the average time of observation in the cohort was 63.2 months (standard deviation = 73.12 months, median = 27 months). For males, the average time observed in the cohort was 66.1 months (standard deviation = 74.08 months, median = 29 months). Females were observed in the cohort for an average of 45.6 months (standard deviation = 53.61 months, median = 21.5 months). Over the 20-year period, the carpenters in the cohort worked for a total of 192,371,021 hours.

Overall, the proportion of females was 2.6%, ranging from 1.6 to 2.4% over time. The proportion of female workers across years was similar to statistics published by BLS for the construction industry (The Center for Construction Research and Training 2007). Carpenters entered the cohort at a mean age of 29.4 years (median = 28.0). As time proceeded, the average age of the carpenters increased. The average age started at 38.3 years in 1989, peaked at 44.9 years in 2005, and declined to 42.0 years in 2008. Compared to the BLS's average age of workers in the construction industry for the years 1985 to 2005, the average age of carpenters in our cohort by year was slightly higher (The Center for Construction Research and Training

2007). A comparison of the average age of the cohort to BLS's average age for workers in the construction industry by year is provided in **Figure 1**.

Claims Reported by the Cohort

A total of 27,551 claims were reported by the union carpenters over the period of interest. The incidence rate for all claims reported by the cohort over the 20-year period was 28.6 (95% CI: 28.3-29.0) claims per 100 FTEs. The peak incidence rate for all claims was 44.9 (95% CI: 42.9-46.9) per 100 FTEs in 1991. The lowest incidence rate occurred in 2008 with an incidence rate of 15.9 (95% CI: 15.0-16.8) per 100 FTEs. Adjusting for age, gender, union tenure, and injury classification system, we observed a relative reduction in the reporting of all claims of 52.4% (95% CI: 47.1-57.3%) over the 20-year period.

Out of the 27,551 claims that were reported by the union carpenters in the cohort, 23,766 (86.3%) were considered to be OSHA-recordable. Twenty-four percent of the OSHA-recordable claims (n = 5,701) involved PLT. We observed a decline in both OSHA-recordable claims as a proportion of all claims and claims involving PLT as a proportion of OSHA-recordable claims by year (**Figures 2A** and **2B**). There were a total of 842 "Overexertion with lifting" claims involving PLT, 679 "Struck by object" claims involving PLT, and 577 "Fall to a lower level" claims involving PLT.

The distribution of time at risk, claim counts, crude incidence rates, and adjusted rate ratios with 95% confidence intervals by age category, gender, union tenure category, and year for OSHA-recordable claims and claims involving PLT are presented in **Table 2**. For OSHA-recordable claims, younger age, female gender, and less union tenure were associated with higher claims incidence rates (**Table 2**). For claims involving PLT, gender was the only variable significantly associated with increased reporting; the adjusted risk ratio of females compared to males was 1.45 (95% CI: 1.22-1.72).

Women and individuals aged 20-30 years old had higher rates of “Struck by object” claims that involved PLT with adjusted rate ratios of 1.51 (95% CI: 1.07, 2.12) when compared to males and 1.45 (95% CI: 1.19, 1.77) when compared to individuals ≥ 50 years old, respectively (**Table 3**). For “Fall to a lower level” claims involving PLT, gender was the only variable significantly associated with reporting; females were less likely to report claims than males (adjusted risk ratio = 0.30, 95% CI: 0.13-0.69). Only individuals aged 30-40 demonstrated increased rates of reporting “Overexertion with lifting” claims that involved PLT.

When stratifying the incidence rates by age, we observed age to influence the temporal trends in incidence rates for all claim categories in the early years of the observation period. The most pronounced effect of age on the temporal trends of incidence rates was for OSHA-recordable claims and claims involving PLT; we present the temporal trends of the age-stratified data in **Figures 3A** and **3B**. Age appeared to influence reporting of both OSHA-recordable and claims involving PLT in earlier years with younger workers reporting at higher rates. The influence of age on reporting appeared to decline as time proceeded; the age-stratified incidence rates for both OSHA-recordable claims and claims involving PLT converged at the end of the period of observation.

Similar to the temporal trends observed for the total claims incidence rates, declines were observed for OSHA recordable claims and claims involving PLT, including those involving the more common injury mechanisms (**Table 3**). The largest decline was observed for “Fall to a lower level” claims involving PLT. A high of 135.8 “Fall to a lower level” claims involving PLT per 10,000 FTEs occurred in 1990 with a low of 6.6 claims per 10,000 FTEs occurring in

2008. This translated to an adjusted relative reduction of 93.1% (95% CI: 86.2-96.5%) from 1990 to 2008. "Struck by object" claims involving PLT declined from an observed high of 178.8 events per 10,000 FTEs in 1991 to 18.6 events per 10,000 FTEs in 2008, an adjusted relative reduction of 88.2% (95% CI: 81.5-92.4%). An adjusted relative reduction of 82.5% (95% CI: 58.4-92.8%), a decline from a high of 198.6 events per 10,000 FTEs in 1990 to a low of 23.7 events per 10,000 FTEs in 2007 was observed for "Overexertion with lifting claims" involving PLT.

We assessed the effect of changing injury classification systems in 2003 by evaluating the adjusted rate ratios of the injury classification indicator variable for each category of claims. After adjusting for age, gender, union tenure, and year, the rate ratio for claims coded using the ANSI system (before 2003) compared to claims coded using the OIICS system (2003 and after) was 1.00.

Comparisons to BLS Estimates

The cohort's OSHA-recordable claims incidence rates with 95% confidence intervals are compared to the BLS's point estimates (standard errors were not available) for all injury and illness cases by year in **Figure 4**. The cohort's OSHA-recordable claims incidence rates were consistently higher than BLS estimates for workers in the construction industry. The discrepancy between cohort incidence rates for OSHA-recordable claims and all injuries and illnesses rates from BLS data was large and decreased throughout the years. In 1992, the absolute difference between the cohort's OSHA-recordable claims incidence rate and the BLS incidence rate was 24.0 events per 100 FTEs, with a rate ratio of 2.83**.** By 2008, the absolute difference in the incidence rates was 8.0 events per 100 FTEs, with a rate ratio of 2.69 (**Table 4**).

The comparison between the cohort's incidence rates for claims involving PLT and BLS incidence rates for lost time cases for the construction industry demonstrated a trend similar to that of all OSHA-recordable injuries and illnesses. We present the comparisons by year in **Table 5**. As time proceeded the absolute discrepancy in the incidence rates of the cohort for claims involving PLT and BLS data for lost time cases diminished (**Figure 5**). We present the cohort's incidence rates for claims involving PLT by the "Struck by object," "Fall to lower level," and "Overexertion with lifting" injury mechanism groupings with their counterpart BLS point estimates in **Figures 6A**, **6B**, and **6C**, respectively. Absolute and relative comparisons of the cohort data to BLS data by injury mechanism groupings are presented in **Tables 6**, **7**, and **8**. In earlier years, the cohort's incidence rates were higher than BLS rates for "Struck by object" and "Fall to a lower level" injuries. However, in later years, BLS incidence rates surpassed those of the cohort's. For "Overexertion with lifting" injuries, the cohort's incidence rates were consistently higher than BLS rates.

Discussion

We had the opportunity to study a large dynamic, retrospective cohort of 26,591 carpenters and their workers' compensation claims over a 20-year period to analyze the trends of their work-related injury and illness through the combination of two administrative datasets. Their injury rates were then compared to BLS SOII data for construction industry for the years 1992-2008.

After adjusting for age, union tenure, and year, women had higher rates of reporting for all claim categories with the exception of "Fall to a lower level" claims involving PLT (women were found to have lower rates of reporting). After adjusting for the other covariates, age was significantly associated with injury rates; younger workers' rates of claims overall were higher as were rates for OSHA-recordable claims, "Struck by object" claims involving PLT, and "Overexertion with lifting" claims involving PLT. Workers with the least union tenure reported more claims overall and more OSHA-recordable claims.

Incidence rates in all categories of claims declined among the union carpenters and in the BLS SOII data. The absolute discrepancy between the incidence rates of the cohort and BLS data diminished substantially overtime, while the relative differences, as measured by incidence rate ratios, demonstrated a more moderate decline. Temporal trends of incidence rates for claims involving PLT and BLS lost time cases nearly converged in the later years of observation with the exception of "Overexertion with lifting" claims involving lost time, for which BLS was consistently lower. The increased severity of PLT claims among the cohort and BLS lost time cases likely translated to improved sensitivity of detection by both L&I and BLS. This likely amounted to a better correspondence between the cohort's PLT claims incidence rates and BLS lost time cases incidence rates as we demonstrated in our results.

We expected our results to correspond with prior research suggesting that BLS undercounts work-related injury and illness in all working populations (Azaroff, Lax et al. 2004; Leigh, Marcin et al. 2004; Morse, Dillon et al. 2005; Rosenman, Kalush et al. 2006; Boden and Ozonoff 2008) and in construction workers, specifically (Welch, Dong et al. 2007). Our findings are consistent with the literature that suggests BLS undercounts work-related injuries and illnesses in construction workers as well as supports prior research that demonstrates younger workers, workers with less union tenure, and female workers are associated with increased reporting of work-related injuries and illnesses in the construction industry.

Oregon lies in close geographic proximity to Washington with many workers traversing state lines for employment (Horwitz and McCall 2004); hence we might expect injury rates of the Washington union carpenters to be similar to those calculated for Oregon construction workers. We found that the overall claims incidence rate for the Washington union carpenters cohort over the 20-year period was 28.6 per 100 FTEs, far higher than the workers' compensation claims incidence rate of 3.5 per 100 FTEs in Oregon construction workers for the years 1990 to 1997 (Horwitz and McCall 2004). However, this discrepancy is likely attributable to the different legal requirements of reporting to workers' compensation between the two states (Oleinick and Zaidman 2010) as well as different methods used to calculate exposure time. Oregon requires the reporting of claims where work-related injury and illness is believed to have resulted in 3 or more days of disability or permanent disability. Whereas the workers' compensation database of Washington State captures first aid claims *and* claims that do not involve time away from work. The incidence rate of claims involving PLT, a better comparison to the Oregon construction data, for the union carpenters in Washington State was 5.3 per 100 FTEs over the 20-year period, confirming out expectation that injury rates between Washington carpenters and Oregon construction workers would be similar.

Our results from the comparison of the cohort's incidence rates of "Overexertion with lifting" claims involving PLT against BLS incidence rates of "Overexertion with lifting" lost time cases confirm the conclusions we drew from the systematic review we performed to accompany this research. Our systematic review suggested that BLS undercounts work-related musculoskeletal diseases (MSD) in all working populations. As "Overexertion with lifting" injuries are musculoskeletal in nature, the absolute discrepancy between the cohort's and BLS incidence rates observed reaffirms the conclusions of our systematic review. It is likely that the inherent nature of work-related MSDs, such as "Overexertion with lifting" injuries, makes it difficult to establish their work-relatedness and results in under-reporting to both WC and BLS (Blessman 1991).

The observed differences in the claims reporting rates by gender may be related to differences in health care seeking behavior between men and women. Prior research has suggested that women are more likely to seek care for all symptoms as well as musculoskeletal symptoms compared to men (Verbrugge 1985; Klonoff and Landrine 1992; Almeida, Trone et al. 1999). Thus, the increased reporting of claims among women may reflect their increased predilection to seek care for a perceived event or condition. However, it is interesting that we observed lower rates of "Fall to a lower level" claims involving PLT among women. This lower rate of serious falls could indicate that women have lower exposure to workplace environments in which they are at risk of falling or they may control their risk more effectively than men. This observation warrants further investigation.

Given the declines in injury and illness incidence rates observed in both the cohort and BLS data, we must consider the context of our findings. Beginning in the late 1980's, major construction owners began to pre-qualify bidders with safety and health performance as a criterion (Welch, Dong et al. 2007). This new attention to workplace safety served as the vehicle through which workplace safety programs and return-to-work programs gained popularity among construction employers and oversight agencies. The introduction of these programs may have resulted in safer workplaces accompanied by a concomitant reduction in injuries. We observed the greatest decline in incidence rates of the cohort to occur in "Fall to a lower level" claims involving PLT, the one injury mechanism grouping for which a safety standard was instituted during the period of observation by Washington State, subsequently followed by Federal OSHA (Lipscomb, Li et al. 2003). With this example, we might accept that the declines in claims incidence rates we observed in the cohort over the 20-year period might be partially explained by improved safety in which the *actual* rates of injuries were reduced. This scenario, in which improved safety climates reduced *actual* injury rates, may also apply to BLS statistics for construction workers nationally.

The declines in incidence rates observed in the carpenters' union and BLS data may not simply represent a reduction in the *actual* rate of injuries and illnesses. The observed declines may also be an artifact of policy changes that have resulted in less rigorous reporting standards (Friedman and Forst 2007). For example, in 2002, changes in OSHA recordkeeping required that a work-related injury or illness that was caused by the aggravation of a pre-existing condition must be a significant aggravation, rather than just an aggravation, to be considered OSHA-recordable. Additionally, the 2002 changes expanded the definition of work restriction such that a worker must suffer more impairment in order for his injury or illness to be considered OSHA-recordable. These changes did not reduce the number events that occurred; though, they might have reduced the number of events that would be recorded on OSHA-logs, the source of BLS data.

The housing market slowdown in 2002 might have also contributed to the reduction in reporting observed in the cohort and construction workers nationally. The housing market slowdown, coupled with the inherent contingent nature of construction employment, could have substantially reduced the job security of some construction workers. With reduced job security, construction workers might have been incentivized to not report work-related injuries and illnesses by fear of reprisal through the reduction of hours and/or job loss (Rosenman, Gardiner et al. 2000; Shannon and Lowe 2002; The Center for Construction Research and Training 2007). The decline in the housing market would have predominantly affected carpenters involved in residential construction. However, carpenters involved in residential construction represented a small proportion of the cohort. It is likely that the housing market economic downturn of 2002 remains one of many factors that might have contributed to the decline in *reported* injury incidence rates.

Economic downturns are often associated with increased self-employment and misclassification of employed construction workers as independent contractors (The Center for Construction Research and Training 2007). This misclassification of workers is another means through which the recording of injuries and illnesses among construction workers nationally may have been reduced. Employers are incentivized to reduce the number of workplace injuries and illnesses because companies with high injury and illness rates as determined by OSHA logs are more likely to undergo OSHA inspection (Welch, Dong et al. 2007). By classifying workers as independent contractors, employers are not required to record these workers' injuries and illnesses on OSHA logs and can avoid paying workers' compensation on their behalf. Thus, the misclassification of workers likely reduced the capture of injuries by both WC and BLS. However, the effect of misclassification on our cohort, specifically, is unlikely given that union membership and independent contractor status are mutually exclusive.

As part of their union benefits, carpenters in the cohort had access to private health insurance. Because of the ready availability of health care and the barriers to and stigmatization associated with reporting work-related injury and illness to WC (Dembe 2001), carpenters in our cohort may have sought care for their work-related injuries and illnesses through their private health insurance rather than through the WC system. In a previous analysis of the cohort data for the years 1989 to 2003, Lipscomb et al. demonstrated that for musculoskeletal back disorders, private health care utilization rates increased, while WC rates declined over the observed period of time (Lipscomb, Dement et al. 2009). The access to private health insurance among carpenters in our cohort may have contributed to the phenomenon of cost-shifting, which indirectly caused a reduction in the reporting of events overtime to L&I. Cost-shifting may have contributed to decreases in reporting to BLS by construction workers nationally as well. As the proportion of construction workers with access to private health insurance was 84% and 52% nationally for unionized and non-unionized workers, respectively in 2005 (The Center for Construction Research and Training 2007), the effect of cost-shifting for construction workers nationally was likely less pronounced than in the cohort.

Limitations

In critiquing our research, we realize that the unknown precision, a result of the lack of standard error information for the BLS data, of absolute and relative risk estimates for the cohort comparisons against BLS data is a limitation.

Union presence may raise the level of regulatory activity of both WC and OSHA (Weil 1992; Weil 1996). Because union workers are more likely to exercise their rights under labor statutes (Weil 1992), they may behave in a manner differently from their non-union peers in regulating their exposure to and reporting of work-related injury and illness. Little research has been conducted on how unionization affects rates of injuries and illnesses and reporting of injuries and illnesses. However, we might consider that union activity reduced the *actual* number of injuries experienced by the cohort as well as increased reporting of these injuries. In any event, we continued to see higher relative rates of the cohort compared to BLS despite marked declines in absolute rate differences; relative discrepancies were greater for more serious events involving PLT. Carpenters' injury rates were lower than BLS for "Fall to a lower level" and "Struck by object" injuries in the later years of observation.

The climate of safety and effect of union activity on the rates and reporting of work-related injuries and illnesses is influenced by geography (Wood 1995). Washington State does not have "right-to-work" (RTW) laws that prohibit the union shop. Thus, new employees, in union shops, are required to join and pay dues to the union (Ellwood and Fine 1987). As such, in Washington State, workers have fewer barriers to union organization than in other states (Ellwood and Fine 1987). More effective union organization in states that do not have RTW laws perhaps allows for increased regulatory activity in the workplace when compared to states that have active RTW laws.

The average age of our cohort was older than the average age of construction workers nationally; this is likely a consequence of the cohort's unionization (The Center for Construction Research and Training 2007). With the average age of construction workers nationally younger than that of the cohort, we might expect the BLS incidence rates to be higher, not lower than the cohort's, given that our analysis and previous research (Chau, Mur et al. 2004; Salminen 2004) have demonstrated that younger workers report more work-related injury.

In Washington State, PLT is defined to occur after the third lost day, while the BLS defines lost time to occur the day after initial injury. However, for our study, the differential requirements of reporting between L&I and BLS, likely augmented our conclusion that BLS undercounted injuries among construction workers. Given that BLS requires a shorter duration of lost time for a work-related injury or illness to be considered a lost time case, we should expect that BLS would be more sensitive in capturing lost time cases than our OSHA approximation for the carpenter cohort. Therefore, the number of events used for BLS's calculation of incidence rates for lost time cases overall and by stratified injury mechanism groupings should be larger. Hence, we should expect that BLS's incidence rates for lost time cases to be higher than the cohort's incidence rates for claims involving PLT. However, as seen in our results, BLS incidence rates were substantially lower than the cohort's for all injuries and illnesses, all cases involving PLT, and "Overexertion with lifting" claims that resulted in PLT.

Though, L&I maintains a state-run WC system, it does not capture the claims of employers with private WC insurance that do not result in PLT. Consequently, we were unable to capture OSHA-recordable injuries and illnesses that did not involve PLT, but involved medical costs, our surrogate measure for events requiring care greater than first aid. Accordingly, the true incidence rates for all OSHA-recordable claims was likely higher than the incidence rates we calculated and the discrepancy between the cohort data the BLS data was perhaps larger than we demonstrated.

As risk of occupational injury is related to race, ethnicity, and employer size (Loomis and Richardson 1998; Pransky, Moshenberg et al. 2002; Leigh, Marcin et al. 2004; Menéndez and Havea 2010; Dong, Fujimoto et al. 2011), information on these variables would have been useful, but was unavailable for this analysis.

Strengths

This study also had a number of important strengths. Linking of WC data to work hour and demographic data allowed us to define our population at risk. As the capture of WC claims occurred through a singly run state system, we are confident that we had access to all reported injury and illness claims. Additionally, we were able to precisely measure exposure time for the cohort through the provision of hours worked by month for each individual. The rigorous definition of the numerator (WC claims from a single database) and denominator (exposure time as calculated from individual hours worked by month) allow us to be confident in our incidence rates and relative risk calculations for this well-defined cohort.

The large number of claims (27,551) and considerable amount of exposure time (192,371,021 hours worked) observed during the 20-year period allowed robust analyses. We had adequate data to conduct reliable sub-group analyses, allowing us to ascertain relative risk by age, gender, and union tenure for the different claim categories. Lastly, the longitudinal nature provided us with the opportunity to assess trends over a 20 year period whereas other analyses of work-related injury and illness have used observation periods of years, rather than decades (Nelson, Park et al. 1992; Lipscomb, Kalat et al. 1996; Silverstein, Stetson et al. 1997; Glazner, Borgerding et al. 1998; Welch and Hunting 2003; Leigh, Marcin et al. 2004; Morse, Dillon et al. 2005; Rosenman, Kalush et al. 2006; Boden and Ozonoff 2008).

Conclusions

Over the 20-year period of observation, we observed reductions in both the cohort's and BLS's incidence rates with the absolute differences between the two diminishing as time progressed. However, relative discrepancies between the cohort data and BLS data remained in large part. The differential reporting observed in sub-populations may reflect differences in workplace exposure, control measures, and reporting practices, not the inherent risk of the demographic groups, themselves. Future research of these cohort data would entail comparing our cohort's age-stratified data to BLS age-stratified data with precision estimates. This would allow us to make more reliable comparisons with known precision by correcting for the age discrepancy between carpenters in the cohort and construction workers nationally.

As occupational injury and illness pose a significant burden to individuals and society at large (Leigh, Markowitz et al. 1997; Morse, Dillon et al. 1998), characterization of this burden, as we attempted in our study, provides a focus for addressing a substantial public health problem. The research presented in this paper is only one of many steps towards better characterizing the burden of occupational injury and illness in construction workers. We can combine knowledge derived from this research with other research efforts, to move towards safer workplaces in the construction industry. Collaboration among researchers, policy makers, and workers, themselves, is necessary to implement evidence-based and effective policies in a practical and palatable manner that reduces the burden of work-related injury and illness.

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Tables and Figures

Table 1: American National Standards Institute (ANSI) and Occupational Illness and Injury Classification System (OIICS) Codes Used for Injury Mechanism Groupings

Mechanism Grouping	ANSI		OIICS	
	Code	Description	Code	Description
Struck by object	20	Struck by (unspecified)	020	Struck by object or equipment, unspecified
	21	Struck by falling object	021	Struck by falling object or equipment
	22	Struck by flying object	0220	Struck by flying object, unspecified
	23	Kicked	0221	Struck by dislodged flying object, particle
	24	Continued noise	0222	Struck by discharged object or substance
	25	Bitten by	0229	Struck by flying object, n.e.c.
	26	Struck by person	0230	Struck by swinging or slipping object, unspecified
	27	Struck by person/crime	0231	Struck by or slammed in swinging door or gate
	28	Stabbed	0232	Struck by slipping handheld object
	29	Struck by NEC	0239	Struck by swinging or slipping object, n.e.c.
			024	Struck by rolling, sliding objects or equipment on floor or ground level
			029	Struck by object or equipment, n.e.c.
			430	Pedestrian struck by vehicle, mobile equipment, unspecified
			431	Pedestrian struck by vehicle, mobile equipment in roadway
			432	Pedestrian struck by vehicle, mobile equipment on side of road
			433	Pedestrian struck by vehicle, mobile equipment in parking lot or non-roadway area
Fall to a lower level	30	Fall from elevation	10	Fall, unspecified
	31	Fall from platform	110	Fall to lower level, unspecified
	32	Fall from ladder	111	Fall down stairs or steps
	33	Fall from piled matter	1120	Fall from floor, dock, or ground level, unspecified
	34	Fall from vehicle	1121	Fall through existing floor opening
	35	Fall on stairs	1122	Fall through floor surface
	36	Fall into open pit	1123	Fall from loading dock
	37	Fall from roof	1124	Fall from ground level to lower level
	39	Fall to a lower level	1129	Fall from floor, dock, or ground level, n.e.c.
			113	Fall from ladder
			114	Fall from piled or stacked material
			1150	Fall from roof, unspecified
			1151	Fall through existing roof opening
			1152	Fall through roof surface
			1153	Fall through skylight
			1154	Fall from roof edge
			1159	Fall from roof, n.e.c.
			116	Fall from scaffold, staging
			117	Fall from building girders or other structural steel
			118	Fall from nonmoving vehicle
			119	Fall to lower level, n.e.c.
			120	Jump to lower level, unspecified
			121	Jump from scaffold, platform, loading dock
			122	Jump from structure, structural element, n.e.c.
			123	Jump from nonmoving vehicle
			129	Jump to lower level, n.e.c.
Overexertion with lifting	121	Overexertion with lifting	221	Overexertion in lifting

Table 2: Hours Worked, Number of Claims, Crude Incidence Rates (IR), and Adjusted Rate Ratios (ARR) for OSHA-Recordable Claims, Claims Involving Paid Lost Time (PLT) by Age Category, Gender, Union Tenure Category, and Year, Union Carpenters, Washington State, 1989-2008

	Hours Worked	# of OSHA-Recordable Claims*†	OSHA-Recordable Claims IR‡ˣ	OSHA-Recordable Claims ARR (95% CI)ˣ	# of PLT Claims†	PLT Claims IR°ˣ	PLT Claims ARR (95% CI)ˣ
Age							
< 20 years	802,603	159	39.6	1.62 (1.32, 1.98)	23	573.1	0.90 (0.60, 1.36)
20-30 years	31,328,455	4,881	31.2	1.35 (1.27, 1.43)	801	511.4	0.87 (0.79, 0.96)
30-40 years	63,078,380	8,584	27.2	1.23 (1.16, 1.29)	1,887	598.3	1.06 (0.98, 1.16)
40-50 years	60,717,277	6,205	20.4	1.05 (1.00, 1.11)	1,484	488.8	1.05 (0.96, 1.14)
≥ 50 years	35,499,527	3,381	19.0	1	815	459.2	1
Sex							
Female	3,187,355	488	30.5	1.17 (1.05, 1.31)	126	790.6	1.45 (1.22, 1.72)
Male	188,719,682	23,059	24.1	1	4,934	518.8	1
Union Tenure							
< 2 years	49,881,783	8,367	33.5	1.40 (1.17, 1.66)	1,904	763.4	1.21 (0.90, 1.62)
2-4 years	30,972,279	4,597	29.7	1.19 (1.00, 1.42)	1,025	661.9	0.94 (0.69, 1.26)
4-6 years	24,881,074	3,006	24.2	1.03 (0.86, 1.24)	627	504.0	0.76 (0.56, 1.04)
6-8 years	21,857,641	2,369	21.7	1.01 (0.84, 1.21)	519	474.9	0.83 (0.62, 1.13)
8-10 years	18,345,264	1,773	19.3	0.96 (0.80, 1.15)	355	387.0	0.73 (0.54, 0.99)
10-12 years	14,216,001	1,179	16.6	0.94 (0.78, 1.13)	224	315.1	0.68 (0.49, 0.94)
12-14 years	10,775,661	722	13.4	0.86 (0.71, 1.05)	158	293.3	0.68 (0.49, 0.95)
14-16 years	9,128,188	667	14.6	1.04 (0.86, 1.27)	111	243.2	0.70 (0.49, 0.99)
16-18 years	7,629,702	430	11.3	0.92 (0.74, 1.13)	70	183.5	0.65 (0.45, 0.94)
18-20 years	4,683,429	241	10.3	1	55	234.9	1
Year							
1989	6,070,969	1,131	37.3	2.35 (2.10, 2.64)	274	902.7	3.34 (2.71, 4.12)
1990	7,955,039	1,610	40.5	2.59 (2.32, 2.88)	423	1063.5	4.02 (3.31, 4.90)
1991	8,503,454	1,683	39.6	2.73 (2.45, 3.03)	450	1058.4	4.51 (3.72, 5.49)
1992	9,103,419	1,680	36.4	2.58 (2.32, 2.87)	402	883.2	3.96 (3.24, 4.83)
1993	8,512,786	1,540	35.5	2.69 (2.41, 2.99)	380	892.8	4.38 (3.59, 5.35)
1994	8,018,041	1,296	31.5	2.50 (2.23, 2.80)	297	740.8	3.89 (3.16, 4.80)
1995	8,062,927	1,257	30.1	2.45 (2.19, 2.74)	280	687.1	3.54 (2.87, 4.36)
1996	8,165,628	1,197	28.6	2.36 (2.11, 2.65)	254	609.9	3.11 (2.51, 3.85)
1997	8,718,329	1,269	28.6	2.41 (2.15, 2.69)	285	644.6	3.42 (2.78, 4.20)
1998	9,291,889	1,342	28.3	2.38 (2.13, 2.66)	264	553.2	2.95 (2.39, 3.64)
1999	10,557,541	1,257	23.4	1.92 (1.72, 2.15)	249	462.2	2.43 (1.97, 2.99)
2000	11,514,489	1,395	23.8	1.94 (1.74, 2.17)	261	444.7	2.33 (1.89, 2.88)
2001	10,618,931	1,055	19.8	1.66 (1.48, 1.87)	214	403.1	2.17 (1.75, 2.69)
2002	9,748,095	901	18.5	1.61 (1.43, 1.82)	206	422.7	2.33 (1.87, 2.91)
2003	9,357,923	882	18.0	1.55 (1.38, 1.75)	155	309.9	1.74 (1.38, 2.20)
2004	9,017,509	750	16.6	1.45 (1.27, 1.64)	143	317.2	1.83 (1.44, 2.33)
2005	9,569,607	732	15.3	1.37 (1.21, 1.56)	117	244.5	1.44 (1.12, 1.85)
2006	11,049,495	802	14.5	1.28 (1.13, 1.44)	127	229.9	1.32 (1.04, 1.69)
2007	13,475,892	912	13.5	1.12 (1.00, 1.25)	152	225.6	1.17 (0.93, 1.45)
2008	15,059,059	953	12.7	1	154	204.5	1

*OSHA-Recordable indicates that claim involved medical expenses or paid lost time.
†Paid lost time is defined to occur after the 3rd lost day in Washington State.
‡Incidence rates are per 200,000 hours worked (100 FTEs)
°Incidence rates are per 20,000,000 hours worked (10,000 FTEs)
ˣResults from Poisson regression analysis

Table 3: Number of Claims, Crude Incidence Rates (IR), and Adjusted Rate Ratios (ARR) for "Struck by object," "Fall to a lower level," and "Overexertion with lifting" Claims Involving Paid Lost Time* by Age Category, Gender, Union Tenure Category, and Year, Union Carpenters, Washington State, 1989-2008

	# of "Struck by object" Claims*	"Struck by object" Claims IR†‡	"Struck by object" Claims ARR (95% CI)‡	# of "Fall to a lower level" Claims*	"Fall to a lower level" Claims IR†‡	"Fall to a lower level" Claims ARR (95% CI)‡	# of "Over-exertion with lifting" Claims*	"Over-exertion with lifting" Claims IR†‡	"Overexertion with lifting" Claims ARR (95% CI)‡
Age									
< 20 years	4	99.7	1.30 (0.62, 2.72)	3	74.8	1.10 (0.47, 2.58)	4	99.7	0.98 (0.45, 2.13)
20-30 years	156	99.6	1.45 (1.19, 1.77)	97	61.9	1.02 (0.82, 1.28)	127	81.1	0.85 (0.70, 1.04)
30-40 years	245	77.7	1.18 (0.99, 1.41)	212	67.2	1.16 (0.96, 1.40)	342	108.4	1.19 (1.01, 1.40)
40-50 years	166	54.7	1.06 (0.88, 1.28)	169	55.7	1.17 (0.96, 1.42)	228	75.1	1.01 (0.85, 1.20)
≥ 50 years	91	51.3	1	85	47.9	1	129	72.7	1
Sex									
Female	18	112.9	1.51 (1.07, 2.12)	3	18.8	0.30 (0.13, 0.69)	20	125.5	1.36 (0.96, 1.92)
Male	652	68.5	1	567	59.6	1	814	85.8	1
Union Tenure									
< 2 years	303	121.5	2.71 (0.94, 7.83)	234	93.8	1.70 (0.69, 4.19)	323	129.5	1.86 (0.89, 3.91)
2-4 years	136	87.8	1.81 (0.62, 5.26)	119	76.8	1.22 (0.49, 3.01)	159	102.7	1.32 (0.62, 2.8)
4-6 years	69	55.5	1.37 (0.47, 4.01)	67	53.9	0.98 (0.39, 2.44)	123	98.9	1.49 (0.70, 3.17)
6-8 years	71	65.0	1.98 (0.68, 5.80)	53	48.5	1.31 (0.52, 3.26)	87	79.6	1.29 (0.61, 2.75)
8-10 years	42	45.8	1.61 (0.55, 4.75)	36	39.2	0.97 (0.39, 2.45)	53	57.8	1.00 (0.47, 2.15)
10-12 years	18	25.3	1.26 (0.41, 3.82)	19	26.7	0.80 (0.31, 2.07)	29	40.8	0.79 (0.36, 1.75)
12-14 years	12	22.3	1.10 (0.35, 3.46)	18	33.4	0.95 (0.36, 2.48)	26	48.3	1.00 (0.45, 2.22)
14-16 years	12	26.3	1.55 (0.49, 4.84)	12	26.3	1.09 (0.41, 2.94)	19	41.6	1.27 (0.56, 2.89)
16-18 years	6	15.7	1.03 (0.31, 3.44)	9	23.6	0.98 (0.36, 2.69)	11	28.8	1.02 (0.43, 2.43)
18-20 years	2	8.5	1	3	12.8	1	5	21.4	1
Year									
1989	54	177.9	6.76 (4.26, 10.71)	40	131.8	14.37 (7.12, 28.99)	39	128.5	2.75 (1.81, 4.18)
1990	65	163.4	6.44 (4.1, 10.11)	54	135.8	14.48 (7.25, 28.96)	79	198.6	4.35 (2.98, 6.36)
1991	76	178.8	8.46 (5.42, 13.22)	55	129.4	16.67 (8.35, 33.25)	81	190.5	4.84 (3.31, 7.06)
1992	64	140.6	7.07 (4.48, 11.16)	57	125.2	17.23 (8.62, 34.46)	65	142.8	3.85 (2.60, 5.70)
1993	46	108.1	6.26 (3.93, 9.98)	39	91.6	13.12 (6.49, 26.55)	66	155.1	4.14 (2.81, 6.10)
1994	41	102.3	6.5 (4.03, 10.48)	44	109.8	17.82 (8.83, 36.00)	43	107.3	2.86 (1.88, 4.34)
1995	41	101.7	5.82 (3.62, 9.34)	28	67.0	9.90 (4.82, 20.33)	48	119.1	3.37 (2.25, 5.05)
1996	35	78.4	4.31 (2.63, 7.05)	15	36.7	4.86 (2.25, 10.52)	47	115.1	3.34 (2.22, 5.03)
1997	33	75.7	4.27 (2.63, 6.94)	35	78.0	12.02 (5.93, 24.38)	40	91.8	2.79 (1.84, 4.23)
1998	42	88.2	4.98 (3.10, 8.01)	27	56.0	8.77 (4.26, 18.04)	45	94.7	3.04 (2.02, 4.58)
1999	22	39.8	2.21 (1.31, 3.73)	24	41.7	6.60 (3.19, 13.65)	44	83.4	2.74 (1.83, 4.10)
2000	29	50.4	2.96 (1.81, 4.84)	23	40.0	6.38 (3.09, 13.19)	42	71.2	2.37 (1.57, 3.57)
2001	14	26.4	1.65 (0.94, 2.89)	26	49.0	7.87 (3.84, 16.14)	28	52.7	1.74 (1.12, 2.71)
2002	24	49.2	3.31 (1.99, 5.52)	26	53.3	8.48 (4.11, 17.51)	45	92.3	3.10 (2.06, 4.67)
2003	18	36.3	2.42 (1.40, 4.16)	13	27.8	4.56 (2.10, 9.89)	24	47.0	1.53 (0.95, 2.44)
2004	13	28.8	1.94 (1.08, 3.47)	12	26.6	4.38 (1.99, 9.64)	21	46.6	1.49 (0.92, 2.41)
2005	18	37.6	2.66 (1.56, 4.55)	15	31.3	5.25 (2.45, 11.22)	20	41.8	1.40 (0.86, 2.26)
2006	16	29.0	1.95 (1.13, 3.38)	17	30.8	4.98 (2.35, 10.55)	22	39.8	1.32 (0.83, 2.12)
2007	12	17.8	1.09 (0.61, 1.93)	20	29.7	4.56 (2.22, 9.37)	16	23.7	0.76 (0.46, 1.24)
2008	14	18.6	1	5	6.6	1	24	31.9	1

*Paid lost time is defined to occur after the 3rd lost day in Washington State.
†Incidence rates are per 20,000,000 hours worked (10,000 FTEs)
‡Results from Poisson regression analysis

Table 4: Incidence Rates, Absolute Incidence Rate Differences, and Incidence Rate Ratios of Claims Involving Paid Lost Time or Medical Expenses for Union Carpenters in Washington State Compared to BLS All Injury and Illness Cases for the Construction Industry (1992-2008)

Year	Cohort*	BLS*	Rate Difference†	Rate Ratio†
1992	37.1	13.1	24.0	2.83
1993	36.5	12.2	24.3	2.99
1994	32.7	11.8	20.9	2.77
1995	31.5	10.6	20.9	2.97
1996	29.6	9.9	19.7	2.99
1997	29.4	9.5	19.9	3.09
1998	29.0	8.8	20.2	3.30
1999	24.0	8.6	15.4	2.79
2000	24.4	8.3	16.1	2.94
2001	20.3	7.9	12.4	2.57
2002	18.5	7.1	11.4	2.60
2003	18.9	6.8	12.1	2.77
2004	16.6	6.4	10.2	2.60
2005	15.3	6.3	9.0	2.43
2006	14.5	5.9	8.6	2.46
2007	13.5	5.4	8.1	2.51
2008	12.7	4.7	8.0	2.69

*Incidence rates are calculated per 200,000 hours worked (100 FTEs).
†BLS data was provided as single point estimate without 95% confidence intervals or standard errors. Without an estimate of the standard error for BLS data, we were unable to calculate 95% confidence intervals for the rate differences and rate ratios.

Table 5: Incidence Rates, Absolute Incidence Rate Differences, and Incidence Rate Ratios of Claims Involving Paid Lost Time for Union Carpenters in Washington State Compared to BLS Lost Time Cases for the Construction Industry (1992-2008)

Year	Cohort*	BLS*	Rate Difference†	Rate Ratio†
1992	883.2	529.5	353.7	1.67
1993	892.8	490.5	402.3	1.82
1994	740.8	486.2	254.6	1.52
1995	699.5	417.6	281.9	1.68
1996	627.0	372.3	254.7	1.68
1997	658.4	364.8	293.6	1.80
1998	574.7	326.9	247.8	1.76
1999	477.4	331.3	146.1	1.44
2000	458.6	318.9	139.7	1.44
2001	412.5	304.6	107.9	1.35
2002	422.7	276.8	145.9	1.53
2003	331.3	259.4	71.9	1.28
2004	317.2	243.7	73.5	1.30
2005	244.5	239.5	5.0	1.02
2006	229.9	219.5	10.4	1.05
2007	225.6	190.3	35.3	1.19
2008	204.5	174.3	30.2	1.17

*Incidence rates are calculated per 20,000,000 hours worked (10,000 FTEs).
†BLS data was provided as single point estimate without 95% confidence intervals or standard errors. Without an estimate of the standard error for BLS data, we were unable to calculate 95% confidence intervals for the rate differences and rate ratios.

Table 6: Incidence Rates, Absolute Incidence Rate Differences, and Incidence Rate Ratios of "Struck by object" Claims Involving Paid Lost Time for Union Carpenters in Washington State Compared to BLS "Struck by object" Lost Time Cases for the Construction Industry (1992-2008)

Year	Cohort*	BLS*	Rate Difference†	Rate Ratio†
1992	140.6	94.2	46.4	1.49
1993	108.1	84.2	23.9	1.28
1994	102.3	85.1	17.2	1.20
1995	101.7	71.5	30.2	1.42
1996	88.2	66.6	21.6	1.32
1997	75.7	70.1	5.6	1.08
1998	92.6	63.1	29.5	1.47
1999	43.6	59.6	-16.0	0.73
2000	50.4	56.5	-6.1	0.89
2001	26.4	58.4	-32.0	0.45
2002	49.2	54.6	-5.4	0.90
2003	36.3	48.2	-11.9	0.75
2004	28.8	44.5	-15.7	0.65
2005	37.6	46.7	-9.1	0.81
2006	29.0	43.3	-14.3	0.67
2007	17.8	38.0	-20.2	0.47
2008	18.6	36.6	-18.0	0.51

*Incidence rates are calculated per 20,000,000 hours worked (10,000 FTEs).
†BLS data was provided as single point estimate without 95% confidence intervals or standard errors. Without an estimate of the standard error for BLS data, we were unable to calculate 95% confidence intervals for the rate differences and rate ratios.

Table 7: Incidence Rates, Absolute Incidence Rate Differences, and Incidence Rate Ratios of "Fall to a lower level" Claims Involving Paid Lost Time for Union Carpenters in Washington State Compared to BLS "Fall to a lower level" Lost Time Cases for the Construction Industry (1992-2008)

Year	Cohort*	BLS*	Rate Difference†	Rate Ratio†
1992	125.2	63.0	62.2	1.99
1993	91.6	56.9	34.7	1.61
1994	109.8	54.9	54.9	2.00
1995	71.9	49.6	22.3	1.45
1996	36.7	43.6	-6.9	0.84
1997	80.3	42.2	38.1	1.90
1998	58.1	38.7	19.4	1.50
1999	45.5	38.3	7.2	1.19
2000	40.0	40.0	0.0	1.00
2001	50.9	39.1	11.8	1.30
2002	53.3	37.9	15.4	1.41
2003	27.8	33.8	-6.0	0.82
2004	26.6	33.3	-6.7	0.80
2005	31.3	33.2	-1.9	0.94
2006	30.8	26.1	4.7	1.18
2007	29.7	27.9	1.8	1.06
2008	6.6	22.6	-16.0	0.29

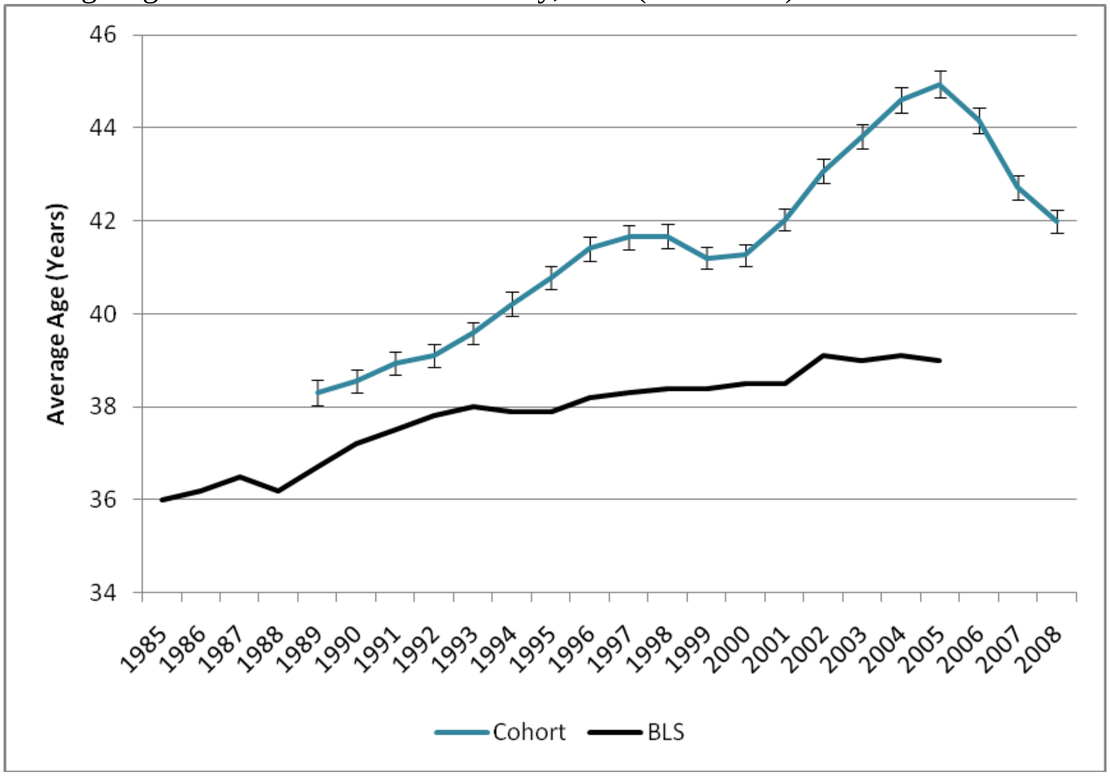
*Incidence rates are calculated per 20,000,000 hours worked (10,000 FTEs).
†BLS data was provided as single point estimate without 95% confidence intervals or standard errors. Without an estimate of the standard error for BLS data, we were unable to calculate 95% confidence intervals for the rate differences and rate ratios.

Table 8: Incidence Rates, Absolute Incidence Rate Differences, and Incidence Rate Ratios of "Overexertion with lifting" Claims Involving Paid Lost Time for Union Carpenters in Washington State Compared to BLS "Overexertion with lifting" Lost Time Cases for the Construction Industry (1992-2008)

Year	Cohort*	BLS*	Rate Difference†	Rate Ratio†
1992	142.8	70.9	71.9	2.01
1993	155.1	65.2	89.9	2.38
1994	107.3	63.3	44.0	1.69
1995	121.5	54.3	67.2	2.24
1996	117.6	49.2	68.4	2.39
1997	91.8	49.0	42.8	1.87
1998	96.9	38.1	58.8	2.54
1999	85.2	40.3	44.9	2.12
2000	73.0	38.6	34.4	1.89
2001	52.7	33.6	19.1	1.57
2002	92.3	30.3	62.0	3.05
2003	51.3	29.2	22.1	1.76
2004	46.6	26.8	19.8	1.74
2005	41.8	24.0	17.8	1.74
2006	39.8	22.2	17.6	1.79
2007	23.7	18.4	5.3	1.29
2008	31.9	16.0	15.9	1.99

*Incidence rates are calculated per 20,000,000 hours worked (10,000 FTEs).
†BLS data was provided as single point estimate without 95% confidence intervals or standard errors. Without an estimate of the standard error for BLS data, we were unable to calculate 95% confidence intervals for the rate differences and rate ratios.

Figure 1: Average Age, Union Carpenters, Washington State (1989-2008) Compared to Average Age for the Construction Industry, BLS (1985-2005)



The Construction Chart Book: The U.S. Construction Industry and Its Workers. 2007. 4 ed. Silverspring, MD: The Center for Construction Research and Training (CPWR)

Figure 2A: Claims Resulting In Paid Lost Time or Medical Expenses (OSHA-Recordable) as a Proportion of All Workers' Compensation Claims, Union Carpenters, Washington State, 1989-2008

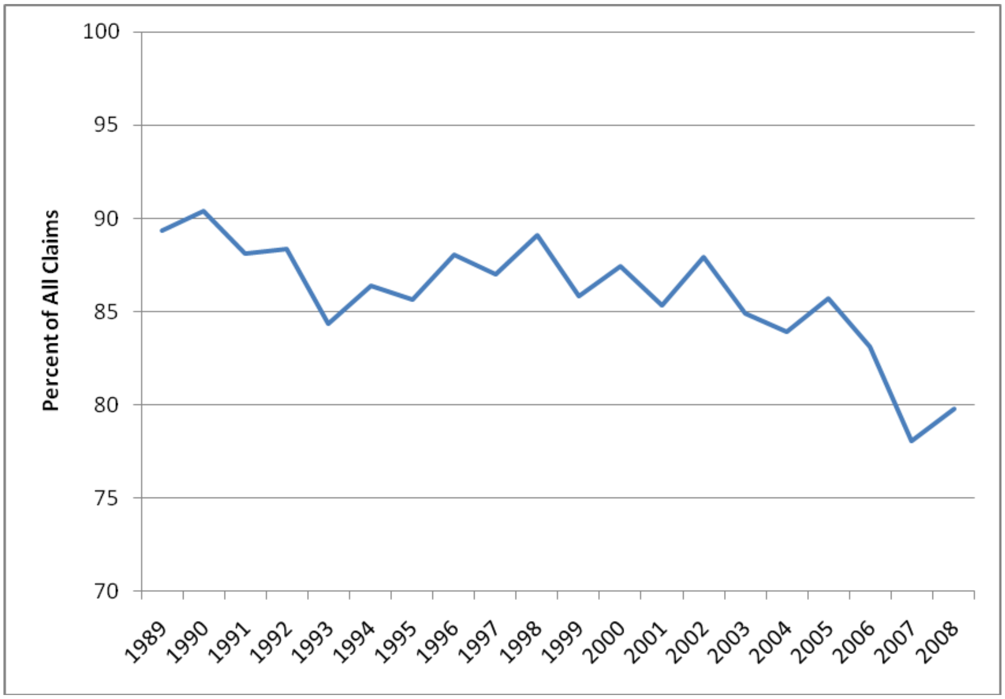


Figure 2B: Claims Invovling Paid Lost Time as a Proporiton of Claims Invovling Paid Lost Time or Medical Expenses (OSHA-Recordable), Union Carpenters, Washington State, 1989-2008

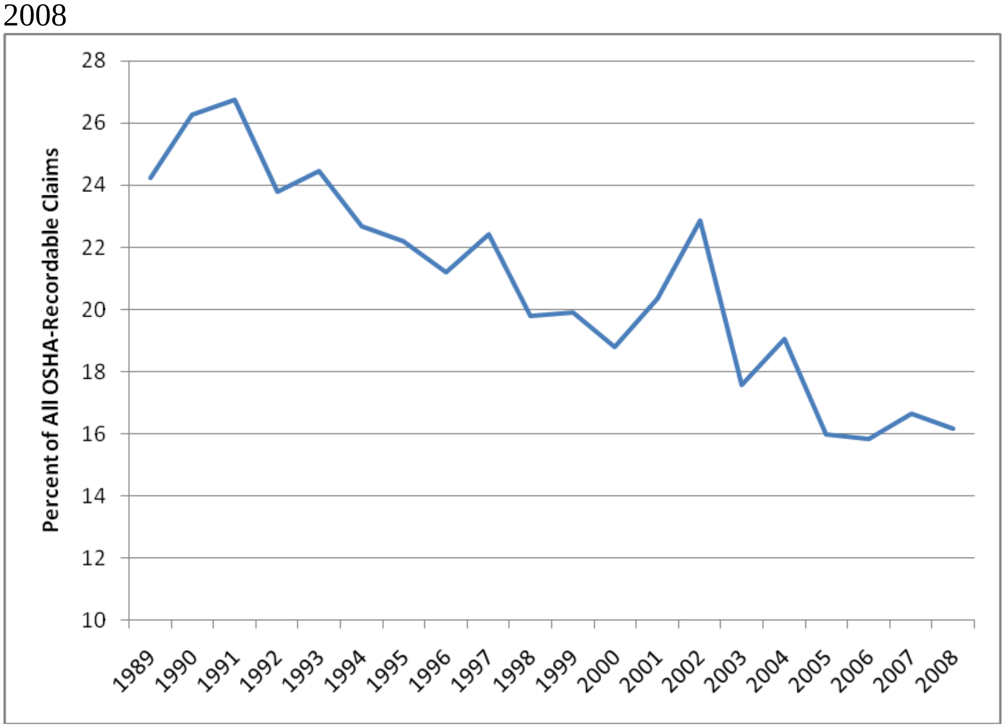


Figure 3A: Incidence Rates of Claims Resulting in Paid Lost Time or Medical Expenses Stratified by Age Category, Union Carpenters, Washington State, 1989-2008*

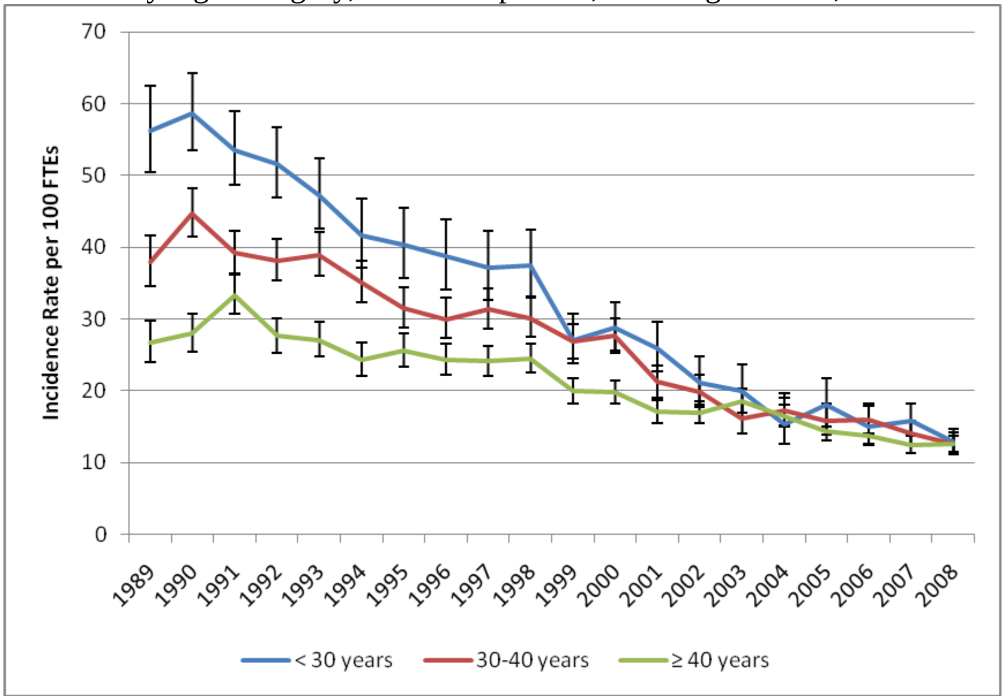
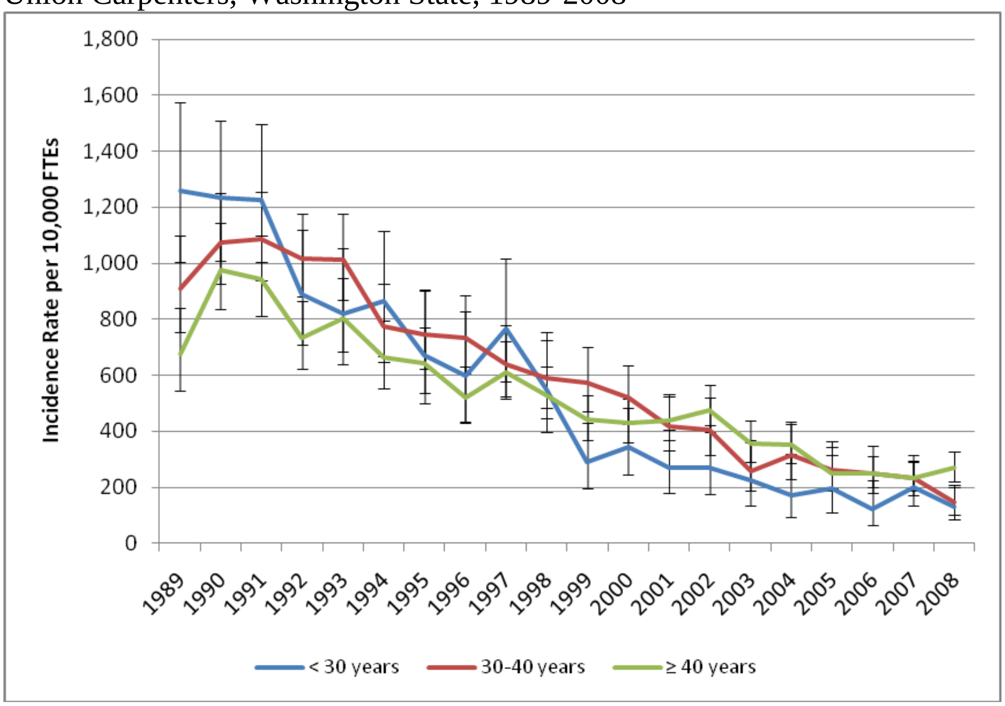
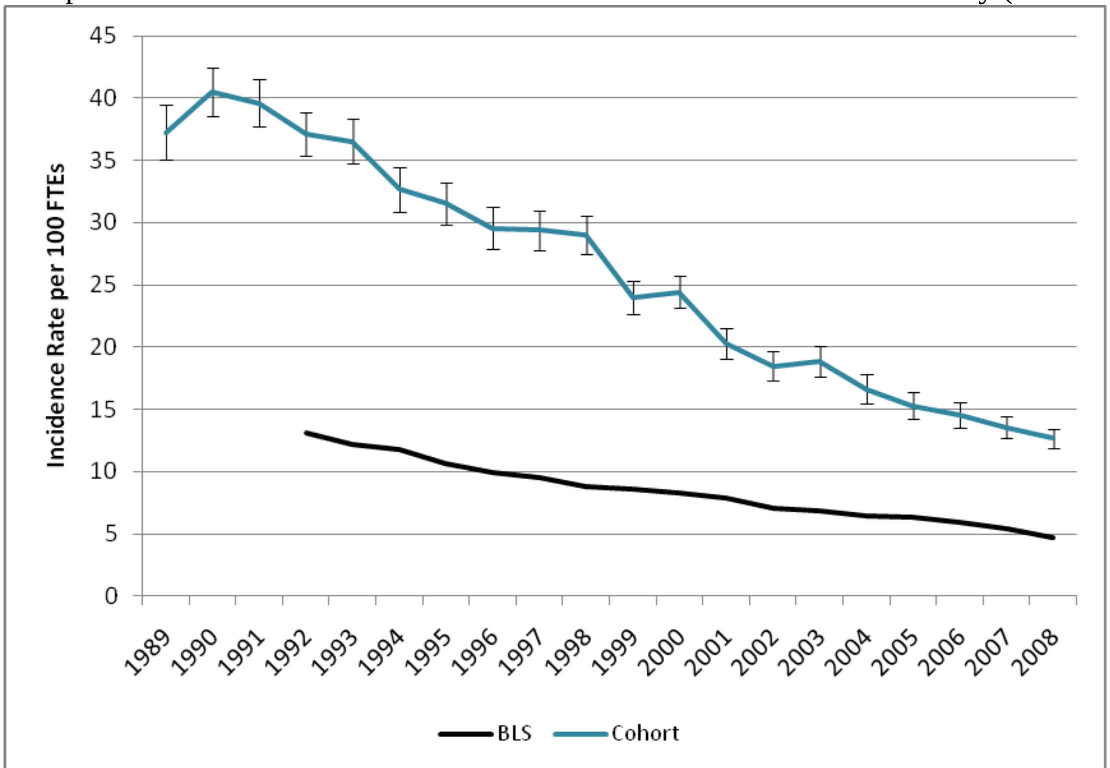


Figure 3B: Incidence Rates of Claims Resulting in Paid Lost Time Stratified by Age Category, Union Carpenters, Washington State, 1989-2008*



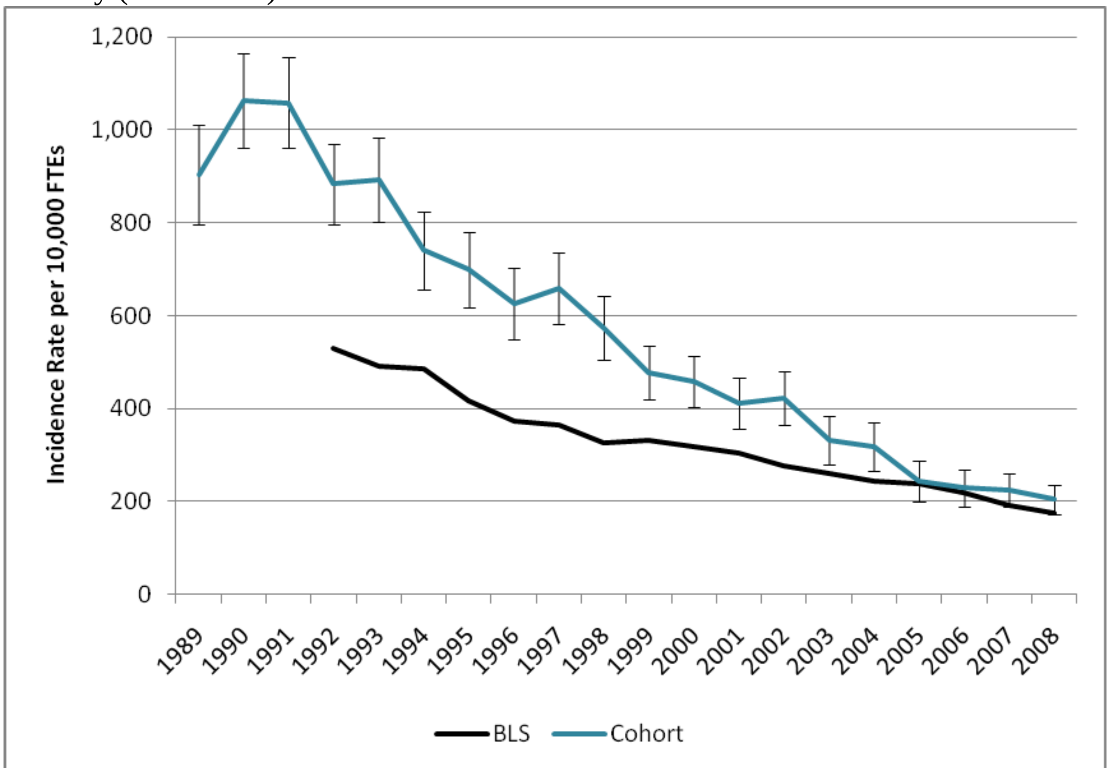
*Paid lost time is defined to occur after the 3rd lost day in Washington State.

Figure 4: Incidence Rates of Workers' Compensation Claims Involving in Paid Lost Time or Medical Costs (OSHA-Recordable), Union Carpenters, Washington State (1989-2008) Compared to BLS Incidence Rates of All Cases for the Construction Industry (1992-2008)*



*Paid lost time is defined to occur after the 3rd lost day in Washington State. The BLS considers lost time to occur the day after initial injury.

Figure 5: Incidence Rates of Claims Involving Paid Lost Time, Union Carpenters, Washington State (1989-2008) Compared to BLS Incidence Rates of Lost Time Cases for the Construction Industry (1992-2008)*



*Paid lost time is defined to occur after the 3rd lost day in Washington State. The BLS considers lost time to occur the day after initial injury.

Figure 6A: Incidence Rates of "Struck by object" Claims Involving Paid Lost Time, Union Carpenters, Washington State (1989-2008) Compared to BLS Incidence Rates of "Struck by object" Lost Time Cases for the Construction Industry (1992-2008)*

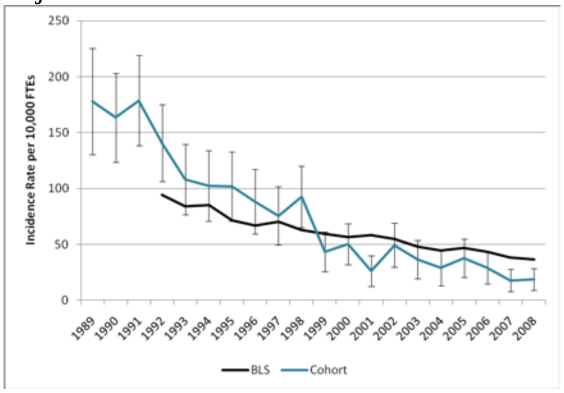


Figure 6B: Incidence Rates of "Fall to a lower level" Claims Involving Paid Lost Time, Union Carpenters, Washington State (1989-2008) Compared to BLS Incidence Rates of "Fall to a lower level" Lost Time Cases for the Construction Industry (1992-2008)*

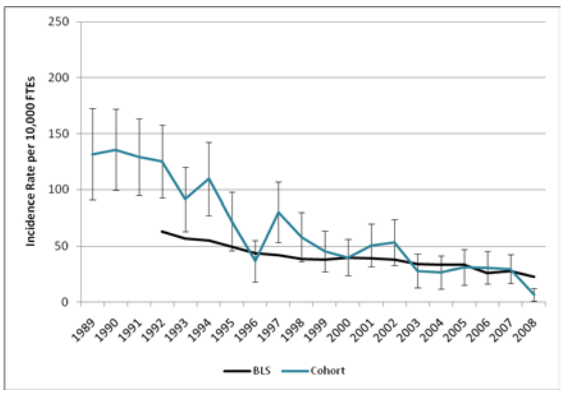
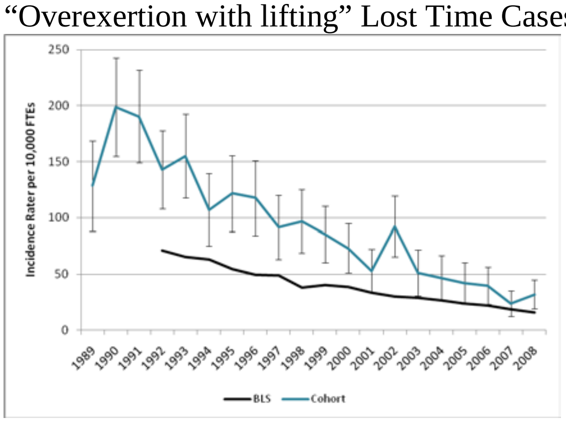


Figure 6C: Incidence Rates of "Overexertion with lifting" Claims Involving Paid Lost Time, Union Carpenters, Washington State (1989-2008) Compared to BLS Incidence Rates of "Overexertion with lifting" Lost Time Cases for the Construction Industry (1992-2008)*



*Paid lost time is defined to occur after the 3rd lost day in Washington State. The BLS considers lost time to occur the day after initial injury.

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